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A Multidisciplinary Melody for the Brain and Body

Montreux, Switzerland • May 28-June 1, 2017
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continued on next page
AIMS AND SCOPE (continued)
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LISTING OF ABSTRACTS

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BENIGN TUMORS

#10105 : Stereotactic radiosurgery for benign brain tumours: Results of multi-centre benchmark studies

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Keywords: plan comparison; multi-centre; benign; benchmark

Objectives: Stereotactic radiosurgery (SRS) is strongly indicated for treatment of surgically inaccessible benign brain tumours. Various treatment platforms are available, but most comparisons have been single centre studies. In 2016, a pre-requisite for all providers selected as SRS/SRT centres in England was to participate in a quality assurance process, informed through collaboration between the national trials QA group and a multidisciplinary expert advisory group. All clinical centres undertook planning benchmark cases, providing a unique dataset of current practice across a large number of providers and a wide range of equipment. This was used to facilitate sharing of best practice and support centres with less experience.

Methods: Four benign cases were provided, with images and structures pre-drawn: intracanalicular vestibular schwannoma (VS), large VS, skull base meningioma and secreting pituitary. No guidance was provided on how to plan these cases. Centres produced plans according to their local practice, and these were reviewed centrally using metrics for target coverage, selectivity, gradient fall-off and normal tissue sparing.

Results: 68 plans were submitted, using 18 different treatment platforms, including Gamma Knife, Cyberknife, Varian (Novalis / Truebeam STx / 2100) and Elekta linacs (Synergy / Versa HD). Linac-based plans used either fixed cone arcs, dynamic conformal arcs, static conformal beams or volumetric modulated arc therapy. 14 plans were subsequently revised following feedback, and review of 5 plans led to a restriction of service in 2 centres. Prescription doses were very consistent for VS and meningioma submissions, but a wide range of doses were used for the pituitary case. All centres prioritised coverage, with the prescription isodose covering ≥95% of 78/82 targets. Selectivity was much more variable, and in some cases this was combined with high gradient index and/or >1mm PTV margin, resulting in large volumes of normal tissue being irradiated. Normal tissue doses were more variable across linac-based plans than GammaKnife or Cyberknife, which may reflect the variety of approaches represented, or the necessary trade-off between different objectives. Conformal plans were possible with all four platforms, however, and improvements were possible by re-planning, even without changing margin size.

Conclusion: These benchmarking exercises give confidence in the safe and consistent delivery of SRS services across multiple centres, but have highlighted areas of different priorities, and potential for service improvement. The data can be used to progress standardisation and quality improvement of national services in the future, and may also provide useful guidance for centres worldwide.
#10330: Correlation between pre-treatment growth rate and tumor control of vestibular schwannomas after gamma knife radiosurgery in the dutch database

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Keywords: gamma knife radiosurgery, pre-treatment growth rate, tumor control, vestibular schwannoma, volume doubling time

Introduction: Prognostic factors of tumor control after Gamma Knife Radiosurgery (GKRS) for vestibular schwannoma (VS) are largely unknown. Recently, it has been reported that the growth rate of VS before treatment is indicative of the chance that radiosurgery achieves tumor control. Such findings may have important implications for treatment strategies and may lead to advise for either microsurgery or higher marginal doses for fast growing tumors. However, studies on this important aspect are limited and show conflicting results. Moreover, the available studies are hampered by methodological limitations such as limited patient numbers and follow-up and two-dimensional assessment of tumor size. The objective of this study is to identify a possible correlation between pre-treatment growth rate and tumor control after GKRS in a large database with sufficient follow-up and volumetric tumor assessments.

Methods: In the prospectively collected database of the Gamma Knife Center Tilburg, 445 patients with VS, treated between 2002 and 2014, that showed documented growth before treatment and who have had a minimum follow-up of 2 years after treatment, were identified. Tumor volumes before, at and after treatment were assessed. GKRS was performed in a uniform way, with a dose of 12-13Gy prescribed to the isodose line covering 90-99% of the target. Failures were defined as tumor progression on 2 consecutive MRI’s beyond 2 years after GKRS, or as judged by the radiosurgical team. Volume doubling times (VDT) before treatment were correlated with the observed tumor control rates and volumetric responses after treatment.

Results: Until now 266 of the 445 patients with documented pre-treatment tumor growth have been analyzed. 25 Patients were lost to follow-up. The median follow-up was 4 years. 25 Patients showed a radiological failure. The 5- and 10-year actuarial control rates were 91% and 78% respectively. VDT varied from 3 to 344 months, with a median of 16 months. Using the Mann-Whitney-U test, the VDT of tumors that showed tumor control is significantly higher than those that failed (p=0.01). After stratifying for VDT at the median, slow growing tumors showed a 5- and 10-year actuarial control rate of 97% and 89%, where the fast growing tumors had a 5- and 10-year control rate of 85% and 68% (p=0.009).

Conclusion: This study clearly shows that the pre-treatment growth rate correlates with the observed tumor control after GKRS. Fast growing tumors are less likely to show tumor control. This finding might justify alterations in the management of VS.

#10310: Rate of residual tumor growth after primary subtotal resection (STR) and the role of upfront versus salvage stereotactic radiosurgery for sporadic vestibular schwannomas

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Keywords: vestibular schwannoma, Gamma Knife, subtotal resection, residual tumor

Background: Modern clinical studies have converged upon “maximal safe resection” as the optimal surgical strategy for moderate-to-large vestibular schwannomas, however data on the long-term outcomes of residual tumor is lacking and the best treatment strategy for residual disease is an open
The goal of this study was to review our rates of residual tumor growth, and the response to salvage versus upfront SRS.

Methods: This retrospective single-institution study included all sporadic vestibular schwannomas treated primarily with subtotal resection at our institution from 2002 – 2015. Patients with less than 1 year of follow-up imaging were excluded. Patients treated with upfront SRS after surgery were analyzed separately. The primary outcome was tumor stability or growth requiring salvage treatment, and response to salvage treatment (surgery or SRS).

Results: 295 patients underwent primary surgery for vestibular schwannoma at our institution between 2002 and 2015. A subtotal resection was performed in 140 of these cases. 49 cases were excluded due to <1 year follow-up imaging. 17 cases received upfront SRS after surgery (12 cases Gamma Knife, 12Gy; 5 cases CyberKnife, 25Gy in 5 fractions). There were 2 failures requiring salvage surgery 1.6 and 2.6 years after SRS (88% control rate at 1.8 median follow-up after SRS). Of the remaining 74 residual tumors managed with observation after STR, 57 (77%) remained stable at a median 4.1 years after surgery. 17 tumors (23%) progressed and required salvage treatment at a median of 2.8 years after STR. 11 were treated with Gamma Knife (12.5 Gy) at a median interval of 2.6 years after surgery, and all remained clinically stable over a median follow-up of 2.3 years after salvage SRS. One was treated with Cyber Knife (18Gy in 3 fractions) and went on to require a second surgery 3 years later. 4 residual tumors were treated with salvage surgery at a median interval of 5 years after STR, and one was lost to follow-up. The control rate of salvage SRS was 92% at 2.3 years median follow-up.

Conclusion: A majority (77%) of residual vestibular schwannomas will remain stable after a primary subtotal resection. Both upfront and salvage SRS had good control rates (~90%) in our series. Further study is needed to define the role of upfront versus salvage SRS after a primary STR.

Keywords: Radiosurgery randomization vestibular Schwannoma

Background: Class I level evidence for treatment of Vestibular Schwannoma is generally lacking. One particular issue that has been put forward as an argument against radiosurgery for this tumor is that it is so quiescent that the effect of radiosurgery only reflects its natural course. In 2014, we introduced a randomized trial to measure the effect of radiosurgery against natural course.

Study design: The study will include 100 patients with newly diagnosed unilateral VS with diameter 5-20mm, age 19-69. Patients are randomized to up-front Gamma Knife radiosurgery or observation by serial MRI. They are followed annually for 4 years. The study is blinded to observer (study radiologist and study physician). The primary endpoint is tumor growth measured as relative to baseline size and volume doubling time at four years. Secondary endpoints include Gardner Robertson hearing Class, need of additional treatment and adverse effects. Patients fill out the PANQOL and EQ-50 forms at each control.

Results: The study has included 80 patients per February 2017 and has so far lost one patient who withdrew. One patient who was randomized to radiosurgery declined such treatment and is followed according to intention-to-treat principle. The practical setup and the experiences learned from the study design will be presented.

OSPO1 - WFSBS: VESTIBULAR SCHWANNOMAS 1

#10104 : Gamma Knife radiosurgery in acoustic neuroma – the Vienna series

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Keywords: acoustic neuroma, benign tumor, Gamma Knife Radiosurgery, tumor control, hearing preservation

Objective: We present long-term follow-up data after Gamma Knife radiosurgical (GKRS) treatment of acoustic neuroma.

Patient and Methods: Six-hundred and eighteen patients were radiosurgically treated for acoustic
neuroma between 1992 and 2016 at the Department of Neurosurgery, Medical University Vienna. Patients with neurofibromatosis and patients who could not yet have a one year follow-up were excluded from the study. Thus, we present data of 557 patients with spontaneous acoustic neuroma and long-term follow-up data on 426 patients with a minimum follow-up of two years. Koos grades at time of diagnosis and at time of GKRS were evaluated. Patients were assessed according to the Gardner-Robertson hearing scale and House-Brackmann facial weakness scale prior to GKRS, and at times of follow-up. Data were evaluated retrospectively.

**Results:** 452 patients (81%) were treated radiosurgically alone and 105 patients (19%) were treated combined microsurgically-radiosurgically. Whereas the combined treatment was favored especially prior to 2002, the percentage of only radiosurgically treated cases has significantly increased since then. The overall complication rate after GKRS was low. The complication rate after GKRS further declined in the last decade. A significant enlargement of the ventricular system (hydrocephalus) after GKRS was only observed among patients harboring Koos grade III or IV tumors. One case of malignant transformation after GKRS was diagnosed (0.2%). Radiological outcome after GKRS revealed stable or decreased neuromas in the vast majority of cases including all Koos grades. The rate of non-functional hearing was already rather high prior to GKRS. At last follow-up, preservation of functional hearing was achieved in 52% of patients classified as Gardner-Robertson grade I or II prior GKRS.

**Conclusion:** GKRS is a safe and effective treatment in patients of all Koos grades. Advancements in the radiosurgical treatment especially over the last decade have led to a low complication rate and excellent outcome.

**OSP01 - WFSBS: VESTIBULAR SCHWANNOMAS 1**

**#10211 : Genetics in Vestibular Schwannomas - a comparison of native tumors and tumors treated by SRS.**

Aril Håvik (1)

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**Keywords:** Vestibular Schwannoma,

**Objective:** Vestibular schwannoma (VS) is a benign tumor with associated morbidities and reduced quality of life. Except for mutations in NF2, the genetic landscape of VS remains to be elucidated. Little is known about the effect of Gamma Knife radiosurgery (GKRS) on the VS genome. The aim of this study was to characterize mutations occurring in this tumor to identify new genes and signaling pathways important for the development of VS. In addition, the authors sought to evaluate whether GKRS resulted in an increase in the number of mutations.

**Methods:** Forty-six sporadic VSs, including 8 GKRS-treated tumors and corresponding blood samples, were subjected to whole-exome sequencing and called tumor-specific DNA variants. Pathway analysis was performed using the Ingenuity Pathway Analysis software. In addition, multiplex ligation-dependent probe amplification was performed to characterize copy number variations in the NF2 gene and microsatellite instability testing was done to investigate for DNA replication error.

**Results:** With the exception of a single sample with an aggressive phenotype that harbored a large number of mutations, most samples showed a relatively low number of mutations. A median of 14 tumor-specific mutations in each sample were identified. The GKRS-treated tumors harbored no more mutations than the rest of the group. A clustering of mutations in the cancer-related axonal guidance pathway was identified (25 patients), as well as mutations in the CDC27 (5 patients) and USP8 (3 patients) genes. Thirty-five tumors harbored mutations in NF2 and 16 tumors had 2 mutational hits. The samples without detectable NF2 mutations harbored mutations in genes that could be linked to NF2 or to NF2-related functions. None of the tumors showed microsatellite instability.

**Conclusions:** The genetic landscape of VS seems to be quite heterogeneous; however, most samples had mutations in NF2 or in genes that could be linked to NF2. The results of this study do not link GKRS to an increased number of mutations.

**OSP01 - WFSBS: VESTIBULAR SCHWANNOMAS 1**

**#10406 : Salvage treatment of vestibular schwannoma: Repeat gamma knife radiosurgery**

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Object: Although several small individual series on repeat Gamma Knife radiosurgery (GKS) for recurrent vestibular schwannoma (VS) following prior GKS have been published, we aim to systematically aggregate data from the literature as well as from our own institutions to better understand the safety and efficacy of repeat GKS for VS.

Methods: All patients that underwent repeat GKS of sporadic VS at two tertiary academic referral centers between 2006 and 2016 were eligible for study. An aggregated dataset of previously published cases plus our own data were analyzed. A cohort of patients treated with salvage microsurgery (MS) following failed GKS were included for analysis.

Results: Sixteen patients from our own institutions were included for analysis. Five patients were previously treated with MS. Mean age at first treatment was 60.1 years, mean time between first and second treatment was 50 months (4.2 years). Mean tumor volume at the first treatment was 0.539 cm³, at the second treatment 1.407 cm³. Mean follow-up after the second GKS treatment was 34 months. Five patients had serviceable hearing (AAO-HNS=A/B) before the initial treatment, none of these had preserved their serviceable hearing after the second treatment. Thirteen patients had good facial nerve function as evaluated by the House-Brackmann grade (HB≥2) before the initial treatment. None of the 13 patients with HB≥2 had worsened facial nerve function after the first GKS treatment. Of 10 patients with a complete dataset, one had worsened facial nerve function after the second GKS treatment. There were no new reported cases of trigeminal neuralgia. Overall, in 12 patients with complete follow-up: 5 tumors grew despite the second GKS treatment, 7 patients have tumor control so far. The combined dataset with patients previously reported in the literature included 88 patients: 86.4% accomplished tumor control after a mean follow-up of 43.2 months, 18.5% maintained functional hearing, 97.4% maintained good facial nerve function, 4.4% developed trigeminal neuralgia. All patients treated with salvage microsurgery accomplished tumor control 26 months after salvage, 73% had good facial nerve outcome.

Conclusion: Salvage treatment of vestibular schwannoma is challenging. Repeat GKS treatment provide poorer tumor control than what can be expected from initial GKS treatment and poorer tumor control than salvage microsurgery, few patients maintain good hearing. The risk of facial and trigeminal nerve dysfunction however, is low - and lower than what can be expected from salvage microsurgery.

Keywords: vestibular schwannoma, acoustic neuroma, recurrence, radiosurgery

OSP02 - FUNCTIONAL 1: MOVEMENT DISORDERS

#10260 : Exploring Local Diffusion MRI Properties for Vim Localisation: Evaluation in Clinical Cases

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Keywords: Vim, automated target localisation, GKS, DBS, tremor

The difficulty to directly visualize the Ventro-intermediate thalamic nucleus (Vim) on the currently routine MRI leads to the application of indirect targeting methods in stereotactic neurosurgical procedures, such as Gamma Knife Surgery (GKS) and Deep Brain Stimulation (DBS), for a treatment of drug-resistant tremor.

There has been a growing effort for automated targeting in the image-processing community based on diffusion-MRI. This technique enables the depiction of the different structural-connectivity properties and therefore, the specific fiber orientation inside each thalamic nucleus.
Our group proposed an automated and robust method across healthy subjects and tremor patients for parceling the thalamus in seven main groups of nuclei while exploring the local diffusion information from the spherical harmonics representation of the orientation distribution functions (ODFs) in k-means clustering framework. One of the resulting parcels is the Ventral-Lateral-Ventral group (VLV) enclosing all motor-related nuclei including the Vim. We aim at further automatic subdivision of the VLV cluster. To this end, within the VLV, we first built a k-nn graph with edges corresponding to the respective ODFs distances and then, we performed a partition in 3 sub-clusters using the NCut algorithm.

The proposed subdivision was compared to the radiological response in the follow-up images of 17 patients treated for tremor with GKS unilaterally. The MRI protocol included pre-operative diffusion-weighted images with 64 (or 72) gradient direction, b=1000s/mm² and voxel-size: 2.2x2.2x2.2mm³, pre-operative and post-operative MPRAGEs with isotropic resolution of ~1mm³ - all of them acquired at 3T. In general, the sub-partition followed a spatial-distribution pattern and for 12 out of 17 cases we observed that one specific sub-cluster encloses entirely or the major part of the contrast enhancement corresponding to the GKS target appearing on the follow-up images.

The evaluation of the sub-partition outcome was further extended in one additional tremor patient treated with DBS, bilaterally. Similar pre-operative MRI data, as for the GKS-treated patients, was acquired. We observed that in each hemisphere both initial targeting point and the final electrode position are inside the anticipated sub-cluster. The final left and right position are 5 and 1 mm distant from the corresponding sub-clusters’ centroids, respectively.

This study shows that the diffusion-MRI-based sub-clustering of the VLV thalamic nuclei could potentially allow, in an automated manner, to narrow the area of Vim’s localization. Our preliminary results will be further investigated in a larger patients dataset, treated by either GKS or DBS, and on diffusion images with higher spatial resolution.

OSP02 - FUNCTIONAL 1: MOVEMENT DISORDERS

#10371 : Staged Bilateral Thalamic Radiosurgery for Patients with Bilateral Tremor

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Keywords: Radiosurgery, gamma knife, thalamotomy, bilateral, Essential tremor, Parkinson’s disease, Multiple sclerosis, tremor, functional, movement disorder

Objective: Gamma knife thalamotomy (GKT) is a well-established treatment for medically refractory tremor patients who are at risk for invasive procedures. The purpose of this study was to evaluate whether staged bilateral GKT provides benefit and acceptable risk to patients suffering from disabling bilateral tremor.

Methods: At a median interval of 22 months, 11 patients underwent staged bilateral GKT during a 17 year period (1999-2016). Eight patients had essential tremor (ET), two had Parkinson’s disease (PD) related tremor, and one had Multiple-sclerosis (MS) related tremor. For the 1st GKT, a median maximum dose of 140 Gy was delivered to the posterior-inferior region of the nucleus ventralis intermedius (VIM) through a single isocenter with 4-mm collimators. Patients who benefitted from unilateral GKT were eligible for a contralateral GKT. For the 2nd GKT, a median dose maximum of 130 Gy was delivered to the opposite VIM nucleus to a single 4-mm isocenter. We used the Fahn-Tolosa-Marin (FTM) clinical tremor rating scale to score tremor, drawing, writing and drinking before and after GKT. We used the Karnofsky performance scale (KPS) to grade quality of life and activities of daily living before and after the GKT.

Results: All patients had improvement in tremor after 1st GKT. The median time to last follow-up after the 1st GKT was 35 months (range, 11-70 months). No patients had tremor recurrence or diminished tremor relief. One patient experienced new temporary neurological deficit (contralateral lower extremity hemiparesis) from the 1st GKT which improved on corticosteroids. The median time to last follow-up after the 2nd GKT was 12 months (range, 2-70 months). Nine patients had improvement in at least one FTM score after the 2nd GKT. Two patients had tremor arrest and complete resolution of function. No patient experienced tremor recurrence or diminished tremor relief after the 2nd GKT. No patient experienced new neurological or radiological adverse effect from the 2nd GKT. Statistically significant improvements were noted in the KPS following the 1st and 2nd GKT.

Conclusions: Staged bilateral GKT provides effective relief for medically refractory, disabling, bilateral tremor without increased risk of neurological complications. It is an appropriate strategy for carefully selected medically refractory bilateral tremor patients ineligible for deep brain stimulation.
**Abstracts**

**#10616 : Bilateral GammKnife Thalamotomy for severe Essential Tremor**

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**Objective:** To assess the feasibility and tolerance of bilateral Gamma Knife thalamotomy (GKT) in Essential Tremor (ET)

**Background:** Unilateral GKT is an established treatment for severe tremors. However, essential tremor is usually bilateral. The persistence of contralateral tremor may induce an impairment in activities of daily living (ADL). Bilateral procedures with thermocoagulation were contraindicated because of the risk of balance, cognitive or speech problems. As the lesion induced by radiosurgery within the VIM is progressive and limited, we proposed a study on bilateral GKT. Here are the preliminary results.

**Methods:** 15 patients (8 women) with severe ET who had benefit from a first GKT and who had a severe permanent contralateral tremor were included. Patients were included if there was no impairment in their balance or speech and if the neuropsychological assessment was stable. The 2nd GKT was performed at least 18 months after the first GKT. Patients were assessed before and quarterly for at least 12 months after GKT2, with tremor rating scale, neuropsychological and gait/balance assessments and MRI. VIM lesioning was performed with Leksell Gamma unit with a single exposure through a 4mm collimator. Radiosurgical dose was 130Grays.

**Results:** here are the preliminary results for 9 patients who completed the study at 1 year. Tremor score on the treated hand was improved by 57%. The improvement of ADL was 95%. Cognitive score and gait assessment were stable. No patient had hypophonia or dysarthria. Two patients were not significantly improved. One patient had a side effect related to GKT2. She developed hemiataxia and dysarthria induced by a hyperresponse pattern 11months after GKT.

**Conclusions:** These preliminary results on bilateral GKT for severe ET in a selected cohort of patients shows that the procedure is feasible without a major risk of cognitive or balance problems. However, a longer follow-up is needed.

**#10263 : Vim’s anatomical landmarks: Indirect targeting vs. direct visualization at 7T MRI**

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**Keywords:** Vim, SWI, 7T MRI, GKS

The ventro-intermediate thalamic nucleus (Vim) is a commonly used target in functional neurosurgery, such as Deep Brain Stimulation and Gamma Knife thalamotomy, for treatment of drug-resistant tremor. Unfortunately, the routinely used clinical Magnetic Resonance Imaging (MRI) does not allow its direct visualization. Consequently, the targeting strategies are indirect, such as atlas-based registration and stereotactic coordinates. Recent findings have shown the potential of the susceptibility-weighted imaging (SWI) acquired at 7T for imaging the thalamic nuclei with Vim being one of them. The aim of this study is to compare the localization of the target points defined by the quadrilateral of Guiot, as used in daily clinical practice, with the visual Vim-area on SWI at ultra-high field.

Data was collected from five young healthy subjects (25±2 y.o., 3 males). At 3T (TimTrio SIEMENS Scanner) we acquired the standard imaging protocol for Gamma Knife thalamotomy (GKT) including T2-weighted (TR/TE=3200/402 ms, 0.5x0.5x1mm³) and T2-weighted CISS (TR/TE=6.18/2.75 ms, 0.4375x0.4375x0.44 mm³) images, and at 7T (Siemens Medical Solutions) we acquired the...
SWI sequence (TR/TE=28/20 ms, 0.375x0.375x1mm³). Guiot targeting was performed bilaterally, six times for each subject using the 3T images. The left and the right Vim-area were manually delineated based upon the intensity variation observed from the SWI as well as the Schaltenbrand and Wahren stereotactic atlas. Both of these tasks were carried out in MITK 3M3 software.

The Vim was outlined for nine out of ten thalami, while the last one was difficult to discriminate due to a presence of a blood vessel. The volumes of the delimited Vim-area are in the interval [76.3, 83.3] mm³ conforming its size expectations. The quadrilateral of Guiot showed to be highly reproducible with a maximum intra-subject variability of 1.1mm. Additionally, these points were always inside the manually delineated Vim and predominantly in the ventral part of the outlined volume showing a tendency of their localization.

This study reports for the first time, to the best of our knowledge, a validation of the clinical targeting against subject-related imaging reference. Moreover, we observed that the clinically used Guiot targeting points are confined in the ventral part of the visually distinguishable Vim as provided by SWI acquired at ultra-high field. Further studies with larger datasets, such as tremor patients and their electrophysiological confirmation, should validate these findings.

Objective: To assess for the first time structural brain changes, by voxel-based morphometry (VBM), before and after unilateral Gamma Knife thalamotomy (GKT) for drug-resistant tremor. To identify differences between clinical responders and non-responders to GKT.

Methods: Thirty-eight patients (mean age 71.8 years) with severe refractory right essential tremor (ET) were treated with unilateral left GKT. Targeting of ventro-intermediate nucleus (Vim) was performed with Leksell Gamma Knife using a single 4-mm collimator and 130 Gy. Neurological, neuropsychological and neuroimaging (3 Tesla, including 3D T1 weighted) assessment had been done at baseline and 1 year after GKT. Clinical responders were considered those improved in tremor score (Fahn-Tolosa-Marin) with at least 45%.

Results: Thirty-one (81.6%) patients were responders (R) and 7 (18.4%) non-responders (NR). With regard to GM changes after GKT, independently of clinical answer, atrophy was present in extensive areas (right globus pallidus, left putamen, left thalamus, right anterior and medio-dorsal thalamus, cerebellar, right premotor and supplementary motor area, left and right visual association cortex, right ventral temporal, left parahippocampal and posterior cingulate gyrus). The interaction between R - NR with time showed brain plasticity in R remote areas, within left temporal pole (BA 38) and cluster including left occipital cortex (BA 19), visual areas V4 and V5, parahippocampal place area (p<0.005, k=120).

Conclusions: Our results show brain plasticity after unilateral left GKT. Responders present changes in areas involved in motion, mainly locomotor monitoring towards the local and distant environment, suggesting the requirement to recruit in the targeting specific visuomotor networks.
OSP02 - FUNCTIONAL 1: MOVEMENT DISORDERS

#10395 : Correlations between the clinical results and the MR characteristics of the thalamic lesion in Vim Gammaknife radiosurgery for tremor.

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Keywords: radiosurgery, tremor, Vim, imaging

Objective: This study aims at reporting the correlation between the clinical results and the one-year postoperative MR neuro-imaging characteristics of the thalamic lesion after Gammaknife radiosurgery for tremor.

Methods: Between April 2004 and March 2015, a Vim Gammaknife thalamotomy was performed in 319 patients for essential or Parkinsonian tremor in Marseille University hospital with a very stereotyped procedure. A neuro-imaging and clinical assessment was performed at one year FU for 253 patients. The volume of the lesion defined as the whole area of post-contrast enhancement was calculated for each patient in mm³, the pattern of lesion determined and the amount of edema evaluated according to a semi-quantitative scale. A comprehensive clinical evaluation by expert neurologists was performed at the same time. Statistical analysis was performed using R software (Version 1.0.136/2016 RStudio, Inc)

Results: Imaging data were analyzable and reviewed for a total of 169 patients at one year follow-up. Among these patients, data from neurological clinical evaluation were obtained for 91 patients. The median percentage of tremor reduction was 70% (0-100%, SD:30%). The median volume of the lesion at 12 months FU (+/- 3 months) was 91.45 mm³ (Mean = 104, Min:0, Max:1120, SD:284) . A correlation was established between the volume of the lesion and the percentage of tremor reduction (Pearson's coefficient of correlation r =+ 0.26 (p=0.0178). In patients regarded as clinical failure (< 45% of tremor improvement), the lesion volume was significantly smaller than in patients deemed responders (> 45% tremor reduction) ,p <0.0001). The amount of edema surrounding the lesion was found to be significantly related to the clinical improvement (p = 0.022). The “cocade” pattern enhancement type was strongly related to good outcome (p<0.001) and the absence of enhancement to the absence of improvement (p<0.00001 ,62% versus 0.07%).

Conclusions: These data confirm our previous results derived from 50 patients with blinded analysis of clinical outcome (Witjas and al. Neurology, 2015). Even though a significant correlation does exist between lesion volume, edema and clinical improvement, concordance is far from being very strong and linear between the imaging and clinical responses. These findings prompt to look for additional factors in order to better characterize the effects of Gammaknife that might also rest upon a delayed non-lesional neuromodulatory mechanism. These fascinating questions are of utmost importance and currently under investigation in our department.

OSP03 - METASTASES 1

#10008 : Implications of HER2 status on local control and adverse radiation effect after stereotactic radiosurgery for brain metastases from breast cancer

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Keywords: Brain metastases, Radiosurgery, Breast cancer, HER2

Objectives: To determine the implications of HER2/neu-amplification (HER2) status on local control and adverse radiation effect (ARE) after stereotactic radiosurgery for the treatment of brain metastases from breast cancer.

Methods: We retrospectively reviewed all Gamma Knife radiosurgery cases from 1998-2013 for the treatment of brain metastases from breast cancer at our institution. Newly-diagnosed brain metastases treated with radiosurgery alone and new or recurrent brain metastases after prior radiotherapy were included, and resection cavities, lesions treated with prior radiosurgery, and lesions with no imaging follow-up were excluded from
this analysis. Hormone receptor status was determined based on pathology reports from the primary breast tumor. Freedom from progression (FFP) and cumulative incidence of ARE for all treated lesions were determined using the Kaplan-Meier method with censoring at last imaging. Univariate analysis by lesion was performed using the log-rank test.

**Results:** 1314 newly-diagnosed or recurrent brain metastases in 204 breast cancer patients were included for analysis. The median imaging follow-up was 9.0 months. Actuarial 1- and 2-year FFP probabilities by lesion were 89% and 79% overall. HER2 positive status was associated with worse FFP; 1-year and 2-year FFP probabilities were 85% and 75% for HER2 positive tumors versus 95% and 86% for HER2 negative tumors (p<0.0001). Further stratification of HER2-positive lesions by ER status showed no significant difference in FFP or ARE, whereas among HER2 negative tumors, 1- and 2-year FFP probabilities were 97% and 91% for ER positive versus 92% and 80% for ER negative metastases. A dose-response relationship was seen in HER2-positive lesions (p<0.001). In HER2 positive lesions, the use of systemic therapy within 1 month of radiosurgery was associated with improved tumor control (p = 0.0007) and did not increase the risk of ARE. The cumulative incidence of ARE at 1 and 2 years was low at 2% and 6% for HER2 positive tumors versus 2% and 3% for HER2 negative tumors (p=0.11).

**Conclusions:** Radiosurgery for HER2-positive brain metastases from breast cancer appears to be associated with poorer tumor control with low incidence of ARE. Treatment intensification with dose escalated radiosurgery or concurrent treatment with systemic therapy should be considered.

**OSP03 - METASTASES 1**

**#10064 : Hypofractionated stereotactic radiotherapy for the treatment of brain metastases: analysis of 400 cases**

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**Keywords:** brain metastases, hypofractionation

**Objectives:** To analyze radiographic and survival outcomes in a large cohort of patients with brain metastases who received hypofractionated stereotactic radiotherapy (HSR) with a focus on short- and long-term tumor response, complications and mortality.

**Methods:** Patients with brain metastases who underwent HSR between 2010 and 2016 were included in the study. Radiation treatments were performed with Gamma Knife 4C and Perfexion (Elekta AB, Stockholm, Sweden), Cyber Knife (Accuray, Sunnyvale, CA, USA) and linear accelerator TrueBeam STX (Varian Medical Systems, Palo Alto, CA). The indications for HSR were determined by the presence of large volume tumors or proximity to critical brain structures. Patients with multiple brain metastases were subjected to a combination of HSR and stereotactic radiosurgery (SRS). Radiation schemes were selected depending on the number of metastases, size, location, proximity to critical brain structures, histological type of primary cancer and patient general condition. Following treatment the patients underwent control MRI examination with standard protocols (2 mm T2 and 1 mm T1 with double contrast enhancement) at 8 weeks and then every 3 months. The median follow-up time after HSR was 9 months.

**Results:** The study revealed that the application of HSR for the treatment of large volume or critically located brain metastases provided a high level of local control (12-month local control rate was 86%). Shrinkage of tumor volume by more than 50% was observed in a vast majority of patients with radiosensitive tumor histology, which resulted in considerable improvement of the patients’ neurological condition. Complications in the form of radiation necrosis occurred in 20% of patients at a median of 7.6 months after HSR. History of previous brain irradiation increased the risk of radiation necrosis (HR=3.4, p<0.001). For the entire cohort 12-month and 24-month overall survival rates after HSR were 45% and 24% respectively. There was no statistically significant difference in the median survival of the patients receiving HSR alone and those receiving HSR plus SRS. Mortality within 2 months after HSR was 10% and was associated with neurological deterioration or systemic disease progression. The best survival results were obtained in patients belonging to the first RPA-class who achieved one-year survival in 73% of the cases.

**Conclusion:** HSR and its combination with SRS is an effective treatment strategy for patients with brain metastases having at least one large unresectable lesion or a lesion located in/near critical brain structures.
OSP03 - METASTASES 1

#10269 : The role of number metastasis in the diagnosis specific graded prognostic assessment (ds-GPA) for lung, renal cell carcinoma (RCC) and melanoma

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Keywords: brain metastases, cumulative intracranial tumor volume, ds-GPA, net reclassification index, stereotactic radiosurgery, lung, melanoma, renal cell carcinoma

Background: The diagnosis specific graded prognostic assessment (ds-GPA) model is one of the most prevalent methods of prognostication for patients with cerebral metastases. The ds-GPA models for lung, RCC, and melanoma each contain number of metastases as one of the prognostic inputs. Recent literature has revealed that the impact of number of metastases has on patient outcomes is often overshadowed by the impact of cumulative intracranial volume (CITV) and other clinical variables. With this in mind, we wished to test if a simplification of the ds-GPA model for lung, renal cell carcinoma (RCC), and melanoma was non-inferior to the original model.

Objective: We wished to examine the hypothesis that binarizing the number of metastases to 1 and greater than 1 is non-inferior to the three bin model used for patients with lung, melanoma, and RCC cerebral metastases after accounting for the other components of their respective ds-GPA model.

Methods: Our patient cohort of interest consisted of 4348 patients (3745 lung, 321 RCC, 282 melanoma) from the United States, Japan, and Australia who underwent SRS for one or more brain metastases. We used the statistical metrics net reclassification index (NRI) and integrated discrimination improvement (IDI) in order to examine the ds-GPA model for lung, RCC, and melanoma against a similar model with the only change being the number of metastases category binarized. Through use of these statistical measures we were able to compare the effect of replacing the 1, 2-3, and >3 metastases grouping with 1 and >1.

Results: We found that for lung, RCC, and melanoma no difference between the original ds-GPA and the simplified version was detectable even after controlling for the other elements of each pathology’s respective model (NRI and IDI CI's capturing 0 with p > .05 for each tumor type). In fact, when subgroups of patients with similar tumor pathology were further stratified by institution/location, we found instances where the simplified model was superior to the original ds-GPA.

Conclusion: We found that simplifying the number of metastasis portion of ds-GPA model for lung, RCC, and melanoma was non-inferior to their respective, original ds-GPA models.

OSP03 - METASTASES 1

#10376 : A randomised clinical trial of the 4mm vs. the 8mm collimator for GKR of brain micro-metastases: Interim analysis.

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Keywords: brain micro-metastases, stereotactic radiosurgery, 4mm vs. 8mm collimator, GKR, GKS, clinical trial, interim analysis.
Keywords: SRS, Gamma Knife, Brain Metastases

Introduction: Gamma Knife Radiosurgery (GKR) of large numbers of micrometastases can be time consuming. Beam on time can often become the limiting factor in being able to treat every lesion in a particular patient. One technique to reduce beam on time is to use a larger collimator to a high isodose. This controversial technique decreases the dose gradient inside and outside the target. However, it is uncertain whether this makes a clinical difference, when target and treatment volumes are so small.

Objective: To investigate whether there is a difference in clinical efficacy between treating micro-metastases with GKR using the 4mm or 8mm collimator.

Methods: So far 33 patients undergoing GKR for brain metastases have consented to participate in this trial. Micro-metastases (defined here as under 0.14cc and maximum diameter under 6mm) were randomised to a single shot with either the 4mm or the 8mm collimator. Brainstem lesions and lesions within 11mm of one another were excluded. A marginal dose of 25Gy was prescribed for all lesions

Primary outcome was radiological local control at 12 months post GKR, or at the last imaging follow-up if death occurred during the first year post-GKR.

Results: 72 eligible lesions were identified in 20/33 subjects and underwent randomisation. 38 lesions were randomly assigned to the 4 mm collimator and 34 to the 8 mm collimator.

A marginal dose of 25Gy was prescribed for all lesions. The mean Prescription Isodose was 73.4% (43-93) for the 4mm group and 95.7% (88-99) for the 8mm.

The outcome has been reached by 66% of the micro-metastases and at least one follow up was available for 81% of the lesions. The mean follow-up time was 7.6 months (2.1-18.9). No lesion has shown definite enlargement (up to 30% TV increase) and no radiological evidence of oedema or radionecrosis has been detected. In the 4mm group, 40% of the lesions remained unchanged and 60% got reduced or disappeared. Similarly, in the 8mm group 45% were stable and 55% reduced/disappeared.

Seven patients developed new metastatic lesions at follow up and one of them underwent WBRT. 60% (12) patients have died, three of them from progressive intracranial metastatic disease, at a mean time of 6 months (0.3-11.3) post-GKR.

Conclusions: Initial results suggest that optimisation of treatment time for small lesions may be achieved by using the 8mm collimator without compromising clinical efficacy. Further recruitment and follow up is needed.

Objectives: For patients with up to 10 brain metastases (BM), studies increasingly support excellent disease control and toxicity outcomes with stereotactic radiosurgery (SRS) in lieu of whole brain radiotherapy (WBRT) or as salvage therapy for recurrence after WBRT. Outcomes for patients with 10 or more metastases treated with SRS remain unclear. We report our institutional experience of treatment of patients with 10 or more brain metastases at first SRS treatment session.

Methods: We identified 97 patients with 10 or more brain metastases (BM) receiving fixed-frame SRS (FFSRS) without WBRT for newly-diagnosed or recurrent BMs at our institution between September 1998 and December 2013. We reviewed treatment-related outcomes of overall survival (OS), treated lesion freedom from progression (FFP), freedom from new metastases (FFNM), and adverse radiation effect (ARE).

Results: Among the 97 FFSRS-treated patients, the median age was 56 (range 17-84) and median KPS 80 (range 40-90). Primary histologies within the cohort were breast (38), lung (28), melanoma (22), and other (9). Median number of BM per patient was 12 (IQR 11-16). Median total treatment volume was 4.3 cc (IQR 2.3-11.5 cc). Forty-three patients received FFSRS without WBRT as upfront BM radiotherapy and 54 as salvage therapy after prior WBRT, with median OS 7.8 and 8.8 mo, respectively. Sixty patients had available follow up imaging. FFP at 1 year with 95% confidence intervals for upfront vs. salvage FFSRS was 70% (49-84%) vs. 55% (30-74%) by patient and 94% (91-96%) vs. 86% (81-90%) by lesion. FFNM at one year for upfront vs. salvage FFSRS was only 9% (2-22%) vs. 14% (4-30%). At progression, 40 patients received additional FFSRS, 20 (21%) had WBRT, and one had partial brain radiotherapy. Symptomatic ARE was observed in 1% of 1018 treated lesions over the patients’ disease course. Seven patients experienced symptomatic ARE.
Conclusions: Our institutional experience demonstrates excellent local control following FFSRS for patients with 10 or more BM as upfront therapy or at recurrence following prior WBRT. Rates of ARE were modest, consistent with prior studies. Expectedly, these patients with large burden metastatic disease had a high rate of new metastases often requiring salvage SRS or WBRT.

OSP03 - METASTASES 1

#9858 : Pattern of Failure after Resection and Post-Operative Radiosurgery to the Surgical Cavity

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Keywords: Cavity, Gamma Knife, Pattern of Failure

Objectives: Stereotactic radiosurgery (SRS) after surgical resection of brain metastases has been shown to be an effective alternative to whole brain radiation for local control. In this study we assessed local failure patterns after post-op SRS to the surgical bed of completely resected brain metastases.

Methods and Materials: In a phase III randomized study (NCT00950001), 132 patients, who had no more than 3 brain metastasis with at least one completely resected were randomized to SRS or observation (OBS). Complete resection was verified by postoperative magnetic resonance imaging (MRI) and SRS was delivered to the cavity by post-op day 30. Using the Elekta Perfexion Gamma Knife unit, SRS was delivered with a 1 mm margin and the prescription dose was target volume dependent which ranged from 12 to 16 Gy. Tumor recurrence in the resection cavity or its immediate vicinity was identified on routine follow up MRI. The first MRI that identified recurrence was imported into the Leksell GammaPlan software and registered with the cavity treatment planning MRI. The recurrence was contoured and its position was evaluated relative to the prescription isodose line. The location of recurrence was classified into three categories; 1) “in-field”, 2) “cross-field” and 3) “marginal” if the recurrence volume was within, crossed, or adjacent to the prescription isodose line, respectively. The minimum dose delivered to the area of recurrence was quantified.

Results: 12 of the 64 patients randomized to SRS had local recurrence after SRS. Five cases failed in-field, 4 cases were cross-field and 3 cases were marginal. The minimum dose received by the volume showing in-field failure during SRS delivery ranged from 12 to 20 Gy. All marginal failures were notable for having dural involvement with the recurrence occurring adjacent to the prescription isodose line.

Conclusion: The factors contributed to failure after SRS are complicated. In-field failures may be due to an inadequate prescribed dose or a biologic resistance to radiotherapy. Marginal failures maybe related to inadequate margins. A larger margin, particularly along the dura may help increase local control with SRS after surgery. Cross-field failures are likely multifactorial due to factors allowing to both in-field and marginal failures. Evaluation of the clinical factors and comparison to the failures within the OBS arm are ongoing.

OSP04 - WFSBS: MENINGIOMAS

#10261 : Long-term clinical and volumetric outcomes of patient treated with stereotactic radiosurgery for parasagittal meningiomas: The impact of meningioma histology

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Keywords: stereotactic radiosurgery, meningioma, outcome
Background: The proximity of meningiomas to the superior sagittal sinus and bridging veins complicates gross-total resection of parasagittal meningiomas. Sub-total resection may result in continuous meningioma growth with repeat surgery that may be associated with higher morbidity. Stereotactic Radiosurgery (SRS) has emerged as a common treatment option for parasagittal meningiomas, and provides a relatively safe, minimally invasive treatment that decreases the need for surgery. Still, the optimal approach for parasagittal meningiomas, the long term volumetric outcome and prognostic factors following SRS remain unclear.

Objective: To review our long term volumetric results for the treatment of parasagittal meningiomas with LINAC-based radiosurgery, and determine possible factors affecting prognosis.

Methods: We retrospectively reviewed our prospectively collected data base of patients treated at our institution between 2004-2013. Volumetric assessment of all follow-up MR-image data-sets were performed using the iPlan Image software (BrainLab AG). Kaplan-Meier analysis was used to determine survival. Cox regression analysis was used to identify independent prognostic factors.

Results: Our cohort consisted of 44 patients with 46 parasagittal meningiomas. There were 29 pts(66%) with WHO grade I tumors and 15 pts(34%) with WHO grade II tumors. Female gender was 65.5% and 20% in our WHOI and WHOII meningioma patients respectively. Previous surgery was performed in 71.74% of the tumors, while 40.9% of the patients suffered from pretreatment neurological symptoms. The mean follow-up time was 47.23 months. Local control (LC) was achieved in 100% of the WHO I group, compared to 62.5% in the WHO II group (p<0.001). The five-year progression-free survival (PFS) rate was 79.4% and 26.3% in the WHOI and WHO II groups, respectively (p<0.001). Five-year overall survival (OS) rate was 95.8% and 74.2% in the WHOI and WHO II groups, respectively (p<0.034). 15.9% of patients suffered from symptomatic peritumoral edema which was transient in all but one patient. The mean volumetric tumor reduction was 26.25% and 5.13% for WHOI and WHOII meningiomas, respectively. Histological grade and pretreatment neurological symptoms were found to be a significant unfavorable prognostic factor for LC and PFS in our patients. Other factors such as tumor volume, or previous craniotomy were not found to have a significant effect on outcome.

Conclusions: Stereotactic Radiosurgery for parasagittal WHO I and WHO II meningiomas offers a relatively safe and effective treatment modality, with good long term volumetric local tumor control, PFS and OS.

WHO II meningiomas display significantly worse outcomes.

OSP04 - WFSBS: MENINGIOMAS

#10162 : Stereotactic radiosurgery (SRS) for intracranial meningiomas

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Keywords: stereotactic radiosurgery, brain lesions, meningiomas, intracranial

Introduction: Many intracranial meningiomas are eloquent sites where surgical resection poses considerable risk of neurological deficit. The objective of this study is to review of the use of Stereotactic Radiosurgery (SRS) for these lesions in a single centre.

Materials and Methods: This ratified Ethics approved study audits a disease-specific database for all patients with meningioma consecutively treated by linear accelerator-based SRS. Head fixation was via a BRW Head-Ring using Radionics-Software for planning with a rigid quality assurance evaluation throughout the whole process. Dose delivery was via a “cone” based approach for “spherical” lesions, or via a mini-multi-leaf-collimator (MMLC) to larger or more irregular shaped lesions. Dose range was 11-16Gy. Statistical evaluation was conducted using SPSS v24 and survival analysis was performed using the Kaplan-Meier product limit method.

Results: From 1st May 1991 to 31st July 2015, 270 meningiomas were treated in 235 patients (19 patients with ≥2 tumours). Females constituted 73% (n=172) of patients treated, with a median age of 54 years (range 7-87). For eligible intracranial meningiomas, the cavernous sinus was the most frequently involved site (47%, n=127), followed by the petrous ridge (37%, n=101), and clivus (13%, n=36), though many lesions involved multiple anatomical sites. The most common presenting feature was diplopia (26%, n=70), followed by involvement of cranial nerve (CN) VI (19%, n=52), headache (16%, n=44) and involvement of CN V (16%, n=44). Cone-based treatment delivered a
A median dose of 14.0Gy to a median volume of 2.8cm³ in 167 patients. MMLC based intensity modulated radiosurgery delivered a median dose of 13.5Gy to a volume of 7.2cm³ in 103 patients. Median follow-up of all patients was 6.9 years. Patients receiving SRS had 5- and 10-year progression-free survival and overall survival rates of 91% and 84%, and 90% and 82% respectively. For 35 patients with demonstrated progression, median time to failure was 3.6 years (range 0.01 to 21.6 years). Cause-specific survival rates were 96% at 5 years, and 92% at 10 years post-SRS. Fifty-one percent of patients presenting with headache had improvement post SRS (54/107), 54% reported improved diplopia (38/70), and 48% had improvement in CN VI function (25/52). Few patients had worsened symptoms post-SRS. Three patients had worsened trigeminal nerve involvement, and four patients had worsened headaches post-SRS (<4%).

Conclusion: Single session SRS provides a convenient, effective, and safe means of treating many intracranial meningiomas.

OSP04 - WFSBS: MENINGIOMAS

#10227 : Survival Outcomes of patients underwent LINAC-Based Stereotactic Radiosurgery for Radiation-Associate Meningioma – Comparative Case Control study

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Keywords: SRS, Meningiomas, Radiation-associate meningiomas, outcome

Objective: Our goal was to compare the clinical and imaging outcomes of Radiation Associate Meningiomas (RAM's) patients with those of Sporadic Meningiomas (SM's) patients who underwent Stereotactic Radiosurgery.

Methods: Fifty-three patients harboring 102 RAM's and 163 patients with 204 SM's were treated consecutively by stereotactic radiosurgery in our institution between March 2004 and 2012. Clinical and radiological follow-up (mean 42.53 months) was completed in all patients. Study groups were compared for age, sex and for previous microsurgery. Multifocal meningiomas observed in 31 (58.5%) and 31 (19%) patients with RAM's and SM's respectively (p<0.001). Fifteen (28.3%) RAM's and 17 (10.4%) SM's patients had either atypical or malignant histology (p=0.003). Average initial tumor volume was 5.99 and 4.43 cc (RAM's, SM's respectively). Clinical data were collected from hospital records. Radiological control rate was assessed by volumetric measurements on Ax3DT1+Gd. MR data sets at the end of follow-up using the iPlan Image 5.2 (BrainLab AG). Local tumor control (LC), disease progression free survival (PFS) and overall survival (OS) were calculated as well.

Results: The mean reduction in tumor volume at the end of follow-up was 1.46 (24%) and 0.65cc (15%) in the SM group and the RAM group respectively. LC was 89.6% in the SM, compared to 72.5% in the RAM (P<0.001). The PFS in the SM was 85.3% with a mean time of 99.05 months (95% CI, 91.12 to 106.96), and 46.2% in the RAM with a mean time of 61.83 (95% CI 51.9- 71.7) (p<0.001). The OS in the SM group was 95.7% with mean survival time of 122.2 months (95% CI, 118.7 to 125.7), compared with 81.1% in the RAM group with mean survival time of 103.7 months (95% CI, 92.6 to 114.78).

COX's analysis found that age>60, previous irradiation, previous surgery, multiplicity and histology had a negative impact on OS and PFS.

Conclusion: Radiosurgery was found to be an effective treatment for RAM and SM. When compared to spontaneous meningiomas, radiation-associate meningiomas manifest with significantly higher multifocal disease and tendency for WHOII/III histology. Stereotactic radiosurgery for RAM's results more frequently in radiological recurrent disease particularly in non-benign meningiomas. However, in RAM's patients whose tumor affect critical structures and/or are poor surgical candidates, stereotactic radiosurgery may provide satisfactory clinical and radiological control rates.

OSP04 - WFSBS: MENINGIOMAS

#10373 : Planned subtotal resection followed by GKR for complex skull base meningiomas: Lausanne experience

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Conclusion: Skull base meningiomas requiring combined treatment are challenging lesions, with non-negligible morbidity. Performing planned subtotal resection in order to make GKS possible seems to be a valid strategy to achieve local control while limiting neurological morbidity. Surgical chiasmopexy proved to be very useful in those cases with residual tumor close to optic pathways, to limit the radiation dose received by the former. In cases when single fraction GKS is not suitable, hypofractionation with the new Leksell Gamma Knife ICON can be a valuable alternative.

#9746 : Clinical Outcome of Gamma Knife Radiosurgery for Skull Base Meningiomas after Surgery: Effect for Residual Tumors and Preservation of Cranial Nerve Function and Recurrence Rates

Satoka Shidoh (1), Masahito Kobayashi (2), Takayuki Ohira (3), Ryosuke Tomio (3), Tadashige Kano (4), Kazunari Yoshida (3), Takeshi Kawase (3)

Objective: To evaluate long-term outcome of residual skull base meningiomas after gamma knife (GK) with our conservative strategies, avoiding excessive irradiation to cranial nerves.

Methods: Sixty-nine patients (51 women, mean age 57.9 y/o) were included and 55 of them underwent surgery before GK. The mean follow-up period was 98.0 months (median 106.2). The mean tumor volume was 5.74 ml (0.2-25.6). Forty-eight patients had residual tumors in the cavernous sinus region. The mean marginal and maximal doses were 13.2 Gy (10-15) and 26.4 Gy. To prevent cranial nerve injuries, the doses for the lateral wall of the cavernous sinus were set below 13 Gy, and those near the superior orbital fissure were below 18 Gy.

Results: Tumor regrowth was observed in 7 patients and the other two showed recurrence outside the irradiation areas. Additional treatments were done in six patients; repeated surgery for three including two with large-sized residual tumors (>18 ml), and repeated GK for three including two with recurrence outside the irradiated areas. No regrowth
was observed in the patients without preceding surgeries. The actuarial progression free survival rate was 88.0%, and the actuarial tumor volume decrease rate was 38.7% at 10 years. Malignant transformation were not observed. Preexisting abducens nerve paresis got worsened in one patient. Improvement of visual or oculomotor function was observed in four patients. Tumor volume >10ml was significantly associated with tumor regrowth.

**Conclusion:** GK with our conservative planning is safe and effective over the long term for skull base meningiomas.

**OSP04 - WFSBS: MENINGIOMAS**

**#9986 : Stereotactic radiosurgery for the treatment of meningiomas eligible for complete resection**

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**Keywords:** LINAC SRS, Meningeoma, surgically resectable

**Objective:** Microsurgical resection is the first recommended treatment for meningiomas especially if sufficient resection can be achieved (Simpson Grade I&II). Stereotactic radiosurgery (SRS) is established as treatment option for meningiomas considered inoperable due to critical localisation or involvement of vulnerable structures. In this study, we evaluated the efficacy and safety of SRS in cases where a Simpson Grade I or II resection could be achieved but either patient’s wish or condition excluded surgery.

**Methods:** In this retrospective single-center analysis (1995-2014) we included all patients who underwent single fraction LINAC based SRS for microsurgically resectable (Simpson Grade I&II) cranial meningiomas with clinical follow-up of ≥6 months. Histologically confirmed WHO II/III tumors were excluded. We analyzed local tumor control by magnetic resonance imaging, early (first 6 month after SRS) and late treatment related complications, including symptomatic peritumoral edema requiring steroids (rated by the Common Terminology Criteria for Adverse Events; CTCAEv4.03). Local control was estimated by Kaplan-Meier method.

**Results:** 85 patients (f:m=65:20, mean age 60 years) were treated with LINAC-SRS for 92 supra-(67.4%) or infratentorial (32.6%) meningiomas localized in skull base (63.0%), convexity (20.7%), parafalcine (14.1%) or other areas (2.2%). Treatment indication was based on documented tumor growth in 71.7% or recurrence after surgery in 28.3%. Mean follow-up was 68.7 ±48.8 months. Mean tumor volume was 4.1 ±3.6ml, mean radiation parameters were 13.2 ±2.2 Gy surface dose at 65.8 ±13.9% isodose level. The estimated 2-,5-, and 10-year tumor control rate was 99%, 93% and 93%, respectively. Local recurrence was observed in one case after 180.4 months (1.2%) and loco-regional (out of dose) recurrence in five patients after 17.7–155.7 months (5.9%). Minor early complications (headache, dizziness) occurred in 4.7%; one patient suffered from seizures. Late complications encompassed permanent deterioration of cranial nerve function in two cases (CTCAE:1;2) and transient seizures in one patient. Temporary steroid use due to symptomatic peritumoral edema was observed in 7.1%.

**Conclusion:** SRS can be considered as treatment alternative for patients with meningiomas eligible for Simpson Grade (I&II) resection either refusing or harboring contraindications to microsurgery. SRS treatment provides reasonable long term tumor control with low morbidity rates.

**OSP04 - WFSBS: MENINGIOMAS**

**#10381 : Gamma-Knife radiosurgery as first line treatment for benign cavernous sinus meningioma: a multicentric prospective study**

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**Keywords:** Radiosurgery, gamma knife, cavernous sinus meningioma

**Objective:** Gamma knife radiosurgery (GKRS) is a consistent option for the treatment of cavernous sinus meningioma (CSM). We propose a multicentric prospective study reporting the local tumor control and clinical outcomes after GKRS as first line treatment for CSM.

**Methods:** From January 2010 to August 2016, all patients treated in Lille and Lausanne by first-line GKRS for a benign cavernous sinus meningioma were included. The exclusion
criteria were: non-typical radiological lesion, multiple meningiomas. Clinical outcomes (including visual acuity, oculomotor and trigeminal dysfunction), dosimetric data (treatment dose, treated volume, selectivity / conformity index) and imaging follow-up were reported.

Results: A total of 85 patients were treated. The median age at diagnosis was 52 y/o (range 24-84). The median follow-up was 27 months. The median target volume was 3.49 cm³. The pre-GKRS deficits were: oculomotor palsy in 55%, trigeminal dysfunction in 39% and a visual acuity decrease in 8%. The median prescribed dose was 14 Gy, at the 50% isodose line, with a median of 14 shots. The mean conformity and selectivity index were respectively of 97% and 75%. After GKRS, 45 % of patients improved their clinical situation, 42 % were stable. Three (3.6%) patients worsened their previous deficit at last follow-up. No new deficit was reported. Tumor volume decreased in 49% of patients and was stable in 49% of cases. One patient harbored a tumor volume increased while improving his pre-GKRS symptoms (no additional treatment needed).

Conclusion: GKRS is safe and effective modality to treat benign CSM. At last follow-up, 87% of patients were clinically improved or stabilized with a local tumor control reached in 99% of patients.

**Keywords:** gamma knife, cerebellopontine, meningiomas, hearing

**Background:** The presence of the hearing apparatus in the vicinity of cerebellopontine angle (CPA) meningiomas makes hearing function, theoretically, at risk during gamma knife treatment.

**Objective:** To assess the hearing function after gamma knife treatment of CPA meningiomas and assess factors affecting the hearing outcome. Hearing preservation, to the best of our knowledge, has never been separately addressed in studies involving gamma knife radiosurgery for CPA meningiomas.

**Methods:** In this study, we included patients with CPA meningiomas with serviceable hearing and tumor extension in to the region centred on internal auditory meatus. These included 66 patients that underwent a single session of gamma knife radiosurgery between 2002 and 2014. The most common presenting symptoms were facial pain, facial numbness, vertigo and disequilibrium. All the patients had serviceable hearing before treatment (Gardner-Robertson (GR) grade 1 and 2). Fifty-seven patients (86%) had GR grade 1 hearing and 9 patients (14%) had GR grade 2 hearing. The median tumor volume was 7 cc (1.5-41.4 cc) and median prescription dose was 12 Gy (10-12 Gy). The median maximum cochlear dose was 6 Gy (1.5-11.1 Gy). The median follow up was 33 months (6-149 months).

**Results:** At the last follow up, the tumor was stable in 38 patients (58%), shrank in 26 patients (39%) and progressed in 2 patients (3%). The tumor control rate was 97%. The hearing remained stable in 59 patients (89%) and worsened in 7 patients (11%). The GR grade, after treatment, decreased from grade 1 to 2 in 6 patients and from grade 2 to 3 in one patient. In all the patients, the hearing remained serviceable except one patient. Hearing preservation was determined to be maintained serviceable hearing according GR hearing score. The hearing preservation rate was 98%. The 5- and 10-year serviceable hearing preservation rate was 82% and 75%, respectively. The median time to hearing deterioration was 14 months (6-22 months).The median maximum cochlear dose in the patients with preserved and worsened hearing was 6 Gy and 5.5 Gy, respectively. No statistical significance was found. Two patients developed symptomatic edema. In one patient, the symptoms were temporary and in the other, symptoms were due to tumor progression.

**Conclusion:** Gamma knife radiosurgery for CPA meningiomas provides excellent hearing preservation in addition to high tumor control rate.

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**Keywords:** gamma knife, cerebellopontine, meningiomas, hearing
OSP05 - PHYSICS 1
#9935 : Quality Assurance of Gamma Knife Icon Radiosurgery

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Keywords: Quality Assurance, Gamma Knife Icon, Overall accuracy

Purpose: Quality assurance results of Gamma Knife Icon™ (GKI) for one year were analyzed to assess the accuracy of frameless Gamma Knife surgery and stability of the system.

Methods: Routine QA works on the radiological part such as absolute dose rate measurement, verification of couch movement, absolute comparison between calculated and measured dose distribution, end-to-end test of positional accuracy were performed. The image quality of the cone-beam CT (CBCT) of GKI was measured biweekly with Catphan® 503 phantom. The positional accuracy of CBCT was assessed daily using four ball bearings on a manufacture provided phantom. The accuracy of the high definition motion management (HDMM) system was also assessed with a home-made device using a micrometer.

Results: Measured dose rates coincided with calculated values with mean error of 0.68 +/- 0.08% and measured half-life of cobalt 60 was 5.391 +/- 0.040 years. Gamma index pass rates with 3.0%/1.0mm criterion were greater than 99.1% for all single shots. A virtual target plan showed 98.6 +/- 1.6% gamma index pass rates at various locations in an anthropomorphic phantom. The positional accuracy of CBCT was 0.08 +/- 0.06mm and 0.06 +/- 0.05mm, respectively. For one year, the mean offset of the focus was 0.1 +/- 0.0 mm. The mechanical accuracy of the CBCT coordinate system was stable for one year (0.06 +/- 0.02mm deviation). For 2.5 mGy CTDI images, contrast to noise ratio was 1.13 +/- 0.3, and uniformity was 14.6 +/- 0.7%. For 6.3 mGy CTDI images, they were 1.78 +/- 0.08 and 14.5 +/- 0.7%, respectively. The slope of the HDMM values with respect to the real movement was 1.03 +/- 0.01 along the x-axis and 1.00 +/- 0.03 along the z-axis. The end-to-end test on the positional accuracy of the mask based irradiation was 0.9 +/- 0.3mm in an anthropomorphic phantom. Image co-registration showed 0.4 +/- 0.1 mm deviation between CT and CBCT images and 1.0 +/- 0.3mm deviation between MR and CBCT images.

Conclusions: Overall accuracy of a millimeter order was verified for a frameless gamma knife surgery by various quality assurance works.

OSP05 - PHYSICS 1
#9934 : Assessment of co-registration accuracy of Gamma Knife Icon cone beam computed tomography

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Keywords: Gamma Knife Icon, cone beam CT, co-registration accuracy

Purpose: The accuracies of co-registration between the stereotactic images and the cone beam CT (CBCT) images of Gamma Knife Icon were assessed and parameters to enhance the accuracy were studied.

Materials and Methods: The accuracy of the co-registration procedure was evaluated by co-registering CBCT images taken at various situations to a reference CBCT. Then, stereotactic CT images of an anthropomorphic head phantom were obtained and co-registered to the CBCT images taken at arbitrarily moved positions. The coordinates of fifteen landmarks inside the phantom were measured. The co-registration was performed with four different ranges in the patient head and their accuracies were compared.
**Results:** Co-registration between CBCT images showed deviations of 0.2 +/- 0.1 mm. After co-registration of stereotactic CT images to the CBCT images, the mean and standard deviation of the coordinate values in the left-right (x-axis), anteroposterior (y-axis), and craniocaudal (z-axis) direction was 0.0 +/- 0.3 mm, -0.3 +/- 0.2 mm, and 0.0 +/- 0.2 mm, respectively. The overall mean three dimensional deviation was 0.4 +/- 0.1 mm. Co-registration of MR images to CBCT images were related with larger errors. The three dimensional difference of AC coordinates was 1.1 +/- 0.3 mm and that of PC was 0.9 +/- 0.3 mm. These differences were statistically correlated with the movement of coordinate systems calculated by the co-registration procedure. The target coverage ratios in the CBCT based system was lower than those in the fiducial marker based system, 92.2 +/- 7.1 % versus 97.9 +/- 1.7 % (p = 0.000). A region of co-registration (ROC) covering skull base area produced smaller co-registration error than other regions (p = 0.000).

**Conclusion:** Image co-registration error of GK Icon CBCT was similar with the registration error of the fiducial markers and the resolution of the images. In order to reduce the co-registration error, a portion of the MR images including skull base area is recommended for co-registration.

**OSP05 - PHYSICS 1**

**#10131 : Patient positioning accuracy in Gamma Knife radiosurgery with mask fixation and cone beam CT**

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**Keywords:** Gamma Knife ICON, mask, CBCT

**Purpose:** The Leksell Gamma Knife ICON introduces a mask fixation capability for patient setup and an optical tracking system for patient position monitoring. The purpose of this study is to evaluate the treatment target positioning accuracy at different stages of the mask-based Gamma Knife radiosurgery (GKRS) procedures.

**Methods:** CBCT imaging was applied to 11 patients who underwent multi-session mask-based GKRS and 7 patients with single session frame-based GKRS. A reference CBCT image set was obtained for each patient before the first session using the 6.3mGy dose setting. Setup CBCT images were acquired for each mask patient before each fraction using the 2.5mGy dose setting and repeated whenever a treatment pause was triggered by the motion surveillance system that tracks a fiducial marker attached to the patient nose. The treatment target positioning accuracy within the workflow of a mask-based GKRS is analyzed in terms of: 1) the registration change between the planning MR images and the reference CBCT images as obtained from the frame based GKRS with CBCT imaging; 2) the inter-fraction patient positioning accuracy determined from the registration changes for different fractions of a mask-based GKRS; 3) the intra-fraction patient positioning accuracy calculated as the difference between the registration changes for the initial setup scan and the intra-fraction CBCT scan following a treatment pause.

**Results:** The averaged values of the absolute translational changes in the X,Y,Z directions and the rotational changes along the X,Y,Z axes from the MR/CBCT image registrations for the 7 frame-based cases are 0.16mm,0.1mm,0.28mm and 0.41°,0.19°,0.12°, respectively. The corresponding numbers for the 41 inter-fraction registrations are 0.82mm,0.72mm,1.48mm,0.74°,0.78°, and 1.37°. The averaged values of the absolute differences in the translational and rotational changes between the 17 intra-fraction scans and the corresponding initial setup scans are 0.38mm,0.44mm,0.70mm and 1.12°,0.35°,0.86°, respectively. The smallest set of differences observed for the 17 treatment pauses are 0.01mm,0.03mm,0.03mm, and -0.16°,0.1°, -0.09°. This indicates minimum head movement despite some movement of the patient nose.

**Conclusions:** The registration changes between the planning MR images and the reference CBCT images are in general much smaller than those between the reference and the setup CBCT scans. The largest discrepancies in the CBCT registrations are usually seen in the Z direction for the translation changes or along the Z axis for the rotational changes. The optical tracking system may report a false alarm in some cases, owing to the inaccurate correlation between the nose reflector and the patient’s skull.

**OSP05 - PHYSICS 1**

**#10268 : A monolithic silicon detector array for small field QA in Stereotactic Radiotherapy: DUO**

Khalsa Al Shukaili (1), Stephanie Corde (2), Marco Petasecca (3), Anatoly Rosenfeld (4), Michael Lerch (5)
Abstracts

“A monolithic silicon detector array for small field dosimetry in Stereotactic Radiotherapy: DUO”

Introduction: Stereotactic radiosurgery (SRS) commissioning and quality assurance (QA) are challenging as the technique uses extremely small, highly collimated photon beams, which require high geometric precision and dosimetric accuracy. Silicon diode arrays have a number of advantages including: real-time operation (compared to film) and high spatial resolution and small size (compared to ionizing chambers), which make their implementation advantageous for SRS QA. This work aims to characterize the monolithic silicon diode array named “DUO” designed for stereotactic QA.

Methods: DUO is a silicon monolithic detector manufactured on a p-type substrate, designed by CMRP at UOW as shown in figure 1. The pixels are arranged in two cross linear arrays with 256 individually readout pixels for each arm. The pixel pitch is 0.2 mm and the overall detector area is 52 x 52 mm². DUO is placed on a 0.5 mm thick tissue equivalent printed circuit board. Characterization of DUO was performed, and used to measure 6MV beam profiles, percent depth dose and output factor for Elekta SRS cone collimators from 5 to 50 mm diameter on an Axesse ELEKTA Linear accelerator with Agility head. The DUO measurements were compared with results obtained with EBT3 films and Stereotactic field diode (SFD).

Results: The output factor agrees within 1% when compared with EBT3, and 2% with SFD for all cone sizes. The profiles of SRS cones show agreement in the FWHM and (20-80) % penumbra with EBT3 within 1% and 0.6 mm, respectively. The measured depth dose response agreed to within 1.5%, compared to EBT3 for depths beyond the build-up region.

Conclusions: DUO is a suitable detector for stereotactic dosimetry as it has excellent resolution 0.2 mm in a direction of steepest dose gradient, on time data analysis and provides both in-plan and cross-plan measurements. The good agreement with EBT3 films measurements confirms its accurate and precise data.

References


#10115: Extracranial doses on Leksell Gamma Knife Perfexion – in vivo TLD study on 80 patients

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Objectives: Main purpose of this study was to perform an assessment of extracranial patient doses received during treatment on Leksell Gamma Knife (LGK) Perfexion. Results were compared with published data from previous gamma knife systems (model B and C).

Methods and materials: Extracranial doses were measured for 80 patients treated on the LGK Perfexion. Thermoluminescent dosimeters (TLDs) were positioned on patients at seven different following locations: eyes, thyroid, chest, abdomen, pelvis, knee and ankle. Measured data were evaluated and analyzed in terms of parameters that may affect extracranial doses. Following parameters were considered for analyses: prescribed dose, total irradiation time, distance between isocentre and position of TLDs, volume of prescribed isodose, total integral dose in target volume and total integral dose in brain.

Results: Mean extracranial doses delivered to patients in this study were: eyes (151.2 mGy), thyroid (10.1 mGy), chest (4.1 mGy), abdomen (1.2 mGy), pelvis (0.73 mGy), knee (0.30 mGy) and ankle (0.11 mGy). Significant dependence of extracranial doses was observed on total irradiation time, distance between isocentre and position of TLDs, volume of prescribed isodose, total integral dose

Keywords: extracranial doses, in vivo TLD dosimetry, Leksell Gamma Knife Perfexion
in target volume and total integral dose in brain. In comparison with previous LGK models (B and C), there was observed a significant decrease of the extracranial doses in LGK Perfexion in the range of two to twenty times lower (depending on measured anatomical location).

**Conclusion:** Measured extracranial doses are generally very low and thus safe for treated patients. Observed measured doses are far below dose limits for deterministic effects. In comparison with previous LGK systems, Perfexion appears to be much safer with significantly lower extracranial doses.

**OSP06 - METASTASES 2**

#10339 : Clinical outcome of Stereotactic Body Radiation Therapy for the treatment of abdomino-pelvic lymphnode recurrence in oligometastatic patients

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**Keywords:** sbrt, lymphnode, oligometastasis, metastasis

**Purpose:** the aim of this study is to evaluate local control, overall survival and pattern of toxicity for oligometastatic patients with isolated lymphnode recurrence treated with Stereotactic Body Radiation Therapy (SBRT) and Volumetric Modulated Arcs (VMAT).

**Materials and methods:** Seventy-one patients were treated for a total of 79 lesions from 2009 to 2015. Dose prescription was 45Gy in 6 daily fractions for all patients. Delivery was performed with VMAT and flattening filter
free beams (FFFs). Dosimetric analysis was carried on the treatment plans while clinical outcome was assessed by means of actuarial analysis. Treatment response was assessed by means of the RECIST criteria. Toxicity was recorded according to the common toxicity criteria version 4.0.

Results: with a median follow of 1.5 years (range: 0.2-6.2), 45 patients (63.3%) had solitary metastasis while 26 (36.6%) had multiple lesions. Primary tumour was located in the gastrointestinal tract in 59.1% of patients. Local control was achieved in 97.5% of the lesions with an actuarial rate at 1 year of 83%. Progression free survival at 1 year was 86% while overall survival was 93%. Only 2 patients (3%) developed grade 2 gastrointestinal toxicity, no grade 3 cases were observed.

Conclusion: SBRT with VMAT technique and FFFs can be considered a well tolerated treatment with adequate clinical response in this group of patients confirming its appropriateness in the oligometastatic setting.

OSP06 - METASTASES 2

#9954 : Significant tumor shift in patients treated with stereotactic radiosurgery for brain metastasis

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Keywords: SRS, Brain metastasis, edema, steroids, tumor shifts

Introduction: Linac-based Stereotactic Radiosurgery (SRS) for brain metastases may be influenced by the time interval between treatment preparation and delivery, related to risk of anatomical changes. We studied tumor position shifts and its relations to peritumoral volume edema changes over time, as seen on MRI.

Methods: Twenty-six patients who underwent SRS for brain metastases in our institution were included. We evaluated the occurrence of a tumor shift between the diagnostic MRI and radiotherapy planning MRI. For 42 brain metastases the tumor and peritumoral edema were delineated on the contrast enhanced T1weighted and FLAIR images of both the diagnostic MRI and planning MRI examinations. Center of Mass (CoM) shifts and tumor border were evaluated. We evaluated the influence of steroids on peritumoral edema and tumor volume and the correlation with CoM and tumor border changes.

Results: The median values of the CoM shifts and of the maximum distances between the tumor borders obtained from the diagnostic MRI and radiotherapy planning MRI were 1.3 mm (maximum shift of 5.0 mm) and 1.9 mm (maximum distance of 7.4 mm), respectively. We found significant correlations between the absolute change in edema volume and the tumor shift of the CoM (p<0.001) and tumor border (p=0.040). Patients who received steroids did not only had a decrease in peritumoral edema, but also had a median decrease in tumor volume of 0.02cc while patients who did not receive steroids had a median increase of 0.06cc in tumor volume (p=0.035).

Conclusion: Our results show that large tumor shifts of brain metastases can occur over time. Because shifts may have a significant impact on the local dose coverage, we recommend minimizing the time between treatment preparation and delivery for Linac based SRS.

OSP06 - METASTASES 2

#9958 : Phase I study of spinal cord constraint relaxation with single session spine stereotactic radiosurgery (SSRS) in the primary management of patients with inoperable, previously unirradiated metastatic epidural spinal cord compression (MESCC)

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Keywords: SSRS, SBRT, Cord, myelopathy, epidural

Objectives: We seek to establish the feasibility of using SSRS allowing for spinal cord dose constraint relaxation as the primary management of MESCC in inoperable patients monitoring for radiation related toxicity and radiographic local control (LC).

Methods: Patients with MESCC in the thoracic spine deemed inoperable with no prior history of radiation at the site of interest were enrolled on this prospective Phase 1 single institution protocol. Single fraction SSRS was delivered to a histology dependent prescription dose of 18 or 24 Gy. Spinal cord constraint relaxation was performed from an initial allowable Dmax cohort of 10 Gy only if tumor progression occurred. If the risk of radiation induced spinal cord myelopathy (RM) remained lower than the risk of tumor progression, then the cord Dmax was elevated in 2 Gy increments to a maximum of 16 Gy in the final cohort. Patients were monitored every 3 months with follow-up visits, MRI scans and validated patient reported outcome surveys.

Results: Thirty-two patients enrolled on the trial of which 4, 12, 8 and 8 were in the 10 Gy, 12 Gy, 14 Gy and 16 Gy cord Dmax cohorts, respectively. The most common histology was renal cell carcinoma (n=12). The most common GTV prescription dose was 18 Gy (n=17) followed by 24 Gy (n=15). The median age was 62.7 yrs (range 35-81 yrs). At baseline, there were 10 sites with MESCC Grade 1B, 10 sites with Grade 1C, 9 sites with Grade 2, 2 sites with Grade 1A, and 1 site with Grade 3 epidural extension of disease. The median overall survival of the cohort was 28.6 mos (95% CI 19.6, NR). Of the 32 patients treated with SSRS, 4 were lost to follow-up without post-SSRS evaluation. Of the remaining 28 patients, the 1-year LC was 80.5% and median LC was not met. Six, 12 and 24 months local control rates were 100%, 96% and 96% respectively. Twelve patients were alive during the analysis. Overall survival rates of 6, 12 and 24 months were 84%, 57% and 10% respectively from the time of the first diagnosis and 93%, 83% and 69% from the diagnosis of adrenal metastases. None of the patients experienced any acute of late toxicity.

Conclusions: SSRS is a safe and effective tool in patients with MESCC. Cord constraint relaxation may be considered in inoperable patients with MESCC.

OSP06 - METASTASES 2

#10038 : STEREOTACTIC RADIOSURGERY FOR THE TREATMENT OF ADRENAL OLIGOMETASTASES

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Keywords: stereotactic radiosurgery, adrenal metastases

Purpose: To evaluate the efficacy and safety of adrenal oligometastases treated with hypofractionated stereotactic radiosurgery in a single institution.

Methods and Materials: Between August 2013 and September 2016, we treated 34 adrenal metastases from 29 patients. All lesions except one was treated with linear accelerators, the residual 1 lesion was treated with robotic radiosurgery. Motion management strategy for linear accelerator based treatments was the internal tumor volume formation with 4 dimensional computed tomography and fiducial placement and tracking with the robotic radiosurgery. The prescription dose was 50 Gy in 5 fractions for all patients. The response evaluations were performed with PET-CT after 3 months and upper abdominal CT or MRI every 3 months afterwards. Local control was defined as metabolic response of the first PET-CT imaging and no progression in size afterwards.

Results: The local control and survival analyses were performed on the patients who have at least 3 months of follow up. The majority of the patients had lung cancer primary. The median age of the patients were 58 (43-84), all but one patients were male. The median follow up was 24 months (2-40 months). In 1 patient local progression was detected after 11 montjs, the rest are still under local control. Six, 12 and 24 months local control rates were 100%, 96% and 96% respectively. Twelve patients were alive during the analysis. Overall survival rates of 6, 12 and 24 months were 84%, 57% and 10% respectively from the time of the first diagnosis and 93%, 83% and 69% from the diagnosis of adrenal metastases. None of the patients experienced any acute of late toxicity.

Conclusion: Stereotactic radiosurgery for adrenal oligometastases is a non-invasive, safe and effective local treatment strategy without any compromise in systemic therapy. It is being used as a standard approach in our hospital.

OSP06 - METASTASES 2

#9998 : Outcomes of stereotactic radiosurgery for motor-region brain metastases

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Objectives: Our institution utilizes conservative stereotactic radiosurgery (SRS) dosing and reduces dose by -1.2 Gy for motor region metastases because of toxicity concerns, but this may compromise local control. Here we evaluate freedom from progression (FFP) and risk of adverse radiation effect (ARE) after Gamma Knife SRS for primary motor cortex or frontoparietal brain metastases to consider dosing recommendations.

Methods: Within a cohort of brain metastases with follow-up imaging treated at our institution 1998-2013 with SRS alone upfront or SRS for recurrence after prior radiotherapy, we compared actuarial FFP and risk of ARE for motor cortex or frontoparietal (“motor”) vs. non-motor frontal or parietal (“non-motor”) lesions. FFP and ARE were measured from the date of SRS with censoring at last follow-up imaging.

Results: Among 3920 brain metastases treated with SRS alone upfront or SRS for recurrence, 143 were coded as motor cortex, 75 frontoparietal, and 1727 non-motor frontal or parietal. The median dose was 18 Gy for 218 “motor” metastases vs. 19 Gy for 1727 “non-motor” metastases (Wilcoxon rank-sum p < 0.0001). Lesion quadratic mean diameter (QMD) was highly significantly associated with both FFP and ARE. For newly-diagnosed motor vs. non-motor metastases with QMD <0.75 cm, 0.75-2.0 cm, or >2.0 cm, 1-year FFP probabilities with 95% confidence intervals were 95% (85-98%) vs. 94% (91-96%), 88% (73-95%) vs. 88% (83-91%), and 71% (39-89%) vs. 62% (48-72%) with corresponding 1-year ARE probabilities of 2% (0-11%) vs. 1% (0-3%), 0% vs. 5% (3-9%), and 8% (1-43%) vs. 0%. For recurrent motor vs. non-motor metastases with QMD <0.75 cm, 0.75-2.0 cm, or >2.0 cm, 1-year FFP probabilities were 79% (60-89%) vs. 94% (89-97%), 63% (24-86%) vs. 80% (70-86%), and 50% (1-91%) vs. 70% (32-89%) with 1-year ARE probabilities of 0% vs. 1% (0-6%), 32% (12-69%) vs. 5% (2-11%), and 0% vs. 23% (8-52%). For recurrent metastases, motor location was associated with significantly worse FFP (Cox proportional hazards p = 0.029 and hazard ratio = 2.07, stratified by QMD category), with a trend toward higher risk of ARE (p = 0.09; hazard ratio = 2.76). At least 18.5 Gy was needed to give equivalent FFP for recurrent motor-region metastases.

Conclusions: Local control was worse for recurrent motor-region vs. non-motor metastases, and disappointing for lesions > 2 cm. Given the consequences of uncontrolled tumor and generally low risk of symptomatic ARE, we suggest radiosurgical management of motor-region metastases with at least 18.5 Gy, or hypofractionation.

OS06 - METASTASES 2

#9929 : Stereotactic radiosurgery alone in patients with ≥5 brain metastases.

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Keywords: Multiple Brain Metastases, Stereotactic Radiosurgery, GammaKnife Radiosurgery, Brain Metastases

Study’s Objective: The use of upfront stereotactic radiosurgery (SRS) as the sole treatment for patients with more than five brain metastasis (BM) is still a matter of debate. However, this approach seems to gain momentum. In this study we report our results using SRS alone in patients with ≥5 BM as the initial treatment.

Methods: 103 patients underwent SRS between 2005 - 2016 for the treatment of ≥5 BM at our institution. 30% were male, 70% were female and the median age at SRS was 58. Primary histology was NSCLC in 57% of patients, breast cancer in 28%, melanoma in 12% and colorectal in 3%. All patients were divided by their KPS and by the RPA classification; 12% were class 1, 82% class 2 and 6% class 3. 55 (53%) patients had previous irradiation for 1-4 BM. The mean number of treated BM was 7 (5 - 19) and the mean cumulative BM volume treated was 3.6 cc (0.06 – 27.7). We performed subgroups analyses based on these characteristics. Extracranial disease status prior to SRS was classified as stable in 28% versus progressive in 72%.

Results: Median follow-up after SRS was months 5.1 months (0-57). Local control, based on RANO criteria, was achieved in 75% of patients. Median overall survival (OS) was 6 months. 72% developed new distant metastases. Multivariate analyses revealed that cumulative volume of treated BM (p=0.0128),
stable extracranial disease status (p=0.00195) and RPA (p=0.0221) were independent prognostic factors for OS. Specifically, patients with a cumulative volume of treated BM £ 6 cc (OR: 2.54, p=0.006, IC95: 1.3 – 4.99) had better prognosis. The total number of BM had no impact on survival (p= 0.206). No factor was found to be predictor for local recurrence. RPA was also significant (p=0.0265) in terms of distant recurrence in multivariate analyses.

Conclusion: This study suggests that SRS is a reasonable option for the management of patients with ≥5 brain metastases, especially when the cumulative treatment volume is £ 6 cc, as it was associated with favorable OS and local control.

OST07 - WFSBS:
OTHER SKULL BASE

#10042 : Gamma knife radiosurgery for hemangiopericytoma.

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Keywords: gamma knife, hemangiopericytoma

Background: Intracranial hemangiopericytoma (HPC) is a rare tumors that composes under 0.5% of all primary brain tumors. This tumor is notable for aggressive clinical behavior such as high rate of recurrence after surgical resection and proclivity for extracranial metastases. Formerly this tumor type was categorized into meningioma variants. Even now classification of this tumor and the relationship to solitary fibrous tumor are still controversial. For the management of recurrent intracranial tumors, we applied Gamma Knife radiosurgery (GKRS) in case tumors were well-circumscribed and less than 3 centimeters in diameter. In this study we evaluated the efficacy and the role of GKRS considering control of intracranial HPC.

Materials and Methods: Between April 2004 and April 2016, we treated 12 patients with intracranial HPC by GKRS. All patients underwent surgical resection prior to GKRS. Two patients had been treated with conventional fractionated external beam radiotherapy (EBRT) before GKRS and one patient had been treated with linac-based stereotactic radiosurgery (SRS) before GKRS. The mean age of the patients at first GKRS was 44.8 (range, 16 to 75) years. During follow up five patients out of 12 underwent total 15 repeat GKRS for newly developed tumors or tumor regrowth. The mean volume of all tumors treated by GKRS was 3.6 (range, 0.2 to 23.6) ml and the mean prescription dose at the tumor margin was 17. (range, 13 to 20) Gy.

Results: The median follow-up time was 70.3 months (range 4 to 160 months). Ten patients out of 12 were alive at the last follow-up visit without any serious neurological deficit. One patient presented extracranial metastasis and died from cerebrospinal dissemination of the tumor at 71 months after the 1st GKRS. Another patient died from a colon cancer during the follow-up. The 3-, 5-, and 7-year overall survival rate of the patients was 87.5, 87.5 and 58.3% respectively. Five patients out of 12 developed extracranial metastasis (lung, liver, pancreas, bone). The 3-, 5-, and 7-year progression free survival (PFS) rate after initial GKRS was 55.6, 27.8 and 27.8% respectively

Conclusions: Though PFS rate is relatively low, GKRS is thought to be an effective management option for patients with recurrent hemangiopericytoma.

OST07 - WFSBS:
OTHER SKULL BASE

#9931 : Trigeminal schwannomas: systematic review of management with SRS

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Keywords: trigeminal schwannomas SRS

Trigeminal schwannomas are rare skull base tumors. A direct microsurgical approach usually results in some neurological deficits or complications. Stereotactic radiosurgery (SRS) has emerged as a treatment alternative to microsurgery. To conduct an analysis assessing the effect and complications of SRS in trigeminal schwannomas, a systematic review of all cases of trigeminal schwannomas treated with SRS was performed. The search revealed 10 papers with a total enrollment of 398 patients whose follow-up data obtained from 1999 to 2016. The mean age was 47.13 years old. Average tumor size ranged from 3.96-8.7 cm3 (mean 5.74 cm3). Of 290 patients with tumor location information, tumors were located predominantly in the middle fossa (type A) in 98 cases and predominately in the cerebellopontine angle (type B) in 77 cases. Tumors
being into both the middle and posterior fossa (type C) in 111 cases and extended extracranially to the orbit, maxillary sinus or infratemporal fossa (type D) in 4 cases. The average prescription dose was 14.37 Gy (range 13.1-16.4 Gy). The mean follow-up period was 60.73 months (range 42.5-98 months). The most recent MR images demonstrated average tumor control rate was 90.95%, tumor shrinkage in 228 patients (57.29%), tumor progression occurred in 36 patients (9.05%). There was no significant correlation between lesion volume and tumor shrinkage. Thirteen patients (3.27%) had no symptom before SRS. Among all cranial nerve impairments before SRS, facial hypesthesia was the most common symptom in 270 (70.13%), facial pain in 84 (21.82%). Symptoms improvement was achieved in 179 (46.49%) among 385 patients with cranial nerve impairments before SRS. Forty-five (11.31%) patients had symptoms worsened and/or additional cranial nerve disturbance. SRS is an alternative for trigeminal schwannomas confirmed by typical imaging.

OSP07 - WFSBS: OTHER SKULL BASE

#10039 : Stereotactic LINAC radiosurgery in the treatment of vestibular schwannomas: results of a single center


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Keywords: LINAC radiosurgery, vestibular schwannoma, tumor control

Objective: The objective of this study was to estimate the clinical and radiological outcome of patients treated by radiosurgery for vestibular schwannomas (VS) in the Toulouse Radiosurgery Unit.

Methods: The records of patients with VS treated between January 2008 and December 2012 in the Toulouse Radiosurgery Unit (Novalis 600N®, BrainLab) were retrospectively analysed. Patients with neurofibromatosis type 2 were excluded. All patients had at least a 36-months follow-up (FU) with a control MRI every 6 months.

Results: 1- Patients characteristics. 119 patients were treated with a mean FU of 75±17 mo. Mean age was 61±13 years and 59.7% were female. At the time of radiosurgery, 42.6% of patients had serviceable hearing and 8.8% some degree of facial palsy. A previous surgery was found in 15.3% of the population. Mean KOOS grade was 2.5±0.7 and mean volume was 1.1±1.1 cc (range: 0.1 – 5.4 cc). Median prescription dose to the tumor margin was 11.1±0.91 Gy.

2- Control rate with at least 36 mo-FU was 91.8%. The results differ with the Koos grade: 100% for grade 1, 92.7% for grade 2, 93.5% for grade 3, 77.8% for grade 4.

3- Cranial nerves complications. A permanent facial palsy (new or worsening of a pre-existing palsy) was found in 5.6% of patients. Trigeminal nerve symptoms appeared in 8.4% (9/107 patients) but 5/6 patients with pre-treatment symptoms were improved. Both complications were significantly related to the increase of volume at 6 months (respectively p<0.02 and p<0.01) and to the KOOS grade (p<0.04 and p<0.03).

4- Serviceable hearing was maintained in 56% of patients (data for 25 cases).

5- Tumor volume. An increase of volume was found at 6 months in 71.6% of cases. It was predictive of failure if superior to 60% of the initial volume with a sensitivity of 62% and a specificity of 89% on ROC analysis.

Conclusion: LINAC-Radiosurgery with Novalis is an effective treatment of VS with a tumor control obtained in 91.8% of cases. The variation of size on the first control MRI could be predictive of the outcome issue and morbidity.

OSP07 - WFSBS: OTHER SKULL BASE

#10203 : First intention radiosurgery and combined approaches in trochlear and abducens nerve schwannomas

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Keywords: LINAC radiosurgery, vestibular schwannoma, tumor control

Objective: The objective of this study was to estimate the clinical and radiological outcome of patients treated by radiosurgery for vestibular schwannomas (VS) in the Toulouse Radiosurgery Unit.
Keywords: radiosurgery, Gamma Knife, combined, schwannoma, oculomotor

Introduction: Most of intracranial nerve schwannomas arise from the cranial nerve (CN) VIII. In these cases, for small to medium-size tumors, radiosurgery has proven its safety and efficacy both for tumor control and function preservation over the last four decades. There are, however, less common schwannomas involving the CN III, IV and VI. The former can be very disabling for patients, due to the associated palsies and decreased quality of life due mainly to vision problems. We prospectively evaluated the safety and efficacy of Gamma Knife surgery (GKS) in these rare cases.

Methods: Five patients with CN IV (3 patients) and VI (2 patients) schwannomas were treated in Lausanne University Hospital between 2010 and 2015. Three were treated with upfront GKS. However, due to a large tumor volume (7.9 cc), one (Vth CN) was referred for planned subtotal excision to our skull-base surgeon, followed by GKS (combined approach). All cases had neuro-ophthalmological evaluation at baseline and at 6 and 12 months and on annual basis after. In one case, a type II neurofibromatosis was diagnosed.

Results: The mean follow-up period was 29 months (range 6-54). The mean target volume at the time of GKS was 1.51 cc (range 0.086-5.8). Initial clinical presentation was only diplopia in four cases and cavernous sinus syndrome in one. The mean marginal dose was 12 Gy (range 12-12). The mean prescription volume was 1.71 cc (range 0.131-6.7). The mean maximal dose to the optic pathways was 1.5 Gy (range 0.1-6.6). Following GKS, at last follow-up, all patients presented clinical alleviation, with disappearance of baseline symptoms. However, one of them had an additional surgical intervention (left superior oblique tendon folding). Tumor control (all with decrease in volume) was achieved in 100%. The particular case, which had combined approach, presented postoperatively with transient IVth, Vth and VIth CN palsies, which completely recovered 3 months later.

Conclusions: Our data suggests that first intention GKS is a safe and effective treatment option for patients with CN IVth and VIth schwannomas, with high rates of both clinical alleviation and tumor control. In cases where the initial tumor volume is too large for first intention GKS, combined approaches can be performed, with favorable and comparable outcomes. Patients require further careful follow-up evaluation for eventual neurological deterioration and/or tumor progression.

Objective: We present long-term follow-up data after Gamma Knife radiosurgical (GKRS) treatment of acoustic neuroma.

Patient and Methods: Six-hundred and eighteen patients were radiosurgically treated for acoustic neuroma between 1992 and 2016 at the Department of Neurosurgery, Medical University Vienna. Patients with neurofibromatosis and patients who could not yet have a one year follow-up were excluded from the study. Thus, we present data of 557 patients with spontaneous acoustic neuroma and long-term follow-up data on 426 patients with a minimum follow-up of two years. Koos grades at time of diagnosis and at time of GKRS were evaluated. Patients were assessed according to the Gardner-Robertson hearing scale and House-Brackmann facial weakness scale prior to GKRS, and at times of follow-up. Data were evaluated retrospectively.

Results: 452 patients (81%) were treated radiosurgically alone and 105 patients (19%) were treated combined microsurgically-radiosurgically. Whereas the combined treatment was favored especially prior to 2002, the percentage of only radiosurgically treated cases has significantly increased since then. The overall complication rate after GKRS was low. The complication rate after GKRS further declined in the last decade. A significant enlargement of the ventricular system (hydrocephalus) after GKRS was only observed among patients harboring Koos grade III or IV tumors. One case of malignant transformation after GKRS was diagnosed (0.2%). Radiological outcome after GKRS revealed stable or decreased neuromas in the vast majority of cases including all Koos grades. The rate of non-functional hearing was already rather high prior to GKRS. At last follow-up, preservation of functional hearing was achieved in 52% of patients classified as Gardner-Robertson grade I or II prior GKRS.
Conclusion: GKRS is a safe and effective treatment in patients of all Koos grades. Advancements in the radiosurgical treatment especially over the last decade have led to a low complication rate and excellent outcome.

OSP07 - WFSBS: OTHER SKULL BASE

#9885 : Gamma Knife radiosurgery for facial nerve schwannomas

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Keywords: facial nerve, gamma knife, radiosurgery, schwannomas

Object: The aim of this study was to determine the efficacy and safety of gamma knife radiosurgery for the treatment of the patients with facial nerve schwannoma.

Methods: Twelve patients with facial nerve schwannoma underwent gamma knife radiosurgery and their clinical and radiographic data have been evaluated. Females outnumbered males with a ratio of 2:1 and the mean age of the patients was 44 years (range 19-73 years). Most common symptoms were facial palsy (10 of 12 patients) and hearing loss (7 of 12 patients). 5 patients presented with headache. 2 of these 12 patients had prior resection and 1 patient had biopsy taken. Mean tumor volume was 3.1 cc (range 0.4-7.4 cc) and mean margin dose applied to the tumor was 11.9 Gy (range 11-13 Gy).

Results: The mean follow-up period was 44.2 months (range 13-84 months). Tumor control was achieved in all patients. Remission in 4 patients, stable in 8 patients. During follow-up 10 of 12 patients had no change in their facial function, 2 of 12 patients had their function worsened, no patients developed new facial palsy. 11 patients who had servicable hearing retained their hearing, 1 patient who was bilateral deaf since 1 year-old remained deaf.

Conclusions: Gamma knife radiosurgery is an effective and safe treatment modality for patients with either primary or residual facial nerve schwannomas. This treatment modality has showed excellent results in terms of tumor control and facial nerve functional outcomes. These results show us that gamma knife radiosurgery is a good primary treatment option for small to mid sized tumors, patients with good facial function and patients with servicable hearing.

OSP08 - PHYSICS 2

#8981 : Technical, dosimetry and treatment descriptions of the first 200 patients using the first completely automated, stereotactic intracranial radiosurgery rotating gamma ray unit (Infini) in the American continent.

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Keywords: Stereotactic Intracranial Radiosurgery

Introduction: During the 1990’s other companies (OUR) in Asia begun developing stereotactic gamma ray machines that rotated, needing a significant less amount of cobalt 60 sources (25 or 30) with the same dosimetry characteristics than the Gamma Knife units of that time. Recently the first fully automated rotating gamma ray unit called the Infini by Masep (Schenzen, China) has been installed in El Salvador Central America and 204 patients have been treated so far. The purpose of the current communication is to evaluate the technical singularities of this system and to briefly review basic dosimetry and patient treatment process in order to better understand this relatively new intracranial stereotactic radiosurgery machine.

Technical characteristics: There are six rows containing 5 cobalt sources each, that are focused at the isocenter rotating at one cycle per minute. The mechanical precision of the machine was 0.4 mm on average of all collimators tested (0.11 for the 4mm, 0.16 for the 8mm, 0.17 for the 14mm and 0.20 for the 18mm collimator) the offset registered at 15Gy on all axis was 0.0 as measured along the different profiles. Initial dose rate was 3.89 Gy per minute, dose at the center of the target at the anthropomorphic phantom was 0.97 (criteria 0.95-1.05)
Pathology and treatment characteristics: Thus far 204 patients have been treated: 85 (42%) benign tumors, 44 (22%) with malignant tumors, 38 (19%) vascular lesions of diverse types and 34 (17%) with “functional” indications such as trigeminal neuralgia, tremor and pain.

Conclusions: Infini® is a reliable machine with mechanical characteristics at least comparable to its better known predecessor, the Gammaknife®. By obtaining the same results with substantially less amount of cobalt sources makes the machine more efficient.

OSP08 - PHYSICS 2

#10221 : Quality Assurance of InCise™2 Multileaf Collimator for CyberKnife M6™ System

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Keywords: QA, CyberKnife, MLC

Objective: To report quality assurance (QA) procedures and results for the newly released InCise™2 Multileaf Collimator (MLC) installed on our CyberKnife M6™ System.

Methods: Accuray recently released its second version of Multileaf Collimator (MLC), InCise™2 MLC, for clinical use on CyberKnife M6™ System. As one of the test sites, we not only did a thorough evaluation of InCise™2 MLC during commissioning, but also generated a system of QA procedures to ensure the MLC performance and short term and long term stability. Our MLC QA program includes daily, monthly and annual tests. A patient-specific QA for each case treated with MLC is also performed with a pinpoint chamber and film measurements. A Picket Fence test in a standard perch position is performed daily for a quick check of MLC positioning accuracy. For monthly QA, we performed a MLC Garden Fence test for leaf / bank positioning in standard (A/P) and clinically relevant non-standard positions. Total system and delivery accuracy with MLC is also assessed with End-to-End tests monthly. In annual QA, besides the tests in monthly QA, we also check the consistency of dosimetric parameters, including MLC leaf transmission, MLC beam profiles, output factors and tissue-phantom ratios, etc. Data for more than one and half years was analyzed to assess the MLC short term and long term stability.

Results: No significant MLC positioning errors (>0.5mm) were observed with visual inspection from daily Picket Fence tests. Based on monthly Garden Fence tests, mean leaf position offsets were -0.05±0.13mm for X1 leaf bank and -0.08 ± 0.12mm for X2 leaf bank. No significant difference on mean leaf positioning offsets was observed between different leaf orientations. The change of mean leaf position offsets with time was less than 0.2mm, indicating a stable MLC positioning accuracy. Total system accuracy with MLC was 0.43±0.21mm as shown in the monthly End-to-End tests. All measurements for the dosimetric parameters were stable and well within the manufacturer specifications. Point dose measurements for more than 30 patients agreed with calculation within 3%, and all film measurements passed 3%/2mm Gamma evaluation for more than 95% of the measurement points.

Conclusion: QA procedures were setup for the Incise™2 MLC installed on CyberKnife M6™. Our QA results indicate that the Incise™2 MLC has a good short term and long term stability.

OSP08 - PHYSICS 2

#10355 : Dosimetric verification of MLC based CyberKnife treatments using Monte Carlo

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Keywords: QA, CyberKnife, Monte Carlo, EGSnrc, independent dose calculation

Objectives: Today’s procedures to perform patient-specific quality assurance (QA) for multi-leaf collimator
(MLC) based CyberKnife stereotactic radiotherapy are generally based on dose measurements for every treatment plan. This work describes an alternative approach, which makes use of Monte Carlo (MC) techniques to independently calculate dose distributions.

**Methods:** A vendor-independent MC based dose calculation framework using the EGSnrc MC simulation code system was developed and validated for CyberKnife MLC treatments. Each beam of the treatment plan with its corresponding MLC field shape compiled to an EGS++ geometry is simulated using EGSnrc with a phase space based beam model, creating a pre-patient phase space file for each beam. The framework then samples particles from all beams (weighted according to the treatment plan) and performs energy deposition scoring in the patient CT using DOSXYZnrc. MC calculations were validated against measured depth dose curves (DD) and dose profiles in water in units of cGy per Monitor Unit for several MLC fields. The framework was then validated by comparing MC calculated dose to film measurement for a clinical prostate treatment plan applied to a solid water phantom. Further, for another clinical prostate case, MC dose calculations were compared to TPS dose calculation using a finite size pencil beam algorithm. Both film and TPS dose were compared to MC calculations by gamma analysis with a 10% (global) lowdose threshold using 2% (global) dose difference / 1 mm distance to agreement criteria.

**Results:** Measured and MC calculated dose profiles and DD in water agreed within 3% and 1 mm. MC calculations showed good agreement to the film measurement with 93.4% of voxels passing gamma evaluation. Comparing TPS dose to MC calculated dose showed a gamma pass rate of 93.1% despite dose differences of up to ±10% (global) near bones and metal fiducials.

**Conclusion:** An alternative to measurements for patient-specific QA was successfully developed and validated against measurements.

OSP08 - PHYSICS 2

#10183 : Respiratory Induced Online Correlation Model Uncertainties In Synchrony Tracking System of Cyberknife

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**Keywords:** Respiratory, Lineer Correlation, Synchrony, Cyberknife, Motion

**Purpose:** Synchrony Tracking System (STS) is used to predict and create online correlation model for respiratory induced internal target motion and external markers on the chest wall during treatment. In this study we aimed to evaluate the limits and uncertainties of correlation model system with respect to dosimetric deviations for several plans of Cyberknife radiation therapy system (CKS) by using end to end (E2E) test.

**Methods:** Isocentric plan with fiducial and E2E centroid error results in mm were assumed as reference. Next, isocentric and non-isocentric synchrony plans with phase difference (PD) and with no PD were achieved. The plans with no PD were only irradiated in synchrony phantom. On the other hand, plans with PD were irradiated in synchrony phantom and external markers were placed on the second respiratory phantom in order to create random phase difference during irradiations. Phase shift was obtained by changing the velocity of inhale and exhale periods of second respiratory phantom after linear or nonlinear correlation model generated by the system. E2E centroid error results were analyzed for all plans in order to find out the dosimetric deviations with respect to each other.

**Results:** The total targeting error (TTE) of isocentric fiducial plan from E2E test was 0.12 mm as reference result for no motion induced irradiation. TTE of isocentric and non-isocentric synchrony plans with no PD were 0.35 mm and 0.99 mm respectively for linear correlation model (LCM). TTE of isocentric and non-isocentric synchrony plans with PD were 3.95 mm, 4.17 mm respectively for LCM.

**Conclusion:** Incoherent internal target translation and orientation movement or global body inconsistency cause variations in dosimetric parameters such as source skin distance and depth. This can affect wider and inaccurate irradiation volume during non-isocentric synchrony irradiation even with no PD. Also suboptimal correlation models and predictions between internal target and external markers during PD induced respiratory motion cause much more inaccurate and dosimetric deviated irradiations. These results offer to create accurate, optimal and correct linear or nonlinear correlation models between internal target and external markers during clinical treatments with synchrony tracking system.
OSP08 - PHYSICS 2

#10309 : A revised PTV method to improve conformity for SRS and SBRT conformal dynamic arc plans

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Keywords: SRS, SBRT, conformity, dynamic arc

Objective: SBRT and SRS plans require highly conformal dose to the planning target volume (PTV) to spare adjacent normal tissues. Conformal dynamic arc technique can achieve very sharp dose falloff and efficient delivery. It is routinely used in our institution for SBRT and SRS treatments. However, the conformity is usually not as good as inverse planned volumetric modulated arc therapy (VMAT) technique. Therefore, a simple revised PTV method is presented in this study to improve the conformity of dynamic arc plans.

Materials and Methods: Twelve SBRT (target volume range 8 ~ 108cc) and thirteen brain SRS patients (target volume range 0.7 ~ 47cc) were selected in this study. SBRT plans were created using coplanar arcs and SRS plans were created using three to six non-coplanar arcs using Varian Eclipse treatment planning system (version 13.5). The linear accelerator (LINAC) was a Varian Truebeam equipped with 5mm multi-leaf collimator (MLC). For each case, an original plan was generated by fitting MLC to the PTV and normalized to “100% prescription dose covers 95% of PTV”. Then the 100% isodose volume was converted into a structure (100%IDV). At any radial angle • from contour geometry center in each axial slice, the radius of PTV is defined as R1(•) and radius of 100%IDV is defined as R2(•). The distance between them is calculated as D(•) = R2(•)-R1(•). Then a new PTV radius is calculated as R'(•) = R1(•) - D(•). A revised PTV contour was then generated, and a new plan was developed by fitting the MLC to the revised PTV. Paddick conformity index (PCI) and gradient index (GI) were compared for each case between the original and revised plans.

Results: For the SBRT plans, the revised plan improved PCI by 10% on average (PCI increased from 0.79 ± 0.05 to 0.87 ± 0.04), and no change on GI (4.11 ± 0.25 vs 4.10 ± 0.33). For SRS plans, both original and revised plan were renormalized to 99% PTV coverage. PCI improved by 11% on average (PCI increased from 0.73 ± 0.06 to 0.81 ± 0.07), and no change on GI (2.94 ± 0.51 vs. 2.92 ± 0.55).

Conclusion: Revised PTV method is simple and effective to improve conformity of conformal dynamic arc plans for most SBRT and SRS patients, except for some very irregular concave shape target.

OSP08 - PHYSICS 2

#10388 : Impact of the skull definition on Leksell Gamma Knife IconTM radiosurgery treatment delivery

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Keywords: Gamma Knife, dosimetry, skull definition

Objective: To define the skull volume for Gamma Knife radiosurgery (GKRS) dosimetry, there are two possibilities in IconTM: manual skull scaling measurements and image-based skull definition. We evaluate if dose calculation significantly differs depending on these 2 techniques.

Methods: We included 48 GKRS treatments performed from July 2016 to January 2017 in Lausanne University Hospital, distributed among four groups: convexity lesions (18), parenchymal deep-seated lesions (13), vestibular schwannomas (11) and trigeminal neuralgias (6). For each treatment, we recorded the beam-on time (min), target volume coverage (%), prescription isodose volume (cm³) and maximal dose (Gy) to the nearest organ at risk if relevant (e.g. cochlea) according to each of the 2 skull definition techniques. The image-based contours were performed using CT-scan, which provides more reproducible segmentation than MRI. During this period, the mean dose rate was 3.72 Gy/min.

Results: Between the manual measures and image-based contours, the beam on time varied of +1.27% (corresponding to 27 sec) (p <0.001 Wilcoxon signed rank test), the target volume coverage varied of -0.04% (0.6 mm³) (p=0.22) and the maximal dose to organ at risk varied of -0.37% (0.016 Gy) (p=0.6). Using image-based contours, the mean increase of dose delivery was theoretically of +1.674 Gy per treatment (if no blocked sectors).

Conclusion: The beam on time is significantly increased using image-based contours in comparison with manual
skull measurements, resulting in an increase of the total dose delivery per treatment. The other dosimetric parameters did not differ significantly.

**OSP09 - FUNCTIONAL 2: TRIGEMINAL NEURALGIA**

**#9979 : Gamma Knife Radiosurgery for Idiopathic Trigeminal Neuralgia; does the status of offending vessels influence on outcome?**

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**Keywords:** trigeminal neuralgia; gamma knife radiosurgery; neurovascular compression

**Objective:** To determine pain control and side effects after gamma knife radiosurgery (GKRS) for classical idiopathic trigeminal neuralgia (TN) with or without neurovascular compression (NVC).

**Methods:** This study included 47 patients with type 1 idiopathic TN and Barrow Neurological Institute (BNI) pain class IV or V that were treated with GKRS as a first-treatment modality between January 2005 and March 2015. A retrospective analysis was made of NVC status, pain control, side effects, recurrence, and cross-sectional area.

**Results:** During the median 21.5 months follow-up (range, 3–119 months), 36 (76.6%) patients showed good outcomes (improved to below BNI class IIIa). Twenty two patients did not show NVC (group A) and 25 had NVC present (group B). Good outcomes were not different in two groups (group A: 19/22; group B: 17/25) (p = 0.138). The numbers of cases in BNI class I or II, and recurrences were not significantly different between the two groups (p = 0.532, 0.786, respectively). The mean areas, measured at the target coordinate, were 8.64 ± 2.59 mm³ (range, 2.81–12.74 mm³) in non-deviated cases (n = 27) and 2.59 ± 1.68 mm³ (range, 0.80–5.29 mm³) in deviated (n = 10). Side effects were significantly more frequent in deviated cases (8/10; 80%) than in non-deviated (7/27; 25.9%) (p = 0.003).

**Conclusion:** NVC is not a predictive factor for pain control after GKRS for the treatment of idiopathic TN. Side effects may occur more frequently in patients with NVC at the target coordinate when a dorsal root entry zone is used, but the subjective symptoms are not always bothersome.

**OSP09 - FUNCTIONAL 2: TRIGEMINAL NEURALGIA**

**#10192 : Gamma Knife radiosurgery for glossopharyngeal neuralgia: a bicentric experience of 21 patients**

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**Keywords:** pain, neuralgia, radiosurgery

**Objective:** Glossopharyngeal neuralgia (GPN) is a very rare pathology (0.7-0.8/100.000). Patients usually describe short episodes of paroxysmal pain, beginning at the base of the tongue and pharynx and irradiating towards the neck and the internal ear. We aim at reviewing our bicentric experience (Marseille and Lausanne University Hospital) in patients treated with Gamma Knife surgery (GKS) for idiopathic GPN.

**Methods:** Between 2003 and 2015, 21 patients were treated with 25 procedures. Eleven were women and 10 were men. All cases fulfilled the pharmaco-resistance criteria. Were analyzed patients with at least 6 months follow-up. GKS using a Gamma Knife (model B or C or Perfexion) was performed, based on both MRI and computer tomography targeting. A single 4-mm isocenter was positioned in the cisternal portion of the glossopharyngeal nerve at a mean distance of 14.6 +/- 3mm (range 9.3-23.5) anteriorly to the emergence of the nerve. The target was placed in the cisternal part for 2 and close to the glossopharyngeal meatus in 23 procedures. The mean maximal dose was 81.4 +/- 6.7 Gy (range 60-90). Three cases have had previous microvascular decompression (MVD), which was effective for 2, 8 and 13 years, respectively.

**Results:** The mean follow-up period was 5.2 +/- 3 years (range 0.9-12.1). At 3 months follow-up,
91.6% of the cases were pain free (BNI classes I to IIIA). At one year, 81.8% were still pain free (BNI classes I to IIIA), with 60% of them being BNI class IA. Recurrence appeared in 59.1%, in a mean time of 13.6 +/-10.4 months (range 3.1-36.6). Of them, 35% were controlled with medication and 25% (3 cases, 4 procedures) underwent a new radiosurgical procedure after 7, 17, 19 and 30 months, respectively. From these cases, two needed another open surgical procedure, with one undergoing a thermocoagulation and another a neurotomy. At last follow-up, 16 cases (80%) were still pain free (BNI I-IIIA, 60% BNI IA). No complication was reported.

Conclusion: As in all cranial neuralgias, the reference technique remains MVD, as it addresses the cause (e.g. the neurovascular conflict). Radiosurgery is a valuable alternative, less invasive, with a very high rate of efficacy, in the absence of complications. The most important aspect is that the fifth nerve is easily identifiable, while the ninth nerve remains more challenging, so as its targeting. A multidisciplinary approach including a neurologist and neuroradiologist might be necessary, both for diagnosis and imaging purposes.

OSP09 - FUNCTIONAL 2: TRIGEMINAL NEURALGIA

#10455 : Gamma Knife radiosurgery for medically refractory trigeminal neuralgia: long terms outcomes

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Keywords: Gamma Knife, radiosurgery, trigeminal neuralgia

Objective: To analyze the long-term outcomes for medically refractory trigeminal neuralgia (TN) treated by Gamma Knife Radiosurgery (GKRS) in our institution.

Methods: We included 309 patients treated consecutively by GKRS for medically refractory TN, between 2011 and 2014, in Lille University Hospital. Clinical baseline, treatment parameters and functional outcomes (using Barrow Neurological Institute (BNI) Pain Intensity Score) were reported.

Results: The mean age was 62 y/o (range, 23 to 86). 13% of patients harbored a pre-GKRS hypoesthesia. A vascular conflict was reported in 230 (82%) patients. The mean dose was 90 Gy at the 100% isodose line, delivered at a mean distance to the root-entry zone of 9.6 mm. The mean dose to the first 10 mm$^3$of the brainstem was 9.7 Gy. The mean delay before clinical improvement was 4.8 weeks. Patients with BNI

Conclusion: GKRS is effective to treat medically refractory TN, with half of patient free of medication at last follow-up, with a very low morbidity.

OSP09 - FUNCTIONAL 2: TRIGEMINAL NEURALGIA

#10459 : Role of trigeminal nerve length in determination of adequate dosing and target planning using CyberKnife stereotactic radiosurgery

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Keywords: CyberKnife, stereotactic radiosurgery, trigeminal neuralgia.

Objective: CyberKnife stereotactic radiosurgery (SRS) is routinely used for treatment of trigeminal (TG) neuralgia by non-isometric, conformational high-dose administration to the corresponding nerve root-core. Given its proximity to the brain stem, nerve-core treatment optimization has required careful selection of dose and distance to achieve efficacy without compromising safety. We consider how the cisternal nerve length contributes to divergent outcomes in two treatment plans.

Methods: We conducted a retrospective, single-institution review of 91 patients treated with CyberKnife for TG neuralgia in during 1/2005 to 5/2007 (Plan A, N = 47) and 1/2009 to 8/2013 (Plan B, N=44). Plan A (vs B) conservatively targeted the nerve core at 2 mm (vs 2.5 mm) and set the maximum brainstem dose to 10 Gy. The primary outcome was pain control at follow-up. Select secondary outcomes included changes in Barrow Neurologic Institute (BNI) pain and numbness scores. Length of the cisternal TG nerve, max brainstem dose, prior treatments, SRS treatment planning, and demographics were recorded. Univariate, multivariate and receiver operating characteristic curve analyses were performed.

Results: Patients were followed for a mean 23 months, and 62% were naïve to prior treatment. CK was
administered in one fraction (92%) to a median and max dose of 60 and 75 Gy, respectively. Plans A and B exhibited treatment failure, durable improvement, and pain recurrence in 17.6%, 29.4%, and 52.9% vs 8.5%, 70.2%, 21.3%, respectively. Nerve length, volume, and max brainstem dose were 7.48 vs 10.3 mm, 0.034 vs 0.036 cc, and were 33.7 and 48.8 Gy, respectively. Length significantly predicted any pain improvement under Plan A, but not Plan B, which was better predicted by treatment history (AUC = 0.82). Under Plan A, shorter nerves demonstrated a corresponding decrease in treated volume and under Plan B, longer nerves were less likely to have bothersome post-SRS numbness.

**Conclusion:** Our analysis demonstrates the ongoing challenge with predicting CyberKnife SRS treatment outcomes for TG neuralgia, and highlights how individualized consideration of TG nerve anatomy should assume an increased role in future patient selection. While patients who present with longer TG nerves may already be optimal candidates, those with shorter lengths and additional favorable history, will possibly benefit from a more aggressive dosing protocol.

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**OSP09 - FUNCTIONAL 2:**

**TRIGEMINAL NEURALGIA**

**#10210 : Image-guided Robotic Radiosurgery for Trigeminal Neuralgia: three-year follow-up results in 207 patients**

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**Keywords:** trigeminal neuralgia, facial numbness, stereotactic radiosurgery, frameless radiosurgery, Cyberknife

**Introduction:** A cohort of 207 patients affected by Trigeminal Neuralgia (TN) was treated by Cyberknife radiosurgery and regularly followed for at least 36 months.

**Methods:** Patients with typical TN and severe drug-resistant pain (grade IV-V on the Barrow Neurological Institute [BNI] scale and numerical rating scale [NSR] scores >5) were selected and treated with image-guided robotic radiosurgery (Cyberknife, Accuray Inc., Sunnyvale, Ca). The treatment was delivered in single session using a non-isocentric technique, a 5-mm collimator and the trigeminal node set. A 5-6 mm segment of the nerve was contoured as treatment target. A 58/60 Gy dose was prescribed to the 80% isodose. Clinical re-evaluation was performed at 3, 6, 12, 18, 24 and 36 months. BNI and NRS scales have been used to assess the pain level before the treatment and during the follow-up. The BNI facial numbness scale was used to assess the development of sensory disturbances following the treatment.

**Results:** 6 months after the procedure 191 out of 207 patients (92%) were pain-free (BNI I-IIIa). Mild hypoesthesia (grade II BNI) was reported by 14 (6.7%) and severe bothersome hypoesthesia (BNI grade IV) by 1 (0.5%). 11 patients reporting no improvement after treatment (5.3%) underwent a second procedure. Twenty-five out of 207 (12%) pain-free patients who experienced recurrent pain within 3 years from the treatment underwent retreatment with restoration of analgesia. Peak of recurrent pain was found 12 months after the first procedure (13 patients), while other 7 occurred after 18 months and 5 after 24 months. Overall, 36 patients underwent second treatment (17%). All of them developed stable pain relief while the rate of moderate and somewhat bothering (grade III BNI) versus to severe and very bothersome hypoesthesia (grade IV BNI) was, respectively, 13 and 6. Follow-up MR imaging showed focal contrast enhancing restricted over the target region in 16 patients without significant association with pain control or hypoesthesia. Brainstem edema was found in one case (the only patient developing BNI grade IV hypoesthesia). Actuarial pain control rate after 6, 12, 24, 36 months was, respectively, 92%, 90%, 77% and 71%. Rate of moderate and severe sensory disturbance was 9.2%.

**Conclusions:** Cyberknife radiosurgery targeting a 5-6 mm segment of the TN with a prescribed dose of 58-60 Gy is a safe and effective treatment for TN providing high pain control rates with an acceptable risk of sensory complications, which are typically found after re-irradiation.
OSP09 - FUNCTIONAL 2: TRIGEMINAL NEURALGIA

#10467 : Image-guided Robotic Radiosurgery for Trigeminal Neuralgia: three-year follow-up results in 207 patients

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Keywords: trigeminal neuralgia, facial numbness, stereotactic radiosurgery, frameless radiosurgery, Cyberknife

Introduction: A cohort of 207 patients affected by Trigeminal Neuralgia (TN) was treated by Cyberknife radiosurgery and regularly followed for at least 36 months.

Methods: Patients with typical TN and severe drug-resistant pain (grade IV-V on the Barrow Neurological Institute [BNI] scale and numerical rating scale [NSR] scores >5) were selected and treated with image-guided robotic radiosurgery (Cyberknife, Accuray Inc., Sunnyvale, Ca). The treatment was delivered in single session using a non-isocentric technique, a 5-mm collimator and the trigeminal node set. A 5-6 mm segment of the nerve was contoured as treatment target. A 58/60 Gy dose was prescribed to the 80% isodose. Clinical re-evaluation was performed at 3, 6, 12, 18, 24 and 36 months. BNI and NRS scales have been used to assess the pain level before the treatment and during the follow-up. The BNI facial numbness scale was used to assess the development of sensory disturbances following the treatment.

Results: 6 months after the procedure 191 out of 207 patients (92%) were pain-free (BNI I-IIIa). Mild hyposthesia (grade II BNI) was reported by 14 (6.7%) and severe bothersome hyposthesia (BNI grade IV) by 1 (0.5%). 11 patients reporting no improvement after treatment (5.3%) underwent a second procedure. Twenty-five out of 207 (12%) pain-free patients who experienced recurrent pain within 3 years from the treatment underwent retreatment with restoration of analgesia. Peak of recurrent pain was found 12 months after the first procedure (13 patients), while other 7 recurred after 18 months and 5 after 24 months. Overall, 36 patients underwent second treatment (17%). All of them developed stable pain relief while the rate of moderate and somewhat bothering (grade III BNI) versus to severe and very bothersome hyposthesia (grade IV BNI) was, respectively, 13 and 6. Follow-up MR imaging showed focal contrast enhancing restricted over the target region in 16 patients without significant association with pain control or hyposthesia. Brainstem edema was found in one case (the only patient developing BNI grade IV hyposthesia). Actuarial pain control rate after 6, 12, 24, 36 months was, respectively, 92%, 90%, 77% and 71%. Rate of moderate and severe sensory disturbance was 9.2%.

Conclusions: Cyberknife radiosurgery targeting a 5-6 mm segment of the TN with a prescribed dose of 58-60 Gy is a safe and effective treatment for TN providing high pain control rates with an acceptable risk of sensory complications, which are typically found after re-irradiation.

OSP10 - WFSBS: VESTIBULAR SCHWANNOMAS 2

#10344 : Gamma Knife surgery for facial nerve schwannomas

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Keywords: facial schwannoma; radiosurgery; Gamma Knife surgery; functional recovery

Background: Facial nerve schwannomas are rare tumors and account for less than 2% of intracranial neurinomas, despite being the most common tumors of the facial nerve. The optimal management is currently under debate and includes observation, microsurgical resection, radiosurgery (RS) and fractionated radiotherapy. RS might be a valuable alternative, as a minimally invasive technique, in symptomatic patients and/or presenting with tumor growth.
Abstracts

**Methods:** We review our series of 4 consecutive cases, treated with Gamma Knife surgery (GKS), during the period July 2010 and January 2017. Clinical and dosimetric parameters were assessed. GKS was performed in all cases using the Leksell Gamma Knife Perfexion.

**Results:** The mean age at the time of GKS was 44 years (range 34-56). The mean follow-up period was 42 months (range 12-60). The first symptom was facial palsy in 2 (50%) cases and hemifacial spasm in 2 (50%). All had a facial palsy at baseline, one with House-Brackmann (HB) II, 2 with HB III and one with HB VI. The mean target volume at the time of GKS was 0.360 cc (range 0.030-0.638) and the mean prescription isodose volume was 0.462 cc (range 0.052-0.805). The mean maximal dose delivered was 12 Gy at the 50% isodose line. The mean dose received by the cochlea was 3.8 Gy (range 0.1-10). The mean number of isocenters was 6.5 (range 1-10). One patient benefited from a staged-volume GKS. At last follow-up, facial palsy remained stable in 2 cases (one HB II and one HB III), and improved in 2 (one from HB III to HB II; one from HB VI to HB II). Regarding hemifacial spasm, both patients presenting one at baseline had a decrease in its frequency and intensity.

**Conclusion:** In our experience, RS and particularly GKS appear to be an appropriate therapeutic option in the management of these tumors. However, it should be also accompanied by a rehabilitation program, in collaboration with specialized colleagues, so as to give the patients the best chances for recovery. Radiosurgery remains a minimally invasive technique and with a small risk of functional decline, which should be putted in balance with the patient's baseline clinical status and tumor characteristics.

**Keywords:** adverse radiation effect; Gamma Knife surgery; radiosurgery; vestibular schwannoma; cochlea; vestibule

**Objective:** Vestibular schwannomas (VSs) represent a common indication of Gamma Knife surgery (GKS). While most studies focus on long-term morbidity and adverse radiation effects (AREs), none describe the acute clinical AREs that might appear on a short-term basis. These types of events are investigated, and their incidence, type, and outcomes are reported in the present paper.

**Methods:** The included patients were treated between July 2010 and March 2016, underwent at least 6 months of follow-up, and presented with disabling symptom during the first 6 months after GKS that affected their quality of life. The timing of appearance, as well as type of main symptom and outcome, were noted. The prescribed dose was 12 Gy at the margin.

**Results:** Thirty-five (22%) of 159 patients who fulfilled inclusion criteria had acute clinical AREs. The mean followup period was 30 months (range 6-49.2 months). The mean time of appearance was 37.9 days (median 31 days; range 3-110 days). In patients with de novo symptoms, more frequent were vertigo (n = 4; 11.4%) and gait disturbance (n = 3; 8.6%). The exacerbation of a preexisting symptom was more frequently related to hearing loss (n = 10; 28.6%), followed by gait disturbance (n = 7; 20%) and vertigo (n = 3; 8.6%). In the univariate logistic regression analysis, the following factors were statistically significant: age (p = 0.002; odds ratio [OR] 0.96), hearing at baseline by Gardner-Robertson (GR) class (p = 0.006; OR 0.21), pure tone average at baseline (p = 0.006; OR 0.97), and Koos at baseline (Koos Grade I used as reference) (for Koos Grade II, OR 0.17 and p = 0.002; for Koos Grade III, OR 0.42 and p = 0.05). Fractional polynomial regression analysis showed a nonlinear relationship between the outcome and the radiation dose rate (minimum reached at a cutoff of 2.5 Gy/minute) and the maximal vestibular dose (maximum reached at a cutoff of 8 Gy). The clinical acute AREs disappeared in 32 (91.4%) patients during the first 6 months after appearance. Permanent and somewhat disabling morbidity was found in 3 (1.9% from the whole series): 1 each with complete hearing loss (GR Class I before and V after), hemifacial spasm (persistent but alleviated), and dysgeusia.

**Abstracts**

**OSP10 - WFBS:**

**VESTIBULAR SCHWANNOMAS 2**

**#10205 :** Acute clinical adverse radiation effects after Gamma Knife surgery for vestibular schwannomas

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Conclusions: Acute effects after radiosurgery for VS are not rare. In most cases, none of these effects are permanent, and they will ultimately improve or disappear with steroid therapy. Permanent AREs remain very rare.

OSP10 - WFSBS: VESTIBULAR SCHWANNOMAS 2

#10157 : Influence of volumetric parameters of the IAC on hearing for patients with vestibular schwannomas

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Keywords: Vestibular schwannoma, hearing, internal auditory canal

Introduction: Anatomical parameters of the petrous bone and tumor could perhaps predict clinical findings in patients with vestibular schwannoma. This information might be important to determine the optimal parameters of the dosimetric planning and to estimate hearing outcome.

Materiel & Methods: We have retrospectively analyzed anatomical and clinical parameters on a series of 656 patients treated radiosurgically for a vestibular schwannoma. Hearing status was evaluated with the Gardner-Robertson classification. The high-resolution CT at bone windows and high-resolution MRI-T2 and MRI-T1 gadolinium have been used to analyze linear and volumetric measurements of the IAC and the part of the tumor located into the IAC. We estimate the erosion of IAC bone by comparison of the ipsi- and controlateral IAC volume. We correlate the IAC volume and linear measurements with the % of IAC occupied by the tumor. We compare the bony erosion of the IAC and % of intrameatal tumor with hearing level before Gamma Knife irradiation and hearing status at last follow-up.

Results: The pre-treatment anatomical and audiological data of all patients were analyzed in LGP 10.0, and the patients were followed prospectively for tumor control and hearing outcome. The volume of IAC at the side of the schwannoma was increased in comparison with the controlateral side in 87% of cases, and was increased by more than 120% of the controlateral IAC volume in 66% of cases. We found an extremely significant association (p<0.0001) between the ratio Vol IACipsi/Vol IACcontra and the volume of tumor located into the IAC, as well as the % of tumor volume located into the IAC. The pre-radiosurgical ipsilateral hearing level (GR grade and useful/not useful hearing status) was significantly associated (p=0.034 and p=0.0032, respectively) with the volume and the % of tumor volume located into the IAC. Therefore, the ratio Vol IACipsi/Vol IACcontra and the % of tumor volume located into the IAC are parameters related to hearing loss and could be used in the decision process for treatment or wait-and-scan.

Conclusions: The IAC can be eroded by the intracanalicular part of the schwannoma. Volumetric parameters of the IAC and intrameatal volume of the tumor are significantly related to patients hearing status and some cut-off of these parameters can be used to decide when the wait-and-scan attitude must be stopped in favor of radiosurgical treatment.

OSP10 - WFSBS: VESTIBULAR SCHWANNOMAS 2

#10010 : Impact of neuro-imaging on GTV definition in radiosurgical treatment of acoustic neuroma

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Keywords: Radiosurgery, Imaging, Acoustic neuroma

Objective: Acoustic neuromas (AN) have a close proximity to radiosensitive critical structures (i.e. inner ear, cranial nerves). Single fraction radiosurgical (SRS) treatment requires precise definition of the target volume as well as the surrounding critical structures (CS). Therefore, various imaging modalities are available with cranial computed tomography (CT) and different magnetic resonance imaging (MRI) sequences. The aim of this study was to evaluate to what extent this affects the definition of gross tumor volume (GTV) and identification of CS. There are no clear guidelines for the imaging modality to be used for delineation of GTV and CS in SRS, so far.

Methods: The GTV, anterior-posterior and transverse diameter of the internal acoustic canal (IAC) were conducted with a variety of different image modalities...
(plain CT window widths, T1 TFE 3D, T2 TSE 2D, T1 FFE 3D, T2 DRIVE 3D) in 73 patients and compared with each other. Furthermore, the identification rate of CS (trigeminal nerve, labyrinthine artery) was evaluated. The obtained GTVs were compared to the respective T1 TFE 3D volume for every individual. Significance in volume changes were verified using Wilcoxon signed-rank test.

**Results:** The average deviation from the GTV obtained in T1 TFE 3D imaging was 43.4 ± 23.1% (for CT brain window), 18.7% ± 21.3 (T2 TSE 2D), 27.7% ± 17.9 (T2 DRIVE 3D) and 15.5 ± 10.4 (T1 FFE 3D). All deviations were significant (p <0.0001). The anterior-posterior and transverse diameter of IAC showed significant (p<0.0061) differences between T1 TFE 3D imaging and CT brain and bone window and T2 weighted MRI. The rate of inner ear identification was 99% in T2-weighted sequences and 100% in CT bone window. The identification rate of the trigeminal nerve was 97% in T2-weighted MRI compared to 34% in CT brain window.

**Conclusion:** Various imaging modalities are available for the definition of the GTV and CS. However, differences in the predefined GTV (up to 43% in CT and 18% in T2-MRI respectively) significantly depend on the image modalities in use. How far these differences affect dosimetry remains unclear and should be part of further investigations.

**OSP10 - WFSBS:**
VESTIBULAR SCHWANNOMAS 2

**#9906 : Frameless three-fraction radiosurgery for large vestibular schwannomas**

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**Keywords:** vestibular schwannoma; Radiosurgery; Hypofractionation; Large tumors; Frameless radiosurgery; Cyberknife

**Background:** Large acoustic schwannomas (VS) are tumors with a diameter of >3 cm or a volume >8 cm³. They are usually considered not amenable to conventional, single-fraction stereotactic radiosurgery (SRS) because a large section of the brainstem may be exposed to harmful doses of radiation. The problem can be avoided by using a hypofractionated irradiation scheme.

**Methods:** Twenty-five patients with VS of >8 cm³ (range 8-24 cm³, median 9.5 cm³) were treated from August 2007 to January 2016 at the CyberKnife center at the University of Messina, Italy. All patients underwent 3-fraction radiosurgery with a total dose ranging 18-19.5 Gy.

**Results:** Follow-up period ranged from 12 to 106 months (median 48 months). Radiological growth control was achieved in 88% of cases: 11 tumors (44%) displayed no relevant size variation; 11 (44%) showed a >50% volume shrinkage. Three patients (12%) needed salvage tumor resection. No patient presented worsening of trigeminal sensory disturbances or facial nerve dysfunction. No patient had serviceable hearing before treatment. Five patients (20%) developed hydrocephalus after treatment or showed deterioration of the preoperative ventricular enlargement with new neurological symptoms. All 5 patients were treated with ventriculo-peritoneal shunts with full recovery. Actuarial progression-free survival rates at 1 year and 5 years were 97% and 83%, respectively.

**Conclusions:** The current and other published results suggest that hypofractionation may extend the indication of SRS to VS larger than 8 cm³. The tumor control rate is not significantly different from smaller tumors. Hydrocephalus is the only complication recorded in our series. This complication is related to preoperative ventricular size and can be easily and effectively treated with minor surgery. Even though the limited experience and short follow-up currently available in the literature do not provide sufficient support for widespread application of hypofractionated SRS in younger patients with large VS, further studies on the issue are warranted.

**OSP10 - WFSBS:**
VESTIBULAR SCHWANNOMAS 2

**#10353 : Volumetric changes in growing vestibular schwannomas post stereotactic radiosurgery**

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**Keywords:** growing, vestibular, schwannoma, volumetric

**Background:** Growing vestibular schwannomas are a unique group that are often difficult to manage in the setting of stereotactic radiosurgery (SRS). This work aims to quantify the effect of SRS on the growth of these tumors.
Introduction: Previous publications suggest that vestibular schwannomas (VS) which grow rapidly prior to stereotactic radiosurgery (SRS) are more likely to continue growing after treatment. However this is based either on potentially inaccurate tumour length or small patient numbers. In University Hospitals Bristol (UHBristol) the majority of patients with VS have treatment after documented growth. The aim of this study is to accurately describe the volumetric changes pre- and post-SRS of growing VS and investigate if the tumour’s growth kinetics are predictive of these changes.

Method: Patient cohort consisted of patients with VS treated with SRS who had a MRI scan within 24 months prior to SRS demonstrating growth and minimum 2 years MRI follow-up. To ensure volumetric accuracy, MRI scans >1.5mm slice interval were excluded. Scan closest to 1 year pre-treatment, treatment day and all post treatment scans were imported into Oncentra Planning System (Elekta, Stockholm). VS was contoured to establish tumour volume at all timepoints (pre, day 0, and 1/2/3 year post SRS). The rate of volume change of the VS was calculated per month and statistical analysis utilised Pearson Correlation.

Results: 60 consecutive patients with VS were treated at UHBristol with SRS 10/2013-12/2014. 3 were excluded due to lack of growth on scans 4-8 months prior to treatment and 14 due to inadequate pre-treatment scans. 43 patients had 173 scans contoured. Tumours were treated on Perfexion Gamma Knife (Elekta, Stockholm) with mean 12.3Gy to 50% isodose with 99% coverage, conformity index 0.83 and gradient index 2.85.

At 4-22 months pre-treatment the mean VS volume was 1.36cc; at SRS 1.94cc; at 1 year 1.19cc; and 2 year 1.08cc. Pre-treatment tumours grew mean +8.2%/month [+0.29-+36.8%/month]. 38 patients had adequate scans at 1 year and 43 at 2 year post-SRS. At 1 year post treatment overall rate of growth was -2.9%/month [-6.7+-3.3%/month]: 86.8% smaller; 5.3% stable; 7.9% grew but rate of growth reduced from +9.3%/month to +2.2%/month. At 2 years compared to treatment day mean growth was -1.9%/month [-3.4-+2.3%/month]: 88.4% shrank; 4.7% grew then stabilised; 4.7% initially shrank then grew; 2.3% continued to grow at a slower rate.

There was no correlation between rate of growth prior to treatment, most VS shrink in the first 2 years post SRS. The rate of pre-treatment growth does not predict post treatment continued growth or degree of shrinkage.

Conclusion: Despite growth pre-treatment, most VS shrink in the first 2 years post SRS. The rate of pre-treatment growth does not predict post treatment continued growth or degree of shrinkage.

OSP10 - WFSBS: VESTIBULAR SCHWANNOMAS 2

#10065 : Is multisession radiosurgery more effective than single session radiosurgery to preserve the hearing in patients affected by a sporadic vestibular schwannoma? Preliminary results from a prospective randomized clinical trial

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Keywords: vestibular schwannoma, acoustic neuromas, radiosurgery, hypofractionated radiotherapy, hearing preservation

Objective: The treatment strategy for the patients affected by sporadic vestibular schwannomas is recently changing and the number of patients which undergo radiosurgery as a primary treatment modality for such lesions is continuously increasing.

While the question about the best treatment is waiting for more definitive results, the attention is actually focusing on the hearing function sparing.

The aim of the present study is to investigate about the potential advantages of multisession radiosurgery(mRS) compared to single session radiosurgery(sRS) in terms of hearing preservation.

Patients and methods: The present is an ‘ad interim’ analysis of a prospective randomized clinical trial.

The primary end-point of the study is the difference in term of hearing preservation between patients treated with mRS and sRS because of a sporadic acoustic neuroma.

The conditions for patient eligibility are:
- sporadic acoustic neuroma diagnosis.
- Age≥18 years old
- KPS≥70
- Serviceable hearing(class A/B from the AAOHNS classification)
- Written consent

All the enrolled patients are clinically, radiologically and audiometrically evaluated.
The volumetric analysis of the tumor is always performed.

**Results:** At the time of the present analysis 52 patients have undergone a radiosurgical treatment. The mean follow-up period is 27 months. Twenty-nine patients had a sRS and 25 had a three fraction mRS.

In term of hearing preservation, no differences were observed between the two groups. A significant difference was observed between the patients that were class A at the treatment time compared to class B. Indeed, only 10% of the class A patients compared to 53% of the class B patients lost the serviceable auditory function during the follow-up period.

The volumetric analysis showed that most part of the tumors (86%) had a shrinkage or a stabilization. The 14% of the patients experienced a tumor enlargement, at least in the first two follow-up MRIs. No significant differences were observed between the patients treated with mRS and sRS.

**Conclusions:** At our knowledge, the present clinical trial is the first one comparing two different radiosurgical regimens in terms of hearing sparing.

While we are waiting for the definitive results of the present study, the preliminary ones suggest that mRS has no advantages compared to sRS in terms of hearing preservation.

Similarly to surgical studies, the data suggest that the better is the auditory function at the moment of the treatment, the more probable is the hearing preservation.

The volumetric analysis confirms the good tumor control rate.

**Keywords:** Radiation Protection, SBRT, Cyberknife

**Purpose:** Shielding considerations for both, primary and secondary radiation must be revised when switching from a conventional linear accelerator to a Cyberknife (CK). In this context two important parameters to be investigated are the direction distribution of the primary radiation and the modulation factor (MF) of treatment plans, which is linked to secondary radiation. This work assesses the impact of a novel multi leaf collimator (MLC) on the required radiation shielding of the CK analyzing the clinically applied treatment beams.

**Methods:** For 364 patients (163 fixed cones, 180 iris collimator, 21 MLC) the delivered beams were projected onto the boundaries of a 9.5x5.9x3.9 m³ vault in order to obtain a monitor unit (MU)-weighted spatial distribution of the treatment beams. This was accomplished by a previously developed framework, which extracts the beam directions, the corresponding number of MUs and the employed collimator of all treatment beams delivered by the CK. In addition, the total delivered MUs and the prescribed dose were stored in the database for each treatment beam. Using this information, the MF, defined as the ratio of delivered MUs divided by the prescribed dose, was assessed for each treatment plan and used collimator type.

**Results:** Compared to all considered treatments, the MLC beams delivered slightly more MUs to the wall to the left and right of the patient (13.0% vs 12.0%) and the floor (73.5% vs 71.0%). None of the analyzed MLC beams hit the wall at the patient’s feet in contrast to 5.3% of MUs for all treatments. However, comparing the MLC beams only with all extra-cranial treatments, the differences for the wall at the patient’s feet vanish.

The mean MF for the treatments without MLC is 8.5 MU/cGy, while the mean MF for the treatment using the MLC is 6.3 MU/cGy. Taking only the extra-cranial treatments into account, the mean MF for the treatment with and without using the MLC is 7.1 MU/cGy and 10.4 MU/cGy, respectively.

**Conclusion:** The MLC, which was mainly used for extra-cranial treatments, has a minor influence on the direction distribution of the treatment beams compared with the differences arising from treating cranial or extra-cranial entities. If the MLC is employed, the larger field sizes available together with the segmented delivery lead to a reduction of the MF for the considered cases.

OSP11 - PHYSICS 3

**#9991 : Radiation protection considerations when equipping a robotic SBRT delivery device with a new collimator type**

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**Purpose:** Shielding considerations for both, primary and secondary radiation must be revised when switching from a conventional linear accelerator to a Cyberknife (CK). In this context two important parameters to be investigated are the direction distribution of the primary radiation and the modulation factor (MF) of treatment plans, which is linked to secondary radiation. This work assesses the impact of a novel multi leaf collimator (MLC) on the required radiation shielding of the CK analyzing the clinically applied treatment beams.

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**Results:** Compared to all considered treatments, the MLC beams delivered slightly more MUs to the wall to the left and right of the patient (13.0% vs 12.0%) and the floor (73.5% vs 71.0%). None of the analyzed MLC beams hit the wall at the patient’s feet in contrast to 5.3% of MUs for all treatments. However, comparing the MLC beams only with all extra-cranial treatments, the differences for the wall at the patient’s feet vanish.

The mean MF for the treatments without MLC is 8.5 MU/cGy, while the mean MF for the treatment using the MLC is 6.3 MU/cGy. Taking only the extra-cranial treatments into account, the mean MF for the treatment with and without using the MLC is 7.1 MU/cGy and 10.4 MU/cGy, respectively.

**Conclusion:** The MLC, which was mainly used for extra-cranial treatments, has a minor influence on the direction distribution of the treatment beams compared with the differences arising from treating cranial or extra-cranial entities. If the MLC is employed, the larger field sizes available together with the segmented delivery lead to a reduction of the MF for the considered cases.
OSP11 - PHYSICS 3

#9956 : Lessons learnt during a national cross-platform radiosurgery end-to-end audit

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Keywords: end-to-end, intracranial, radiosurgery, dosimetry, audit

The purpose of this work was to assess the dosimetric accuracy of SRS in the UK for linac-based (LB), Tomotherapy (TT), Cyberknife (CK) and Gamma Knife (GK) radiosurgery.

The methodology developed for this assessment employed an anthropomorphic phantom with realistic tissue densities. The simulated scenario featured an irregular 8 cm³ lesion located anterior to the brainstem. The case was presented to 26 UK centres who developed 28 treatment plans: 16 LB, 7 GK, 4 CK and 1 TT. An end-to-end test was conducted for each plan, incorporating immobilisation, scanning, planning and treatment delivery following the local protocol. Previously characterised dosimeters (EBT-XD film and alanine pellets) were placed inside the phantom to measure absolute dose inside the target and brainstem, for comparison with Treatment Planning System (TPS) predictions. Film measurements were compared to TPS dose planes using gamma-analysis.

Alanine measurements showed that LB (including TT) had the largest range in percentage difference to the TPS of 5.2% (-1.3% to +3.9%) with a mean of +0.5%. CK had a range of 2.6% (+1.4% to +4%), with the highest mean difference in comparison to the other platforms (+2.5%). GK showed the smallest range at 2.4% (-0.8% to +1.5%) being comparable to that of CK, with the smallest mean percentage difference (+0.4%) comparable to that of LB. Similar trends were observed in the brainstem with alanine measurements showing a range from -1% to +3.6% (mean= +1.3%), 0% to +1.9% (mean= +0.9%) and -1.1% to +0.9% (mean= +0.1%), for LB, CK and GK respectively. Film measurements showed comparable results between centres, regardless of the platform used. For 3%-2 mm Local-gamma, all except two films showed passing rates above 75%. For 5%-1 mm Global-gamma, all except 2 films showed passing rates above 90%. Large variations were observed in prescription practices, delivery techniques and plan quality.

This audit enabled a comparison of all UK centres in terms of the dosimetric accuracy achieved during treatment delivery. The LB group showed the largest variations in agreement to the TPS, related to more heterogeneous practices within the group, compared to smaller variations seen in CK, and more consistent practices seen in GK. Good overall agreement with the TPS was observed with 2 centres falling above 3.6% (2sd). The results suggest that good agreement with predicted dose distributions is achievable by all modalities. The variations in prescription practices, techniques and plan quality highlight the need for standardisation in SRS practice.

OSP11 - PHYSICS 3

#9866 : Metal artifact reduction with Dual Energy CT for Gamma Knife Radiosurgery in pacemaker patients

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Keywords: Gamma Knife, Dual Energy CT, Metal artifact reduction, pacemaker

Metal artifact reduction with Dual Energy CT for Gamma Knife Radiosurgery in pacemaker patients

Purpose: Pacemaker patients with brain metastases who are to undergo Gamma Knife (GK) radiosurgery are typically simulated with CT as they are not usually MRI compatible. Since the patients are framed and fixated with either titanium (Ti) or aluminum (Al) pins to the skull, metal induced artifacts by the Ti or Al pins are unavoidable. This can result in obscuration and
suboptimal evaluation of brain lesions. Conventional single-energy CT (SECT) with metal artifact reduction (MAR) and newer dual energy CT (DECT) with high keV mono-energy imaging are promising techniques for reduction of metal artifacts. The purpose of this study is to assess the effectiveness of these two methods in metal artifact reduction to enable optimal treatment planning in pacemaker patients undergoing GK radiosurgery.

Methods and Materials: An anthropomorphic head phantom (Radiology Support Devices) fixated with one pair of Ti and one pair of Al pins was scanned with SECT and DECT on GE HD 750 64-slice CT, and SECT on Philips large bore 16-slice CT. Both metal artifact reduction techniques of MAR and DECT on GE, and OMAR (orthopedic MAR) on Philips were compared. The scan and reconstruction parameters are as follows (in the order of [kVp/mA/Collimation (mm)/Pitch/CTDVol (mGy)/Thickness (mm)/Recon]): Philips LB16 [120/482/16x0.75/0.438/65.4/1/UC & UC+OMAR]; GE HD750 [120/220/32x0.625/0.531/65.2/1.25/Standard & Standard+MAR]; and GE HD750 [(80,140)/375/32x0.625/0.531/67.0/1.25/140keV DECT].

Results: Metal artifact reduction when using Ti fixation was best achieved by DECT followed by MAR, then SECT and lastly OMAR (DECT > MAR > SECT > OMAR). In case of Al fixation DECT was again the best, SECT was as good as MAR, and OMAR was the worst (DECT > SECT > MAR = OMAR). More metal artifacts were introduced by Ti than Al pins. For Al pins, while DECT could reduce artifacts, OMAR introduced more artifacts than SECT, and MAR was not effective for artifact reduction.

Conclusions: There were fewer artifacts introduced by Al than Ti. DECT was more effective than MAR in reducing metal artifacts for both Ti and Al. OMAR should not be used in CT acquired for simulation in GK pacemaker patients. Pacemaker patients undergoing GK radiosurgery may be best served by frame fixation using Al pins in combination with DECT because of the least amount of metal artifact generated, and therefore likely better visualization of metastases in the underlying brain parenchyma.

Keywords: stereotactic radiosurgery, orthovoltage, dose uniformity, dose gradient, modulation

Objective: For some stereotactic radiosurgery (SRS) treatment sites, delivering a homogeneous dose to the target volume has been associated with reduced adverse effects and toxicities. Previous work has indicated that lowering the beam energy from the standard megavoltage range to the orthovoltage range results in the improvement of various plan quality metrics in SRS. Modulation of beam energy, even across a small field, may further serve to create homogeneous, conformal dose distributions in orthovoltage SRS delivery. The objective of this work was to build and characterize an orthovoltage energy-modulated SRS system in order to achieve dose distributions approaching rectangular functions.

Methods: Previous work described the design of cone-based, filtered orthovoltage energy-modulated SRS system using mathematical optimization techniques and Monte Carlo simulations. This system uses a NI-ST-traceable 250 kVp irradiator with an auxiliary cone/filter system that was constructed using both in-house machining techniques as well as the commissioning of an outside prototyping firm capable of binder jetting, an additive manufacturing technique, using tungsten. Four nongeferent cone collimators were constructed from free machining brass to be used optionally along with four epoxy-infiltrated bonded tungsten filters of variable thicknesses. Radiochromic EBT3 film measurements of the system were performed in a custom, thin-window water phantom to compare dose distributions derived from open cones to those from filtered cones. Films were scanned with a prototype laser densitometry system.

Results: Measured beam profiles showed that the modulated beams could more closely approach rectangular function dose profiles compared to the open cones, based on quantification of profile flatness and penumbra. This result remained consistent for all four cones and for the three different depths tested. This result confirms previous computational work indicating the benefit of orthovoltage energy fluence modulation.

Conclusion: Both computational and measurement results showed that filtered orthovoltage SRS prototypes are able to achieve dose distributions approaching rectangular function distributions at depth, therefore establishing the feasibility and efficacy of a full future treatment platform that relies on fluence modulation in the orthovoltage energy range to manipulate resulting dose distributions.

OSP11 - PHYSICS 3

#9014 : Optimized orthovoltage stereotactic radiosurgery

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Keywords: stereotactic radiosurgery, orthovoltage, dose uniformity, dose gradient, modulation

OSP11 - PHYSICS 3

#10394 : First stereotactic radiosurgery patient treatment using an MLC-based virtual cone

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Keywords: SRS, cone, MLC

Purpose: The virtual cone is a standardized MLC control point sequence designed to mimic the dose distribution of a 4 mm cone. It was developed to facilitate rapid treatment planning and quality assurance for treatment of small lesions using an MLC equipped linear accelerator. We report on the first patient treatment using the virtual cone.

Methods: The virtual cone is comprised of an MLC control point sequence having multiple non-coplanar arcs and a dose rate that varies as a function of gantry angle. The patient was immobilized using an open-face thermoplastic mask and received a treatment planning CT scan having 1 mm slice spacing. The target volume, a solitary metastasis defined using MR images, was 0.021 cm³ (diameter 3.4 mm). The virtual cone sequence was imported and dose was calculated on a 1 mm grid using Eclipse AAA version 13.6 (Varian Medical Systems, Palo Alto, CA). The plan was normalized such that 99% of the target volume received at least 20 Gy. Measurement using radiochromic film in a phantom was done prior to treatment to confirm dosimetric and geometric accuracy. The patient was localized prior to treatment using orthogonal kV images followed by cone-beam CT and was monitored during radiation delivery using optical surface monitoring.

Results: The ratio of the measured dose to the calculated dose was 1.02. The 2-dimensional magnitude of the difference between the measured and calculated dose distributions was 0.13 mm. After correction for the systematic offset, the maximum distance between the measured and calculated prescription isodose contour was 0.26 mm. These results were consistent with preclinical end-to-end studies using an anthropomorphic skull phantom. The maximum dose was 143.9%, corresponding to a prescription isodose line of 69%. Dose calculation dominated the treatment planning time, requiring 22 min on a cluster of calculation servers, whereas importing the plan and placing isocenter was less than 5 min. Delivery of the plan for the QA measurement required 12 min.

Conclusion: The virtual cone is an efficient technique for treatment of small spherical dose target volumes. Because the control point sequence is standardized, patient specific QA measurements will not be necessary in routine clinical use. Integration of the virtual cone directly into the treatment planning system along with improved dose calculation efficiency will make planning using this technique extremely efficient, potentially allowing for same day treatment. Planned clinical applications of the virtual cone include trigeminal neuralgia and treatment of essential tremor.

OSP11 - PHYSICS 3

#9919 : Two independent dosimetry audits and comparison of TMR10 and Convolution calculation algorithms in the Leksell Gamma Knife treatment planning

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Keywords: dosimetry audit, Leksell Gamma Knife QA, TMR10 and Convolution algorithms

Objectives: Purpose of this study was to make a dosimetry audit after Leksell Gamma Knife (LGK) Co-60 sources reload. Comparison of TMR10 and Convolution calculation algorithms in the Leksell GammaPlan (LGP) was also made by measurement in heterogeneous anthropomorphic phantom.

Methods and materials: Dosimetry audits were performed by two institutions: 1) National Radiation Protection Institute, Prague, Czech Republic (NRPI) (on-site audit) and 2) The MD Anderson Dosimetry Laboratory (MDADL), Houston, USA (postal audit). Measurements were made in three different phantoms: 1) ABS Elekta plastic spherical phantom, 2) adapted anthropomorphic Alderson Rando phantom and 3) Stereotactic Radiosurgery Head phantom from MDADL. Calibration of the LGK unit was verified in the Elekta phantom by two independent PTW 31010 ion chambers. Altogether six measurements in two different orientations were made. Then comparison between planned and delivered dose in anthropomorphic Alderson Rando phantom was done for a test treatment plan calculated by both TMR10 and Convolution algorithms. Mean dose in two PTW 31010 ion chambers positioned close to heterogeneous area in the phantom was measured. All these measurements were performed on-site by NRPI medical physicists. Additionally, irradiation of MDADL head phantom was made. The head phantom consisted of imaging insert
with nylon ball target to obtain imaging for treatment planning and then the insert was exchanged to a dosimetry insert with TLDs and Gafchromic films for dosimetry measurements. After on-site irradiation, the phantom was sent back to MDADL for an evaluation.

**Results:** Deviation between measured and reported calibration dose rate in the ABS plastic phantom was 0.7%. Deviation in mean dose measured by ion chamber positioned within target volume in heterogeneous anthropomorphic head phantom was -1.1% and 2.5% for TMR10 and Convolution algorithms, respectively. Results from MDADL are not yet ready at the time of writing this abstract. Convolution algorithm generally calculated always longer irradiation times by 2-3% on average compared to TMR10. This fact was also supported by measurement results. Based on results from this study the statement that Convolution algorithm provides more accurate calculation is not supported.

**Conclusion:** To perform dosimetry independent audit after a new LGK installation or after Co-60 source reload belongs to a good medical physics practice. Both on-site and postal audits were used in this study. Very reasonable agreement was observed for reported calibration dose rate. Also measurements for target volume mean dose in anthropomorphic heterogeneous phantom for both algorithms showed reasonable results.

**OSP12 - VASCULAR 1**

**#9909 : Time-Staged Gamma Knife Radiosurgery for Large Arteriovenous Malformation**

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**Keywords:** Intracranial arteriovenous malformation, Stereotactic radiosurgery, Gamma Knife surgery, 2-stage procedure

**Object:** We retrospectively analyzed our experience with time-staged Gamma Knife radiosurgery (GKRS) for large arteriovenous malformation (AVM).

**Methods:** Between 1998 and 2016, 835 patients were treated with GKRS for cerebral AVMs. Among the 835 patients, 113 patients had large AVMs with volumes larger than 14 cm³. After exclusion of patients who followed up less than 3 years, a total of 89 patients were enrolled in this study. All patients were treated with a planned time-staged GKRS.

The median age was 32 years (range, 4-60). The most common presentation was seizure (n=22). Fifty-four patients underwent a second GKRS and 11 patients underwent a third GKRS.

The median volume was 22 cm³ (range, 14-59) at first GKRS, 11 cm³ (range, 0.4-33.8) at second GKRS and 2.5 cm³ (range, 0.3-17.4) at third GKRS.

The median marginal dose was 13 Gy at first GKRS, 12Gy at second GKRS and 16 Gy at third GKRS. Nidus obliteration of AVMs was confirmed using transfemoral cerebral angiography (TFCA).

The median clinical follow-up after first GKRS was 76 months.

**Results:** Among the 82 patients who underwent a TFCA following first GKRS, complete nidus obliterations were obtained in 12 patients. Fifty-four patients underwent a second GKRS with a post-GKRS median interval of 39 months. Thirty-three of 54 patients had a 3-year follow-up TFCA. Complete nidus obliteration was confirmed in 18 of 33 patients. Eleven of 33 patients underwent a third procedure with a median interval of 39 months. Eight of 11 patients underwent a TFCA at 3 years after GKRS. Five of 8 patients had a complete nidus obliteration. Therefore, the overall nidus obliteration rate in this study was 60% (35 of 58 eligible patients).

During follow-up period, a hemorrhage developed in 15 patients (17%) including 5 cases of major bleeding and 10 cases of minor bleeding. Only one patient died of intracerebral hemorrhage after GKRS. Symptomatic adverse radiation effects were detected in 12 (13%) of 89 patients. However, permanent morbidity rate was 1% at the last follow-up. No patients in this study developed a delayed cyst formation following GKRS.

**Conclusions:** The management of large AVMs is still challenging. In this study, a time-staged GKRS for large AVMs shows a relative high obliteration rate and a low complication rate.

Although long-term follow-up and repeat GKRS are needed to achieve complete obliteration, a time-staged GKRS might be an effective and safe treatment option in the management of large AVMs.
OSP12 - VASCULAR 1

#10384 : Covering 75% of Nidus with 23 Gy or higher dose improves obliteration of arteriovenous malformations following stereotactic radiosurgery

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Keywords: Radiosurgery, gamma knife, arteriovenous malformations

Introduction: It has been shown that higher margin dose given to the AVM nidus correlates with higher AVM obliteration rates, with the maximum obliteration rate observed at 25 Gy. However, it is not always possible to prescribe such higher margin doses as these can lead to higher rates of adverse radiation effects (AREs) especially in large volume AVMs. Theoretical dose modeling indicated that it is possible to expand specific isodose volumes (e.g. 70% of the maximum dose) closer to prescription isodose without a substantial increase in 12 Gy volume. The purpose of this study was evaluate if a higher dose covering a higher volume of AVM nidus correlates with improved nidus obliteration.

Methods: For this retrospective, single-institution analysis, the authors reviewed their experience in 43 patients who had Gamma Knife surgery between 2007 and 2013. Patients with multiple AVMs, prior Gamma Knife treatment, planed stage treated AVMs, AVMs larger than 10 cm³, or lacking at least three years of follow-up data were excluded. Nidus volume, margin doses, 12 Gy volume, and absolute doses covering various percentages of nidus volume were determined using Leksell GammaPlan® software. The average marginal dose was 20 Gy (range: 16-23 Gy), and the average AVM nidus volume was 3.44 cm³ (range: 0.2579-9.13 cm³). AVM obliteration was confirmed by MRI and/or Angiography. Comparisons between groups were performed using Mann-Whitney U Test and Pearson’s c² test of independence.

Results: Of the 43 patients, a total of 37 (86%) patients had complete obliteration of the AVM over an average follow-up time of 36 months (range: 11-79 months). Our analysis indicated that higher obliteration rates were achieved in patients who received greater than 23 Gy to more than 75% of nidus volume (p = 0.036). Patients who received greater than 23 Gy to 75% of nidus volume did not have increased risk of ARE (p=0.82). Similarly obliteration rates were significantly better (p=0.025) for patients with expanded 70% isodose volume (more than 43% nidus covered with 70% isodose line). Expanded 70% isodose volume was not associated with increased risk of AREs (p=0.56).

Conclusion: Higher dosage (23 gy or higher) delivered to at least 75% AVM nidus volume or expanded 70% isodose volume are associated with higher obliteration rates following AVM radiosurgery without increasing the likelihood of AREs.

OSP12 - VASCULAR 1

#9895 : Obliteration rate of arteriovenous malformations in pediatric patients with or without previous embolization

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Keywords: arteriovenous malformation, pediatric, embolization, obliteration rate

Objective: Evaluate the obliteration rate of arteriovenous malformations (AVM) and clinical results after radiosurgery in pediatric patients with and without previous embolization.

Method: Of the hundred patients undergoing radiosurgery with Gamma Knife, thirty patients had been embolized prior to radiosurgery. All patients have a minimum follow-up of three years. The rate of obliteration, hemorrhage and clinical outcome after radiosurgery were analyzed between the two groups under study.

Results and conclusion: Nidus obliteration was achieved in 63% of patients in the non-embolized AVM group (Group A) and in 59% of the previously embolized AVM group (Group B). During the first three years after radiosurgery, three patients in group A suffered hemorrhage, without sequelae; and one patient in group B, with clinical worsening. In group A, three more patients presented hemorrhage at 7,8 (death) and 10 years of treatment, and in group B one patient at 10 years, passing away. The ratio of the obliteration rate to the AVM volume has been in group A: < 3 cc: 70%, 3-10 cc: 63% and > 10 cc: 20%; and in group B: 73%,60% and 0% for the same volumes, respectively. The clinical situation regarding treatment has worsened in five patients in group A and in two patients in group B.
B, remaining stable or improving in the rest. The relation of appearance of «de novo» AVM between group A and B has been 5 to 1, producing delayed hemorrhage in two of these patients in group A.

Partially embolized AVM in pediatric patients are susceptible to successful treatment with Gamma Knife, without significant differences in the obliteration rate between the two groups.

OSP12 - VASCULAR 1

#10379 : Stereotactic radiosurgery as first-line treatment for non-hemorrhagic arteriovenous malformations in the pre-ARUBA era: long-term functional outcomes and obliteration rates

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Keywords: Radiosurgery, gamma knife, non-hemorrhagic arteriovenous malformation, obliteration

Objectives: The management of non-hemorrhagic arteriovenous malformations (AVMs) remains a greatly debated topic, even more so since the ARUBA trial. We report on the long-term outcomes and obliteration rates after Gamma Knife radiosurgery (GKRS) treatment for such AVMs.

Methods: We retrospectively analyze data from a series of 101 patients harboring unruptured AVMs treated by GKRS as first-line treatment in our University Hospital between April 2004 and September 2011. Inclusion criteria were: age > 18 years old, no clinical history suggestive of acute hemorrhage, no bleeding stigma on the pre-treatment MRI and/or CT scan, minimal follow-up > 3 years. Exclusion criteria were: pediatric population, volume-staged GKRS, prior embolisation or surgical management.

Results: Mean age at presentation was 38.9 years (range 19-64). The main initial symptoms were: epilepsy in 50% of patients and headache in 27% of patients. Mean follow-up was 9.9 years (range 3-13 years). Median target volume was 1.9 cm³ (IQR, 0.8-3.3 cm³), median Spetzler-Martin grade: 2 (IQR, 1 to 2), median Pollock-Flickinger score: 1.067 (IQR, 0.8-1.3), median Virginia score: 1 (IQR, 1 to 2). Median treatment dose was 24 Gy at 50%. 17 patients benefited from a second GKRS after 3 years follow-up without obliteration. Hemorrhage during the post-treatment follow-up was reported in 11 patients (annual risk of 1.1%). Transient post-GKRS morbidity was reported in 4.9% with persistent neurological deficit in 2.9% of patients. The obliteration rate was 72%, based on cerebral angiography and/or MRI. At last follow-up 95% of patients had a mRS ≤1 and 88% of patients were free of symptoms. Concerning epilepsy, 84% of patients were seizure-free at last follow-up.

Conclusions: GKRS as first-line treatment for unruptured cerebral AVMs achieves high obliteration rates while maintaining patient autonomy and even improving their clinical symptoms (e.g. epilepsy).

OSP12 - VASCULAR 1

#10396 : Predictive Factors In Cavernous Malformation Series Treated With Gamma Knife Radiosurgery

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Keywords: cavernous malformation, Gamma Knife Radiosurgery, hemorrhage rate, marginal dose, adverse radiation effects

Background: Cavernous malformations (CMs) natural history has remained unclear several years. This lack of knowledge has made treatment decisions difficult. Indeed, the use of stereotactic radiosurgery (SRS) is nowadays controversial. The purpose of this paper is to analyze factors implicated in bleeding and adverse radiation effects in patients treated with Gamma Knife Radiosurgery (GKRS).

Methods: The authors reviewed ninety-five cavernous malformations prospective database, 57 women and 38 men, underwent GKRS for high-surgical-risk CMs. The median malformation volume was 1570mm³. The median tumor margin dose was 11.87 Gy and the mean tumor maximum dose was 19.56 Gy. Statistical analysis was performed with IBM SPSS software version 20.0 and R Core Team software version 2013.

Results: Ninety-five cavernous were situated in: brainstem (64), thalamus/basal ganglia (12) and hemispheric eloquent areas (19). All patients had experienced at least
one symptomatic bleeding before treatment. Imaging follow-up after SRS revealed lesion volume regression in 39 CMs. The pretreatment annual hemorrhage rate was 3.06% compared with 1.4% during first 3 years latency interval, and 0.16% thereafter (p-value = 0.004). Four patients developed new location-dependent neurological deficits and three patients had edema-related headache after radiosurgery. All of them presented full recovery.

In spite of univariate analysis didn’t find statistically significant association between marginal dose and post-treatment bleeding, Multiple Regression Model, with Akaike’s Information Criterion including sex, showed finally statistically significant association between lower marginal dose and bleeding (p-value=0.03) and no association between target volume and bleeding (p-value=0.13).

Volume and coverage dose show a weak negative correlation with adverse radiation effects (AREs) (p = -0.260, p-value = 0.011). Using Multiple Regression analysis, AREs couldn’t be related to prescribed radiation dose, brainstem location nor multiple pre-treatment hemorrhages.

In Multiple Regression Model, size reduction seemed to relate with patients age (p-value: 0.042) and maximum dose levels (p-value: 0.028).

Conclusions: Marginal dose was the only variable that showed statistically high significant influence on bleeding rate in multiple regression analysis (p-value = 0.030). A lower marginal dose seems to be related with post-treatment rebleeding.

Highly conformal GKRS with lower margin dose average (margin dose average: 11.3 Gy) could be related to safety of this treatment in recent series. In spite of descriptive analysis showed a trend towards relating adverse radiations effects with higher margin dose, we didn’t find statistically significant association in our study. This result could be due to the scarce number of AREs and post-treatment bleeding events in our series.

Keywords: De novo, arteriovenous malformation, gamma knife, radiosurgery, pediatric

Introduction: The concept of «de novo» arteriovenous malformations (AVM) remains a poorly understood condition. It has been documented, observing follow-up radiological studies, that AVMs are dynamic lesions. However, this concept is exceptional in the literature after radiosurgery treatment.

Material and Methods: 108 pediatric patients have been treated for their AVM with Gamma Knife stereotactic radiosurgery. Seven have developed «de novo» AVM on the periphery of the treatment performed in a retrospective study.

Results and conclusions: The mean follow-up period after the radiosurgical treatment of the 7 AVMs with «de novo» AVM was 14.5 years, diagnosing these entities at 5 years of Gamma Knife in 71% of the patients. The mean age at treatment was 7.45 years (3.4-13.6), 5 males and 2 females. About the location of AVMs, one was profound and the rest superficial, with eloquence in 5 of them. The Spetzler-Martin grades were II, III and IV in 2, 3 and 2 patients respectively. In the first treatment the mean volumen of the nidus is 2.6 cc and the mean radiosurgical dose is 20 Gy. Only one patient had hemorrhage at 7 years of radiosurgery. All but one patient has been treated subsequently. The mean volumen of «de novo» AVMs is 8.2 cc. This study corroborates the possibility of developing «de novo» AVM predominantly in childhood, after achieving obliteration of the volumen treated with radiosurgery.

OSP13 - WFSBS: HYPOFRACTIONATION IN SKULL-BASE

#10066 : Five fraction stereotactic radiosurgery (srs) for Brain meningiomas

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Keywords: Stereotatic Radiosurgery(SRS),brain meningiomas, Multisession SRS, Hypofractionation.

Objectives: To describe the efficacy and toxicity of the five fraction stereotactic radiosurgery ( SRS) for brain meningiomas.

Background: Effectiveness of conventional adjuvant EBRT, affront single session gamma knife radiosurgery

OSP12 - VASCULAR 1

#9894 : «De novo» arteriovenous malformations after treatment with gamma Knife radiosurgery in pediatric patients

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Keywords: De novo, arteriovenous malformation, gamma knife, radiosurgery, pediatric
and moderately hypo fractionated radiotherapy for brain meningiomas are well studied and proven to have good local controls with minimum side effects.

Five fractions hypo-fractionated radiotherapy (multisession SRS) was used for relatively large tumors and for those closely lying with critical organs and not suitable for gamma knife single session radiosurgery. This schedule was considered to be beneficial equivalent to single session in terms of local control rate while good protection of critical organs in terms of fractionated irradiation for the large volume meningiomas.

**Methods:** From 01.01.10 to 30.06.16, 1220 patients were treated on Synergy-S (Linac based radiosurgery system). 100 patients of intracranial meningiomas (including recurrent) were treated with 5 fractions radiosurgery. 40% were male and 60% were female patients. Mean age was 41.74 years (range: 18-67 years). Patients were followed up at 6 weeks, 3 months and then 6 months till 5 years time. Mean volume (PTV) was 46.87 cc (range: 2.20-90.20cc). Prescription dose 2500 cGy was used in five fractions at 400 to 500 cGy/day (Mean Fraction dose= 4.5 Gy/day). Mean prescription Isodose line was 80% (range: 65-100%). Median Maximum Dose was 3119 cGy (range: 2442-4284 cGy). Median Mean dose was 3070 cGy (range: 2251-3592 cGy). Median Minimum dose was 2321 cGy (range: 1909-2950 cGy). Review of literature by using Pubmed, Medscape and Pubmed Central was carried out to establish the safety and efficacy of 5 fractions SRS in brain meningiomas.

**Results:** Clinical Improvement was seen in about 88% of the patients, radiologically most of the tumors were stable around 68%, 10% had small residual disease while 10% progressed from original size at about 18 months after SRS. 02% patients were lost to follow-up. 10% patients were dead at median follow-up time of 4.2 years (range:1-5.5 years). 50% of the dead patients had non tumor related death, while 50% had death due to progressive disease. No acute toxicity was observed, while use of steroids was prolonged in about 10% of the patients mean duration was 3 months (range 1-6 months).

**Conclusion:** This retrospective study revealed high local tumor control rate and acceptable toxicity of five fractions radiosurgery for brain meningiomas. Further larger studies required to establish its future use.

**OSP13 - WFSBS: HYPOFRACTIONATION IN SKULL-BASE**

#9896 : Predictors of local control and comparison of single versus fractionated stereotactic radiotherapy for meningiomas – A single institutional experience

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**Keywords:** Stereotactic radiosurgery, Fractionated stereotactic radiotherapy, Meningioma, Magnetic resonance Imaging

**Objectives:** To assess the predictors for local control and to compare outcomes of Linac based SRS(stereotactic radiosurgery) with FSRT(fractionated stereotactic radiotherapy) for meningiomas

**Methods and Materials:** 45 patients of meningioma treated using LINAC based SRS and FSRT were retrospectively analyzed in our institute diagnosed (radiological diagnosis =30, and biopsy proven =15) between 2007 to 2016. Male to female ratio was 17: 28. 12 patients were treated radically with SRS and 33 patients (20 were radically treated, 8 received adjuvant radiation and 5 had radiation on recurrence, post surgery) were treated with FSRT. Patients who received re-irradiation were not included in the study. The median age group in SRS arm was 50 years (range 32-72 years) and in FSRT arm 55 years (30- 76 years) The median dose for SRS was 15Gy (range 12-16Gy), and for FSRT it was 25Gy (range 25-30Gy). The median PTV volume in SRS arm was 3.25cc (range 0.75 to 10.5cc), and in FSRT arm 13.25cc (range 10.45 to 65.3cc). The patients were followed by clinical examination as well as serial imaging with MRI (Magnetic resonance imaging).

**Results:** The median follow up of the entire cohort was 54 months (range 6-84 months). The median follow up of SRS arm and FSRT arm was 48 months (range 12-72 months) and 72 months (range 6-84 months) respectively. The overall survival was 100% in both the groups. The 5 year local control was equivalent in both SRS and FSRT arm (91.6 vs 90.2%; p =0.512). On univariate analysis of the whole cohort, we found that age, gender and PTV volume were predictors for local control. Local control was better for age group < 60 years (p = 0.043). Females had longer
time to relapse than males (p =0.026). The 5 year Local control was 100% for a tumor volume of ≤ 15cc and 91.1% for a tumor volume of >15cc (p= 0.044). No radiation late damage or any adverse events were observed during follow up period in both the arms.

**Conclusion:** SRS and FSRT are equally effective in terms of local control and complication rates. SRS is better for smaller volumes. FSRT is suitable for larger volumes, and with or without surgery. Age, gender and PTV volumes are important predictors for tumor control. Proper selection of cases and longer follow up is required for best outcomes.

**OSP13 - WFSBS: HYPOFRACTIONATION IN SKULL-BASE**

#10389 : Tumor volume reduction and functional outcomes in radiosurgery and fractionated radiotherapy for cavernous sinus meningiomas

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**Keywords:** Radiosurgery, fractionated radiotherapy, cavernous sinus meningioma

**Introduction:** Radiosurgery (RS) and fractionated radiotherapy (FRT) are part of the therapeutic armamentarium for the management of cavernous sinus meningiomas. We propose a systematic review of the local tumor control and clinical outcomes after monofractionated treatment, including gamma knife (GKRS) and linear accelerator (LinacRS), or fractionated radiotherapy.

**Materials and Methods:** We performed a search in PubMed based on the following Mesh terms: “cavernous sinus”, “meningioma”, “radiosurgery”, “gamma knife”, “linac”, “cyberknife”, and “radiotherapy”. Among 425 screened studies, 36 matched all selection criteria: 24 for GK, 5 for Linac and 7 for FRT.

**Results:** We included 2817 patients (GKRS=2047, LinacRS=350, FRT=420). Half of patients benefited from upfront RS or FRT; the other half benefited from adjuvant RS or FRT (combined approach or tumor recurrence). Mean target volume was smaller for RS as compared to FRT (p=0.07). Median marginal dose was 13.9 Gy (range, 11 to 28) for GKRS and 14 Gy (range, 12.8 to 17.7) for LinacRS. For FRT, patients received a mean dose of 51.2 Gy (25.5 fractions, 1.85 Gy each). Mean follow-up was: 48 months (range, 15 to 89) for GKRS, 69 months (range, 46 to 87) for Linac and 59.5 months (range, 33 to 83) for FRT. PFS at 5 years for GKRS, LinacRS and FRT were respectively: 93.6%, 95.6% and 97.4% (p=0.32, Kruskal-Wallis). Monofractionated treatments (GKRS and LinacRS) induced more tumor volume regression than FRT (p=0.001). Tumor recurrence or progression ranged between 3 and 5.8%, without statistically significant difference between modalities (p>0.05). Trigeminal symptoms improved in approximately 54%, and III-IV-VI CN palsies improved in approximately 45%. After GKRS, visual acuity improved in 21% (not enough data available for other modalities). De novo deficits occurred in 5 to 7.5% and adverse radiation effects in 4.6 to 9.3% (all techniques pooled).

**Conclusion:** RS achieved a twice-higher rate of tumor volume regression than FRT. GK series reported an improvement in visual acuity in 21% of the cases. GK, Linac and FRT provided similar clinical post therapeutic outcomes for the trigeminal and oculomotor CN.

**OSP13 - WFSBS: HYPOFRACTIONATION IN SKULL-BASE**

#10375 : STAGED RADIOSURGERY FOR LARGE/CRITICAL INTRACRANIAL MENINGIOMAS: A MONOCENTRIC PROSPECTIVE STUDY.

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**Keywords:** radiosurgery; staged-radiosurgery; meningioma; benign brain tumour; large meningioma

**Background:** The treatment of choice for intracranial meningiomas is surgical removal. However, the complete resection of meningiomas can be difficult or impossible, because of their extension, their proximity to cranial nerves, vascular structures or eloquent areas. Meanwhile, single and staged radiosurgery, in exclusive, adjuvant or salvage setting represents an alternative or complementary viable treatment to the neurosurgery.
Under these circumstances, the staged radiosurgery treatments have been increasing and several authors published excellent results after staged-SRS with a local control (LC) ranging between 90% and 100% and a low treatment-related toxicity, above all because of the potential to deliver sharply focused high doses per fraction without increasing the risk of toxicity.

We present the early and medium-term results of first 53 patients of our ongoing prospective trial on staged radiosurgery for large and/or critical intracranial meningiomas. Reports of symptom control and neurological status are also evaluated.

Methods: The eligibility criteria were either histologically confirmed or imaging-defined benign meningioma diagnosis; large or medium lesion size and/or in critical area; signed informed consent; age ≥ 18 years; and Karnofsky Performance Status (KPS) ≥ 70. All enrolled patients were prospectively followed with clinical, neurological and radiological examinations. The follow-up evaluations were performed after 4 months from the staged-SRS, afterwards every 6 months during the first 2 years and then annually.

Results: The median follow-up for the entire series was 38 months (range, 4-52 months). The LC was obtained in 46 patients (98%) out of 47 available for MRI volumetric analysis. Nineteen (40%) patients presented a partial response, 27 patients (58%) a stable disease. Among 31 (66%) patients who were symptomatic before s-SRS, neurological follow-up showed an improvement in 15 patients (48.3%), stable clinical course in 12 patients (38.7%) and a persistent deterioration of clinical symptoms in 4 patients (13%). The acute toxicity was registered in 8 patients (23.5%). These new symptoms turned up in the patients within few weeks. The adverse events not correlated with radiotherapy were registered in 4 patients (8.5%). None late symptoms due to staged-SRS were reported.

Conclusion: Our findings show that staged-SRS using the CyberKnife is a safe and effective option in the treatment of large-volume benign meningiomas. A good tumour control and a low morbidity and toxicity rates were achieved in our series, either as a primary or adjuvant approach. Long-term follow-up is warranted to confirm these results.

Keywords: trigeminal schwannomas, Multi-fraction SRS, long-term follow-up

Objective: Trigeminal schwannomas (TSs) have traditionally been treated by surgery. This retrospective study illustrates the outcomes of a series of TSs, most of which are large tumors, after multi-fraction stereotactic radiosurgery (MF-SRS).

Methods: A series of 56 TSs were treated using the CyberKnife from June 2007 to June 2015 with the multi-fraction SRS technique in Huashan Hospital, Shanghai, China. The mean age was 50 (range 21-78) years. Microsurgery preceded radiosurgery in 13 patients and Gammaknife SRS in 4 patients. The median tumor volume was 13.3 (range 2.1–48.9) cm³ and 32 of them were larger than 10.0 cm³. The prescription dose was 19.8 (range 13.2-24)Gy, which was delivered in 1-4 sessions.

Result: The follow-up period ranged from 19 to 103 months (median 53.5 months). In all patients MRI follow-up was obtained, the overall tumor control rate was 96.4%. The most frequent symptoms were hypoesthesia/hyperesthesia in 32 patients, diplopia in 10 patients, facial pain in 8 patients. Neurological follow-up examination showed a stable status in 13 patients, whereas 30 patients noted improvement of at least one of their presenting symptoms after treatment. One patient noted a transient ptosis the next day after the first fraction and recovered in a week. One patients had a symptomatic cyst formation of tumor 6 months after SRS, followed by a second subtotal resection. One patient received a VP shunt 8 months after SRS which was due to hydrocephalus.

Conclusions: Cyberknife multi-fraction SRS is an effective and minimally invasive management option for patients with residual or newly diagnosed trigeminal schwannomas with respect to not only long-term local tumor control but also neurofunctional preservation.
Keywords: benign tumor radiosurgery, fractionation, hypofractionated Gamma Knife, Extend, frameless or frame-based

Introduction: We evaluate the clinical and radiological outcome of a series of 14 patients treated for a benign tumor using hypofractionation with the Gamma Knife.

Material & Methods: All 14 patients of our series had a benign tumor located close to the optic pathways. There were 11 meningioma, 2 pituitary adenomas and 1 craniopharyngioma. All patients were treated with 5 daily fractions of a 5-Gy margin dose, either with a frameless system Extend (n=9) or with a conventional frame (n=5) repositioned each day. For frameless procedures, the Extend system was used and provided a submillimetric precision of positioning for all sessions of irradiation.

Results: All patients were followed prospectively. The median follow-up duration was 3.75 years (range 2.5 - 5.5 y). The visual status remained stable for 13 patients and improved for 1 patient. The tumor volume remained stable for 3 patients, reduced over time for 10 patients, and increased for 1 patient. This patient developed an extension of his initial tumor that necessitates a new radiosurgical irradiation on the cavernous sinus. One patient developed 2 new meningiomas 2.5 years after irradiation in other locations, which could have been radiation-induced. No other morbidity was seen.

Conclusions: The medium- to long-term clinicoradiological outcomes of this series of 14 patients treated for a benign tumor using 5 fractions with the Gamma Knife showed excellent results with a high rate of tumor control and no worsening of the visual status.

OSP14 - IMAGING

#10256 : Radiomics analysis for assessing concurrent stereotactic radiosurgery and bevacizumab treatment of recurrent malignant gliomas

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Keywords: Recurrent malignant glioma, radiosurgery, radiomics

This study explored the use of radiomics features as potential biomarkers for predicting the outcome of recurrent malignant gliomas (MG) patients treated by concurrent stereotactic radiosurgery (SRS) and Bevacizumab (BVZ). Thirteen patients with recurrent MG were retrospectively studied. Lesions with <3 cm in diameter were treated in a single fraction and 3-5 cm in diameter were treated in 5 fractions. BVZ was administered immediately before SRS and 2 wks later. MRI studies, including T1- and T2-weighted, dynamic contrast-enhanced (DCE) and diffusion weighted (DW), were performed before SRS, 1 week and 2 months after the completion of SRS. Functional parameters including apparent diffusion coefficient ADC, micro-vascular transfer constant Ktrans, brain blood flow Fb, and blood volume vB were analyzed. Radiomics analysis extracts imaging features (a total of 252 radiomics features) and correlates features with outcomes. Statistical tests were performed with Bonferroni correction to evaluate the change of functional parameters and texture features 1 week and 2 months after SRS. The changes between different WHO grades were evaluated. Correlation tests were used to examine the relationships between changes of functional parameters/radiomics features and patient survival time after SRS. Selected features were used to predict the patient survival time after treatment using Support Vector Regression (SVR) with leave one out cross validation (LOOCV). The median survival time was 13.7 months after treatment. Radiomics analysis was also performed in normal tissues receiving 12 Gy or above. DCE results showed that GTV blood flow dynamics parameters Ktrans(p=0.02) and vB(p=0.04) significantly decreased at 2 months after SRS. No functional parameters reflected statistically significant treatment response at 1 week after SRS. 20 radiomics features from anatomical T1w gray level images and 25 features from functional parameters maps (Ktrans:18, ADC:7) showed significant changes 2 months after SRS. Among these features, 7 Ktrans features and 3 ADC features reflected significant difference as early as 1 week after SRS between WHO Grade 3/4 patient groups. The changes of 16 radiomics features (Ktrans:11, Fb:5) at 2 months after SRS were significantly correlated with patient survival time. Using 2 selected signature features from T1w scans and 3 from DCE parametric maps, 9 out of 13 patients’ survival time could be accurately predicted. The preliminary results demonstrate the effectiveness of using radiomics features for predicting early treatment response. The results also suggest the potential application of radiomics features as potential biomarkers for individualized treatment regime optimization.
OSP14 - IMAGING

#10411 : Tractography in gamma knife anterior capsulotomy planning

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Keywords: Gamma knife capsulotomy obsessive compulsive disorder

Objective: The role of tractography in Gamma Knife Capsulotomy (Gamma-C) planning is still unclear. The anterior internal capsule (AIC) tractography could demonstrate the most important fibers necessary to be severed to achieve best results and reduce complications.

Methods: In this study, the AIC of 20 patients undergoing functional neurosurgery for diverse diagnosis was defined bilaterally in the Iplannet Stereotaxy Software (Brainlab, Germany). The 40 AIC tractography were divided in two halves based on coronal views. The direction of the fibers was studied in the two segments with the objective to define which portions of the fibers would be reached by a single isocenter placed in the ventral most portion of the AIC, and which fibers would be reached if added a second isocenter to obtain an oval shaped distribution in the direction of the ventral-dorsal portion of the AIC. The isocenters were adjusted based on Gamma Plan® Treatment Planning System - TPS (Elekta, Sweden).

Results: Significant difference was observed between both plans, with the single isocenter reaching substantially fibers directed to the ventral-mesial-orbito-frontal fibers, while the two isocenters plan achieved also fibers directed to the lateral-frontal cortex. Classical capsulotomy suggests that these lateral fibers should be also reached, based on size of the lesion, oval in shape.

Conclusions: The routine use of DTI tractography of the AIC may be important to the planning of Gamma Knife capsulotomy. DTI tractography, as well as anisotropy showing the capsule promises the have important role in Gamma-C. In the case of Gamma-C it allows for objective definition of dose constrains to the internal capsule and the fibers to be reached. It may direct the procedure based on severity of the disease, as well as its dominant symptomatology.

OSP14 - IMAGING

#9983 : Differentiating post-SRS radionecrosis from tumor progression using MRI Arterial Spin-Flow Labelling (ASL): Quick, colorimetric, quantifiable and necessary baseline blood flow data used to evaluate SRS treatment of brain metastases and predict outcomes.

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Keywords: radionecrosis, tumor progression, ASL, Gd-, Arterial Spin-Flow Labelling, primary histology, brain metastasis, baseline blood flow, elevated flow, reduced flow, quantifiable analysis, colorimetric analysis

The radiographic differentiation of post-SRS radiation change versus tumor progression is a major issue for any SRS center. We have been using non-Gd+ ASL as a reliable pulse sequence to help decide on the dominant tissue in these lesions and have used this data to assist in the decision for further treatment for four years now. Recent published data confirms that post-SRS elevated flow can be a very reliable predictor of recurrent tumor but the largest study failed to establish baseline data, and we have found that up to 40% of pre-treatment brain metastasis do not have elevated flow at baseline, therefore these tumors would not be expected to have elevated flow when they re-occur. If a baseline is not established, then these ‘low flow’ metastasis would be mistaken as radiation change upon follow-up. We have contacted multiple international centers to join in a larger data pool to verify our initial findings and establish an optimal statistical data base and promote this two-minute pulse sequence characterization to be used with confidence.

OSP14 - IMAGING

#10430 : Stereotactic diffusion tensor imaging tractography for gamma knife stereotactic radio-surgery - Evolution of technique & application.

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Abstracts
Integration of modern neuroimaging into treatment planning has increased the therapeutic potential and safety of stereotactic radiosurgery. We previously reported our method of integrating stereotactic diffusion tensor imaging (DTI) tractography into conventional treatment planning for Gamma Knife radiosurgery (GKRS). The aim of this study is to address some of the technical limitations of our previously reported techniques in a larger series.

Methods: Seventy patients who underwent GKRS composed the study cohort. DTI images were obtained at the time of standard GKRS protocol MRI (T1 and T2 weighted) for treatment, with the patient’s head secured by a Leksell stereotactic frame. All studies were performed using a 1.5-T magnet with a single-channel head coil. DTI was performed with diffusion gradients in 32 directions and coregistered with the volumetric T1-weighted study. DTI postprocessing by means of commercially available software allowed tensor computation and the creation of directionally encoded color, apparent diffusion coefficient & fractional anisotropy mapped sequences. In addition, the software allowed visualized critical tracts to be exported as a structural volume and integrated into GammaPlan as an “organ at risk” during shot planning. Combined images were transferred to GammaPlan and integrated into treatment planning.

Results: Stereotactic DTI images were successfully acquired in all patients, with generation of correct directionally encoded color images. Tract generation was straightforward and reproducible, particularly for axial tracts such as the optic radiation and the arcuate fasciculus. In our original study we noted that Corticospinal tract visualization was hampered by artifacts from the base of the stereotactic frame, but this was overcome by adjusting the gradient parameters. Coregistration of the DTI series with the T1-MR treatment volume at imaging is essential for the generation of correct tensor data. Most patients had pathology in the vicinity of eloquent tracts and/or the cortex. One patient with mesial temporal AVM developed delayed worsening of a pre-existing hemianopia. no other neurological deficits due to radiation were recorded at follow-up.

Conclusions: Reports in the medical literature have suggested that white matter tracts (particularly the optic radiation and arcuate fasciculus) are more vulnerable to radiation during SRS than previously thought. Integration of stereotactic tractography into GK-SRS represents a promising tool for preventing GK-SRS complications by reduction in radiation doses to functional organs at risk, including critical cortical areas and subcortical white matter tracts & further increase our knowledge of critical cerebral structure radiation tolerances to better improve the therapeutic potential and safety of SRS.
Abstracts

OS14 - IMAGING

#8971 : 11C-Methionine PET for distinguishing recurrent brain metastases from radiation necrosis: Limitations of diagnostic accuracy and long-term results of salvage treatment

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Keywords: Brain metastasis, Radiosurgery, Radiotherapy, Recurrence, Radionecrosis, 11C-methionine PET, Salvage treatment

Background: Imaging features of radiation necrosis (RN) are similar to those of local recurrence (LR) of brain metastases (BM) on conventional diagnostic imaging technique. 11C-Methionine PET (MET-PET) has reportedly been useful to provide a differential diagnosis between LR and RN. The aim of this study was to investigate the diagnostic performance of MET-PET and the mid- to long-term results of subsequent management.

Methods: The eligible subjects were enlarging contrast-enhanced lesions (>1cm) on MR imaging after any kind of radiotherapy for BM, suggesting LR or RN but difficult to differentiate. From August 2013 to September 2016, MET-PET was performed for 35 lesions in 30 patients (median age: 63 yrs). Tracer accumulation in the regions of interest was analyzed as standardized uptake value (SUVmax) and lesion/normal tissue SUVmax ratios (LNR) were calculated. The cut-off value of LNR was provisionally set at 1.4. Salvage treatment strategies determined based on MET-PET diagnosis and treatment results were investigated. The diagnostic accuracy of MET-PET was analyzed by Receiver operating characteristic (ROC) curve analysis.

Results: Median interval from primary radiotherapy to MET-PET was 21 months and 13 lesions had received radiotherapy twice or more. The MET-PET diagnoses were LR 17 and RN in 18 lesions. In the median follow-up time of 15 months, final diagnoses were confirmed in 31 lesions (Histological 16, Clinical 15). Mean LNR of LR and RN were 1.70 ± 0.31, 1.13 ± 0.25, respectively. Sensitivity, Specificity, positive predictive value and negative predictive value were 80%, 88%, 86%, 82%, respectively. ROC curve analysis indicated the optimal LNR cut-off value as 1.39 (AUC: 0.89). LNR of 5 lesions incorrectly diagnosed by MET-PET were ranged within 1.4 ± 0.2. Salvage treatment for 17 lesions predicted as LR were surgical resection in 7, radiosurgery in 8. Of 18 lesions predicted as RN, 6 were surgically treated and 3 needed repeat bevacizumab treatment. In 4 lesions which failed to obtain diagnostic conclusion, salvage treatment based on MET-PET diagnosis did not provide significant improvement and treatment strategies had to be changed.

Conclusions: 11C-Methionine PET appeared to have a reliable diagnostic performance for distinguishing LR from RN. The provisional LNR cut-off value of 1.4 in our institution was found to be relevant. Limitations of diagnostic accuracy should be recognized in cases with LNR close to the cut-off value.

OS16 - CLINICAL TRIALS IN PROGRESS

#10440 : Gamma Knife subthalamotomy for Parkinson’s disease

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Keywords: subthalamotomy, parkinson’s disease
**Title:** Gamma Knife subthalamotomy for Parkinson's disease

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**Objective:** To assess the feasibility of Gamma Knife subthalamotomy in Parkinson's disease

**Background:** Chronic STN stimulation is an established treatment for complicated PD. Bilateral subthalamotomy may induce significant and long-lasting results when DBS is not available. However, which alternative can be proposed for patients with surgical contraindications for electrodes implantation? Gamma Knife (GK) thalamotomy is an effective therapy for treating disabling tremor. This technique encounters very few contraindications. We report the results of a prospective trial on GK Subthalamotomy for patients with absolute contraindications for DBS. The primary endpoint was tolerance.

**Methods:** 14 PD patients (10 men, mean age 66.4) with severe motor complications were included. STN DBS was contraindicated because of vasculopathy or anticoagulant treatment. Patients were assessed before and quarterly for at least 24 months after GK subthalamotomy. A unilateral GK subthalamotomy on the most affected side was proposed first followed by contralateral subthalamotomy after M12 if necessary. STN lesioning was performed with Leksell Gamma unit with a single exposure through a 4mm collimator. Radiosurgical dose was 110 Grays.

**Results:** 12 patients were assessed at 2 years. 2 patients died before M6 (stroke, suicide). 7 patients had bilateral GK subthalamotomy, 5 unilateral (2 previous contralateral STN DBS, 2 refusals, 1 unilateral disease). UPDRS motor score was improved by 17.6% at M24, motor fluctuations by 18% and dyskinesia were reduced by 66%. Cognitive score was stable except for one patient. No significant decrease in LEDD was observed. MRI STN lesion appeared 9 months after radiosurgery. One patient was a hyporesponder and 4 had an hyperresponse with clinical consequences: Severe transient dyskinesia (2), transient hemiparesia and delirium (1), permanent hemiplegia.

**Conclusions:** Apart from a significant decrease in dyskinesias, the patients did not improve following STN GK and several experienced adverse effects. Although the cohort is small and with high comorbidities, this study does not indicate that GK subthalamotomy may be a good alternative to DBS for advanced PD.

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**OSP17 - ESTRO: METASTASES 3**

**#9997 : Stereotactic radiosurgery for focal leptomeningeal disease in patients with brain metastases**

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**Keywords:** radiosurgery, brain metastases, cancer, imaging, leptomeningeal

**Background:** Leptomeningeal disease (LMD) presents symptomatically in approximately 5% of patients with metastatic brain cancer. The presence of LMD is conventionally viewed as an indication for whole brain radiation therapy (WBRT) and not suitable for stereotactic radiosurgery (SRS). The purpose of the study was to evaluate the local control rate and overall survival of patients who underwent SRS to focal LMD.

**Methods:** Thirty-two patients with brain metastases and LMD were identified in our prospective Gamma Knife radiosurgery database, from a total of 465 patients that underwent SRS between 2013 and 2015. For 16 patients, focal LMD was targeted with SRS. The median imaging follow-up time was 7 months. The median volume of LMD was 372 mm³ and the median margin dose was 16 Gy. Five patients had undergone prior WBRT. Histology included non-small cell lung cancer (8), breast cancer (5), melanoma (1), gastrointestinal cancer (1) and ovarian cancer (1).

**Results:** Follow-up MR imaging was available for 14 patients. For 13 of the 14 patients, LMD was stable (35.7%) or partially regressed (57.1%) at follow-up. Only one patient had progression of LMD associated with hemorrhage 5 months after SRS. Seven patients developed distant LMD at a median time of 7 months. The median actuarial overall survival from SRS for LMD was 10.0 months. The 6-month and 1-year actuarial overall survival was 60% and 26% respectively. Six patients underwent WBRT after SRS for LMD, at a median time of 6 months, with an overall survival of 3.5 months after WBRT.

**Conclusion:** Focal leptomeningeal metastatic disease may be treated successfully with radiosurgery permitting delay or avoidance of WBRT in some patients.
OSP17 - ESTRO: METASTASES 3

#10015 : Re-irradiation spine stereotactic body radiation therapy (SBRT) for spinal metastases: International Stereotactic Radiosurgery Society (ISRS) Consensus Practice Review

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Keywords: Spine, Vertebral body, Metastases, Retreatment, Stereotactic Radiation

Objective: Spinal metastases recurrent after conventional palliative radiotherapy have historically been difficult to manage due to concerns of spinal cord toxicity in the retreatment setting. Spine SBRT, also known as stereotactic radiosurgery, is emerging as an effective and safe means of delivering ablative doses to these recurrent tumors. To determine the clinical efficacy and safety of spine stereotactic body radiation therapy (SBRT), specific to previously irradiated spinal metastases, a systematic review of literature was performed.

Methods: A systematic literature review was conducted specific to SBRT to the spine using Medline, Embase, Cochrane Evidence Based Medicine Database, National Guideline Clearinghouse and CMAinfobase with further bibliographic review of appropriate articles.

Research questions:
1. Is retreatment spine SBRT efficacious with respect to local control and symptom control?
2. Is retreatment spine SBRT safe?

Results: Initial literature search retrieved 2263 articles; 160 were potentially relevant, 105 selected for in-depth review and 9 studies met all inclusion criteria for analysis. All studies were single institution series: 4 retrospective, 3 retrospective series of prospective databases, 1 prospective, and one phase I/II prospective study (low or very-low quality data). The results indicate that spine SBRT is effective with a median 1-year local control rate of 76% (range, 66-90%). Improvement in patient pain scores post-SBRT were observed to range from 65-81%. Treatment delivery was safe, with a crude rate of vertebral body fracture of 12% (range, 0-22%) and radiation myelopathy of 1.2%.

Conclusion: This systematic literature review suggests that SBRT to previously irradiated spinal metastases is safe and effective with respect to both local control and pain relief. Although the evidence is limited to low quality data, SBRT can be a recommended treatment option for re-irradiation.

OSP17 - ESTRO: METASTASES 3

#10601 : Stereotactic radiosurgery in association with immune checkpoint therapy for brain metastases of non-small cell lung cancer: feasibility and results

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Introduction: Recent reports suggest that immune checkpoint therapy (ICT) combined with stereotactic radiosurgery (SRS) have been associated with greater lesion regression of melanoma brain metastases and decreased local failure. When given concurrently (within 4 weeks), combined SRS and ICT may result in improved freedom from additional new brain metastases.

Objective: To investigate the feasibility and efficacy of ICT administered with SRS in patients with brain metastases of non small cell lung cancer (NSCLC) and evaluate if synergistic effect observed for melanoma is also identified in these patients.

Methods: 101 individual patients with brain metastases from lung cancer, being treated 185 times by SRS between March 2014 and November 2016, and followed in the prospective cohort of the brain metastases clinic at the CHUV where included in this analysis. Systemic treatment use within 6 weeks of SRS was noted. The prescription was 20 Gy in single fraction or 33 Gy in 3 fractions, according to the volume of PTV.

Results: Among the 185 SRS performed, 66 corresponded to single metastases, 48 to 2 - 4 metastases, 27 to 5 -
10, and 10 to > 10 in every single event. The median volume for the PTV was 1.68 ml, the average volume 10.17 ml. Fifty-six patients received only one treatment, 29 of them two and 16 three or more (max. 5).

1-year OS was 56.11% and 72.06% for patients in the chemotherapy and immunotherapy groups, respectively (p=0.26); 1-year brain-DFS was 32.16% (chemotherapy) and 33.84% (immunotherapy; p=0.95). Toxicity was minimal, with 3% grade 2 and no adverse event > grade 2.

Conclusions: SRS in combination with ICT is feasible, without an increase in toxicity. Even if there was a trend for improvement of OS between patients treated with immunotherapy, the brain-DFS was identical in both groups, suggesting that there was no synergistic effect between ICT and SRS in patients with brain metastases of NSCLC.

OSP17 - ESTRO: METASTASES 3

#10303 : Assessing and reducing dose to the hippocampi in stereotactic radiosurgery for four or more brain metastases

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Keywords: Brain Metastases, SRS, Neurocognition, Hippocampus

Background: Stereotactic radiosurgery (SRS) for a few brain metastases (BM) is acknowledged as the optimal method for sparing critical structures, such as the hippocampus. However, in the setting of 4 or more BM, the ability of SRS to spare the hippocampus and, thus, reduce neurocognitive deficits has been questioned. This study reports hippocampal dose from single-fraction, multi-target SRS for 4-10 BM and assesses the feasibility of hippocampal-sparing SRS via plan reoptimization.

Materials/Methods: Patients with four to ten brain metastases receiving single-isocenter, multi-target single-fraction SRS were identified in this IRB-approved study. Hippocampi were contoured using the RTOG 0933 atlas. RTOG 0933 dose constraints were converted to a biologically effective dose using an alpha/beta of 2 (D100: 421 cGy, Dmax: 665 cGy). Number of metastases, total target volume, prescribed dose, and distance of nearest metastasis [dmin] were analyzed as risk factors for exceeding hippocampal dose constraints. If hippocampal dose exceeded constraints, the SRS plan was reoptimized. Key dosimetric parameters were compared between original and reoptimized plans. To determine if a single target would exceed dose constraints, all targets but the metastasis closest to the hippocampi were removed from the plan and dosimetry was compared.

Results: 40 plans were identified. 15 hippocampi (19%) exceeded constraints in 12 SRS plans. Hippocampal sparing was achieved in 10 of 12 replanned cases (83%). Risk factors associated with exceeding hippocampal constraints were decreasing dmin (24.0 v 8.0mm, p=0.002; OR 1.14, 95% CI 1.04-1.26) and higher total target volume (5.46 cm3 vs 1.98 cm3, p=0.03, OR 1.14, 95% CI 1.00-1.32). There was no difference in exceeding constraints for 4-5 vs 6-10 metastases (27% v. 21%, p=0.409) or prescribed dose (18 Gy, p=0.58). For reoptimized plans, there were no significant differences in PTV coverage (99.6% vs 99.0%, p=0.17) or conformity index (2.03 vs 2.09, p=0.78). Six (50%) plans exceeded dose constraints with a single target.

Conclusion: A substantial proportion of hippocampi may receive a relatively high radiation dose from SRS when treating 4-10 BM. Decreased distance of the closest metastasis to the hippocampus and higher total target volume are associated with exceeding hippocampal constraints. Reoptimizing these plans spares dose to the hippocampi and still yields acceptable dosimetric characteristics. Prospective evaluation of the impact of hippocampal dose on neurocognition in the setting of SRS to 4 or more BM would be valuable.

OSP17 - ESTRO: METASTASES 3

#9846 : Stereotactic radiosurgery for elderly patients with brain metastases

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Keywords: brain metastases, stereotactic radiosurgery, age, elderly

Purpose: Recently, with the aging of the population, an increasing number of elderly brain metastasis (BM) patients have been treated with stereotactic radiosurgery (SRS).

Methods: For this IRB-approved, retrospective cohort study, we used our prospectively accumulated database including 3102 consecutive patients undergoing SRS for BMs during the 1998-2015 period. Among these 3102 patients, 1684 were over age 65 years. The patient numbers for the 65-69, 70-74, 75-79, 80-84 and over 85 (max. 96) years of age groups were 557, 524, 382, 166 and 52, respectively.

Results: There was a significant increase in the proportion of elderly patient undergoing SRS in 2006 or earlier (51.1%) versus in 2007 or later (58.0%, p=0.0001). Median survival times (MSTs, months) of the aforementioned age groups were 7.4, 8.1, 7.2, 5.9 and 4.1, respectively (stratified p=0.0001). Although MST differences between each pair of neighboring age groups failed to reach statistical significance, there was a relatively large MST difference between patients under 79 and those over 80 years of age (HR; 1.439 [95% CI: 1.242-1.657], p<0.0001). Furthermore, MSTs of the age groups 65-69, 70-74, and 75-79 years did not differ significantly from the MST of the under-65-year group (8.4 months). Time-to-event outcome analyses showed that these age groups did not differ significantly in cumulative incidences of neurological death (p=0.47), neurological deterioration (0.42), SRS-related complications (0.42) or local recurrence (0.47).

Conclusions: Our results suggest that patients under 79 years of age are not poor candidates for SRS as compared to those over 80 years old.

OSP17 - ESTRO: METASTASES 3

#8943 : Is upfront stereotactic radiosurgery a rational treatment option for very elderly patients with brain metastases? A retrospective analysis of 106 consecutive patients age 80 years and older

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Keywords: Brain metastases, elderly patients, stereotactic radiosurgery, Gamma Knife

Background: Advanced age has been shown to be a factor predicting poor survival in patients with brain metastases (BM). There have been only a few studies focusing on stereotactic radiosurgery (SRS) for elderly BM patients. The present study aimed to investigate the efficacy and limitations of SRS for very elderly BM patients.

Methods: This was a retrospective observational study analyzing 106 consecutive patients (69 males / 37 females) age 80 years and older who received upfront Gamma Knife SRS for BM between January 2009 and October 2015. The median age was 84 years, and the median Karnofsky performance status (KPS) was 70. Fifty-two patients had a solitary BM, and others multiple BM. The median cumulative tumor volume was 3.9 mL and the median dose prescribed was 20 Gy. Overall survival (OS), neurological death rates and distant and local intracranial tumor control rates were analyzed.

Results: No patients were lost to follow-up. Six-month and 12-month OS rates were 54% and 32%, respectively. The median OS time was 7.1 months. Competing risks analysis showed that 6-month and 12-month neurological death rates were 8% and 11%, respectively. In total, 245/311 tumors (79%) in 82 patients (77%) with sufficient radiological follow-up data were evaluated. Six-month and 12-month distant BM recurrence rates (per patient) after SRS were 17% and 25%, respectively. Six-month and 12-month rates of local tumor control (per lesion) were 94% and 89%, respectively. Repeat SRS, salvage WBRT and surgical resection were subsequently required in 25, 4 and 1 patient, respectively. Proportional hazard regression analysis showed that KPS ≥ 70 (HR: 0.444, P < .001), controlled primary disease/no extracranial metastases (HR: 0.361, P < .001) and female sex (HR: 0.569, P = 0.028) were independent factors predicting better OS. Similarly, tumor volume (> 2 mL) was the only factor predicting a higher rate of local control failure (HR: 12.8, P = 0.003).

Conclusions: The present study suggested an upfront SRS strategy to offer a feasible and effective treatment option for very elderly patients with limited BM. In the majority of patients, neurological death could be delayed or even prevented.

OSP18 - VARIOUS 1

#10077 : Gamma knife radiosurgery for intracranial ependymomas

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Keywords: Brain metastases, elderly patients, stereotactic radiosurgery, Gamma Knife
Keywords: ependymoma; radiosurgery; gamma knife

Ependymomas are rare tumors of the central nervous system developing from ependymocytes. Surgery is the reference treatment, supplemented by adjuvant radiotherapy in case of incomplete excision. At the time of the recurrence, a second surgery is preferred, but not always feasible. In these cases, the therapeutic options are limited and radiosurgery seems a good therapeutic alternative.

We present a retrospective series of 21 patients treated by radiosurgery for 33 post-surgical recurrences of ependymomas at the University hospital of Lille, France, between 2003 and 2015. The diagnosis of ependymoma was carried out according to the WHO criteria and the indication of radiosurgical treatment validated by a multidisciplinary staff. The treatments were performed with a Leksell Gamma Knife model 4C. For each patient, the data collected were age, sex, WHO grade of the tumor, number of surgeries, location of recurrence, time between surgery and radiosurgery, prescribed dose and target volume. The overall survival after radiosurgery is 100% at 1 year, 91% after 3 years. Progression-free survival was 85% at 1 year, 80% at 2 years, 64% at 3 years and 51% at 5 years. The local control of lesions treated by radiosurgery is 100% at 1 year, 85% at 2 years, 76% at 5 years and 55% at 10 years. The average duration of follow-up was 4.2 years. Among the different variables analyzed, only the WHO grade of the tumor had a significant impact on local and regional control of the disease (p = 0.03 and p <0.001).

In our series, radiosurgery is a treatment of choice of ependymoma recurrences with a good rate of local control. Patients with Grade 2 ependymomas have better local and regional control of the disease.

OSP18 - VARIOUS 1
#10081 : Endocrine Deficits after Pituitary Adenoma Radiosurgery: Dosimetric Analysis based on Patients treated with the Gamma Knife Perfexion

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Keywords: Complication, Dosimetry, Endocrine, Pituitary adenoma, Radiosurgery

Objective: Endocrine deficits are the most frequent complication after pituitary adenoma radiosurgery (SRS). The clinical and dosimetric factors associated with pituitary insufficiency remain unclear despite more than 30 years of clinical usage.

Methods: Retrospective review of 97 patients having single-fraction SRS from 2007 until 2014. Eligible patients had no history of prior radiation, normal age and gender specific pituitary function before SRS, and at least 24 months of endocrine follow-up. Forty patients (41%) had hormone secreting tumors; 57 patients had non-secreting tumors (59%). The median prescription isodose volume was 2.8 cm³ (range, 0.5-30.5); the median tumor margin dose was 20 Gy (range, 12-27.5). The median follow-up after SRS was 48 months (range, 24-107).

Results: Twenty-seven patients (28%) developed pituitary insufficiency at a median of 22 months (range, 4-69) after SRS. The 2-year and 5-year rates of new endocrine deficits were 17% and 31%, respectively. Multivariate analysis found men (risk ratio, 2.38; P=0.04), smaller gland volume (risk ratio, 0.99; P=0.02), and increasing mean gland dose (risk ratio, 1.31; P<0.0001) to be predictive of new endocrine deficits. Further analysis using receiver operating curves showed the least to most sensitive dosimetric variable for predicting new endocrine deficits were gland volume (AUC 0.65, P=0.01), volume of gland receiving 12 Gy (Vgland12) (AUC 0.68, P=0.02), volume of gland receiving 14 Gy (Vgland14) (AUC 0.71, P=0.01), volume of gland receiving less than 14 Gy (Vgland<14) (AUC 0.83, P<0.0001), mean gland dose (AUC 0.83, P<0.0001), and volume of gland receiving less than 12 Gy (Vgland<12) (AUC 0.85, P<0.0001). The incidence of new deficits based on mean gland dose were <10 Gy, 1/40 (3%); 10-15 Gy, 12/35 (34%); ≥15 Gy, 14/22 (64%). The incidence of new deficits based on Vgland<12 were >300 mm³, 1/31 (3%); 100-300 mm³, 12/49 (25%); <100 mm³, 14/17 (82%).

Conclusion: Endocrine deficits after pituitary adenoma SRS increase in a time and dose dependent manner. Reducing the radiation exposure to the identifiable gland whenever feasible should lower the incidence of new hormonal deficits after pituitary adenoma SRS. The primary weakness of this analysis is the high probability of inter-observer variability in pituitary gland definition.
OSP18 - VARIOUS 1

#9969 : Long-term results of single-session stereotactic radiosurgery for non-vestibular cranial nerve schwannomas

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Keywords: non-vestibular schwannoma, radiosurgery, Gamma Knife, results

Introduction: Non-vestibular schwannomas (NVS) are rare intracranial tumors representing <10% of all cranial nerve schwannomas. For small to medium-size tumors, radiosurgical treatment in a single session is often preferred to surgical resection. The aim of the present study is to analyze the long-term tumor control and morbidity of a series of 30 NVS treated in our center and followed prospectively.

Material & Methods: The data of a series of 30 patients were analyzed. Affected cranial nerves included cranial nerve III (n=1), V (n=8), VI (n=2), VII (n=8), IX-X-XI (n=9), and XII (n=2). Median age was 47. Two patients had neurofibromatosis. A functional deficit of the cranial nerve was present at the time of irradiation for 23 patients (77%). Seven patients (23%) had undergone previous microsurgical resection. All patients were treated by a single-session procedure with a Gamma Knife C or Perfexion. The median tumor volume and margin dose were 1.1cc (range, 0.02-9.9cc) and 12Gy (range, 10-15Gy).

Results: The median follow-up was 6.2y (range, 2-11.5y). We found a significant (i.e., >10% of the initial volume) reduction of the tumor volume during follow-up for 17 patients (57%), and a stable volume for 13 patients (43%). No patient had MR-defined tumor growth during follow-up. We observed a transient worsening of the function of the cranial nerve in the first months after radiosurgery in 2 patients with a facial nerve schwannoma, which was treated successfully with corticoids. No patient developed permanent worsening of the affected cranial nerve, and no other morbidity occurred. Five patients had an improvement of their functional deficit: diplopia resolved for 2 patients with NVS of cranial nerve III and VI, and trigeminal neuralgia resolved for 3 patients with NVS of nerve V.

Conclusions: Based on our experience of 30 patients successfully treated for a NVS by single-session radiosurgery, we concluded that this treatment is very efficient and can be safely delivered in a single session for patients with small to medium-size NVS.

OSP18 - VARIOUS 1

#9847 : Stereotactic radiosurgery for non-functioning pituitary adenoma touching/compressing the optic chiasm: median 12-year post-treatment imaging follow-up results analyzed using competing risk analysis

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Keywords: pituitary adenoma, non-functioning, stereotactic radio surgery

Objectives: Debate continues as to whether stereotactic radiosurgery (SRS) or fractionated stereotactic radiotherapy (FSRT) should be chosen for patients with non-functioning pituitary adenomas (NFPAs) touching or even compressing the optic chiasm. We describe our long-term follow-up results with SRS for such patients.

Methods: This institutional review board-approved, retrospective study used our prospectively accumulated database including 27 patients (14 females, 13 males, mean age; 61 [range; 19-85] years) who underwent gamma knife SRS between 1998 and 2006 for NFPAs touching/compressing the optic chiasm. Twenty-six patients had undergone surgical removal; once in 16, twice in eight and four times in two. The median tumor volume was 5.2 (range; 1.8-50.8) cc. To avoid excess irradiation to the optic apparatus (OA), the tumor was not totally covered with the selected peripheral doses. Instead, the lower part of the tumor was covered with a 50% or a 60% isodose gradient; i.e., 49-98% (mean; 84%, median; 88%) of the entire tumor received the
selected doses. Median doses at the tumor periphery and the OA were 7.6 Gy and 11.0 Gy (ranges; 3.2-10.9 Gy and 8.7-12.9 Gy, respectively.

**Results:** Seven patients (26%) were confirmed to be deceased due to unrelated diseases at a median post-SRS period of 150 (range: 15-174, IQR: 83-154) months. Follow-up MRI showed tumor growth in two patients (7.4%) at the 11th and 134th post-SRS month; the former underwent surgery and the other SRS. Excluding these two patients, the latest follow-up MRI examinations which were performed 13-216 (mean: 139, median: 156, IQR: 116-172) months after SRS showed no size changes in five (18.5%) and shrinkage in 22 patients (74.1%), i.e., the crude incidence of tumor growth control was 92.6% and cumulative incidences of tumor growth-free survival estimated with a competing risk analysis were 96.3%, 96.3% and 91.7% at the 60th, 120th and 180th post-SRS month. Neither SRS-induced optic neuropathy nor endocrinological impairment occurred.

**Conclusion:** In patients with NFPAs touching or even compressing the optic chiasm, SRS achieves good long-term results. The opinion that FSRT is the only appropriate treatment is thus unwarranted.

**OSP18 - VARIOUS 1**

#9766 : Stereotactic radiosurgery for patients with ten or more brain metastases

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**Keywords:** Gamma Knife, SRS, Multiple metastases, Brain Metastases,

**Object:** To evaluate the efficacy of Gamma Knife radiosurgery (GKRS) as treatment in patients with 10 or more metastatic brain tumors.

**Methods:** Between February 2014 and January 2016, 20 patients were treated with GKRS for 10 or more brain metastases. We retrospectively analyzed the data from these patients, with survival and tumor control as primary endpoints. Brain volumes treated with 8 Gy and 12 Gy were measured to explore volume of treated tissue as a contributing factor to tumor control. Pre-treatment and post-treatment magnetic resonance imaging (MRI) studies were reviewed at intervals of 3 months, as were patient records on site.

**Results:** Of the 20 patients treated, 3 were excluded due to insufficient follow-up data. For the 17 included patients the median age was 61 (range 19-76). These patients were treated for a total of 323 tumors, with a median of 17 tumors per patient (10-34). The median survival for these patients was 12.5 months (1.3-16.9). Patient survival was censored at the time of data collection, and the true upper limit of survival is higher than recorded here. The mean percent of brain volume treated was 0.9, with a median of 0.41 (0.07 – 3.38). The mean percent of brain volume that received a dose of 12 Gy was 5.0 (0 – 21.0), and of 8 Gy was 9.0 (1.0 – 31.0). For each of the first three 3-month intervals, the median percent of tumor control was 97%, 96%, and 100%, respectively in the patients with available data.

**Conclusions:** GKRS effectively treats and controls brain tumors, even in patients presenting with 10 or more tumors simultaneously. The number of tumors initially present was not found to have a significant correlation with general tumor control.

**OSP18 - VARIOUS 1**

#10658 : The Development of a Quality Assurance Program for CyberKnife M6 in Chile

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**Objectives:** Robotic technology, image guidance based on sophisticated tracking software and small-field dosimetry issues are incorporated into the CyberKnife® Robotic Radiosurgery System (CK M6). Upon commissioning and external beam auditing (by Equal ESTRO in our case), performance evaluation procedures should be carried out for each of the CK subsystems. Standardization of a quality assurance (QA) program of CyberKnife for suitable circumstances in Chile has not been established. In this research, we investigated the development of a QA program for CyberKnife and evaluated the feasibility of its application.

**Methods:** Considering all the subsystems involved in producing a CK M6 treatment, a list based on bibliographical recommendations was established...
and divided depending on the periodicity of QA tests to be carried out. All these developed Quality Check (QC) lists were later categorized into two groups: machine QA and patient-specific QA. An IBA (myQA®) comprehensive SQL quality control management database was used to schedule every single task and tabulate its expected results and tolerances including daily QA, monthly QA and yearly QA. Purpose and outcome are described and tracked for each test. In order to verify the validity of the established QA program, this QC list was applied strictly during the past year of operation. The acceptable tolerance was based on the careful comparison of values required by the CyberKnife manufacturer and QA results in different publications. The acquired measurement results were evaluated for the analysis of the current QA status and for the verification of the propriety for the developed QA program.

Acquired x-ray images were fed into 6D target locating software to calculate patient translations and rotations. A head-neck phantom, placed at different predefined positions on a treatment couch, was used to evaluate accuracy and precision of the target locating software for the fiducial, 6D skull, Xsight™ spine tracking methods. The dosimetric characteristics of the 6MV beam were also measured. Finally, beam delivery precision and total clinical accuracy were evaluated for the fiducial, 6D skull, Xsight™ spine tracking methods.

Results: The current QA status of the CyberKnife was evaluated from the accuracy of all measurements in relation with the application of the established QA program. Each measurement result was verified to have good agreement within the acceptable tolerance limit of the developed QA program. The Target locating software was found able to define the position of the imaging objects for translations and rotations respectively with an accuracy of 0.2mm and 0.2. The results revealed sub-millimeter beam-delivery precision and dose placement total accuracy for the fiducial, skull and Xsight™ spine tracking methods.

Conclusion: Performance evaluation procedures were carried out for a CK M6. The system was controlled for mechanical accuracy of the manipulator, image quality, kV parameters of the TLS as well as for linac 6MV beam characteristics and beam output parameters. The results revealed sub-millimeter beam-delivery precision and dose placement total accuracy for the fiducial, skull and Xsight™ spine tracking methods. It is considered that the developed QA program in this research could establish the standardization of QC methods for CyberKnife and confirms the accuracy and stability for image-guided stereotactic radiotherapy.

OSP19 - OCULAR TUMORS

#10209 : Retrospective multicenter study on results of gamma knife surgery for uveal melanoma in Europe.

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Keywords: uveal melanoma, gamma knife surgery, results, multicenter study, European Gamma Knife Society

The objective of the present study was retrospective evaluation of results of Gamma Knife surgery (GKS) for uveal melanoma performed in 8 European Gamma Knife centers (Bucharest, Florence, Istanbul, Moscow, Prague, Saint Petersburg, Sheffield, and Zurich), which agreed to participate and provided required information. Study design presumed collection of the various data (62 investigated variables) on individual patients with creation of the integrated database for further statistical analysis. Primary end-points were overall survival, local tumor control, eye retention rate, and morbidity during follow-up. Secondary end-points were tumor response, preservation of visual function on the affected eye, and incidence of metastatic disease after GKS.

In total 349 cases were collected. All patients were treated between July 2001 and October 2015. The stage of treated tumors corresponded to I, IIA, IIB, and IIIA in 26%, 43%, 23% and 7% of cases, respectively. Eye fixation was attained with retrobulbar anesthetic blocking in 65% of cases or suturing of rectus muscles in 24% of cases; in
11% of cases no eye fixation was done. Median marginal dose was 30 Gy (range, 25-30 Gy), median maximal dose was 50 Gy (range, 30-80 Gy), median maximal dose to the ipsilateral optic nerve was 8.7 Gy (range, 0.7 – 61.2 Gy). In 23 patients GKS was done before planned eye-preserving endoresection of the tumor. Follow-up information was available in 314 cases and median length of follow-up was 40 months (range, 1-132 months).

Actuarial survival rates at 3 and 5 years after GKS were 91% and 89%, respectively. Crude tumor control rate was 98%. Complete response was noted in 19% of cases, partial response in 46% of cases. Crude eye-retention rate was 95.5%. In overall 13 enucleations were done owed to tumor progression (5 cases), complications (2 cases), or unknown reasons (6 cases). Complications were noted in 67% of patients, and exudative retinal detachment (15%), cataract (13%), neovascular glaucoma (11%) and retinopathy (11%) were the most common. The risk of loss of the useful vision on the affected eye during follow-up after GKS was 40%. Suturing of the extraocular muscles for eye fixation during irradiation and two-staged treatment (GKS followed by planned endoresection of the tumor) were associated with significantly lower risk of complications and visual loss on the affected eye. Distant metastases after treatment were disclosed in 10% of patients.

In conclusion, GKS seems effective treatment option for management of uveal melanoma at early stage of disease.

Objectives: Visual function preservation is a secondary endpoint of choroidal melanomas (CM) treatment. We aim to identify factors predictable of better visual acuity after radiotherapy treatment.

Methods: A total of 21 patients with unilateral CM were treated in LINAC based with stereotactic radiosurgery since 2014. Sixteen patients, with tumor height ≤8 mm and base ≤16 mm, and median FU of 20 months were enrolled in this retrospective analysis. SRS was delivered to a dose of 50 Gy in five fractions. An eye monitoring system was applied for the acquisition of planning CT and treatment delivery. Standardized A- and B-scan echography and MRI of the eye were performed at baseline and during follow up. Toxicity was graded using the CTCAE v4.0. Structures at risk in the eye, including the delineation of the macula region, were analyzed in the setting of maximum dose received.

Results: Thirteen patients had severe visual loss at baseline and three had preserved (>20/40) visual acuity. Of these three patients, one remained with 20/25 visual acuity at last FU after 10 months, despite development of radiation induced grade 2 cataract (Macula Dmax 45,3Gy; Optic Nerve Dmax 24,7 Gy). One maintained good visual function (20/40) at last FU after 31 months with no treatment toxicity (Macula Dmax 59,7Gy; Optic Nerve Dmax 31,4 Gy). Another had pre treatment cataract and maintained good visual outcome (≥20/25) until 9 months, but developed blindness at 10 months (Macula Dmax 52,7 Gy; Optic Nerve Dmax 21,6 Gy). At 12 months, this patient underwent enucleation due a residual image on MRI. Histological specimen showed residual CM. Of the 13 patients who had severe visual loss pre treatment, four had improvement in visual acuity from 20/80 to 20/25 at 6 months (Macula Dmax 53,5 Gy; Optic Nerve Dmax 21,5 Gy), 20/60 to 20/40 at 4 months (Macula Dmax 58,2 Gy; Optic Nerve: Dmax 31 Gy), 20/80 to 20/30 at 13 months (Macula Dmax 12,2 Gy; Optic Nerve Dmax 36,1 Gy), and 20/70 to 20/50 at 15 months (Macula Dmax 55,2Gy; Optic Nerve Dmax 46,8 Gy). Two of them had pre treatment cataract. One patient developed radiation induced neuropathy (Macula Dmax 51,5 Gy; Optic Nerve Dmax 51,5 Gy). Six patients developed grade 3/4 radiation induced retinopathy, retinal detachment or cataract.

Conclusion: Optic nerve lower Dmax correlates with good visual outcome. Despite high macula Dmax, patients showed improvement of visual acuity. Cataract does not predict worse results.

OSP19 - OCULAR TUMORS

#10220 : Visual outcomes predictors after stereotactic radiosurgery for choroidal melanomas

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Keywords: choroidal melanoma, stereotactic radiosurgery, visual outcomes
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#10399 : Gamma Knife Radiosurgery of uveal melanoma with focus on tumor visualization and eye globe fixation

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Keywords: Gamma Knife radiosurgery, uveal melanoma, MRI, eye immobilization

Objectives: To estimate the reliability of different techniques of eye globe fixation and to determine the most appropriate MRI sequences for tumor visualization and localization.

Methods: From January 2013 to December 2016, 87 patients with uveal melanoma underwent Gamma Knife radiosurgery. The affected eye was immobilized with different techniques (retrobulbar anesthetic block, fixation of two or three rectus muscles), which were tested in order to determine their reliability. For the verification of eye globe position MRI was performed immediately after the Gamma Knife procedure. The stereotactic images before and after radiosurgery were compared using the Leksell Gamma Plan software in terms of the position of the eye globe and the tumor. For visualization of choroidal melanomas, surrounding eye structures and optic pathways different MRI sequences (T1, T2, CISS and T1 with contrast enhancement) were examined to identify the most appropriate ones.

Results: Gamma Knife radiosurgery of uveal melanoma requires reliable eye immobilization, which can be achieved by complete fixation of at least three rectus muscles. Post-radiosurgery MRI revealed that retrobulbar anesthesia could not provide reliable immobilization as significant shift of the eye was observed. MRI visualization of uveal melanoma is a complicated task. The tumor may appear with different signal intensity on T1- and T2-weighted images. In all cases, only the combination of T1, T2 and CISS images allowed us to identify the tumor clearly and to distinguish between the tumor and retinal detachment. We did not find any advantages in T1 with contrast enhancement for tumor visualization.

Conclusion: Reliable eye globe fixation is extremely crucial for radiosurgical treatment; only rigid fixation with suturing of the rectus muscles can give one confidence in precise irradiation. Clear visualization of the tumor can be achieved with T1, T2 and CISS sequences. A combination of precise stereotactic visualization and complete immobilization of the eye makes it possible to perform conformal high-dose irradiation.

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#9870 : Linear accelerator stereotactic radiosurgery for intraocular uveal malignant melanoma - experience with 3D printed model of the eye

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Keywords: LINAC, Linear accelerator stereotactic radiosurgery, intraocular tumor, uveal melanoma, 3D model

Objectives: Malignant melanoma is the most frequent intraocular tumor in adults. One day session LINAC based stereotactic radiosurgery (SRS) of intraocular malignant melanoma is a method of «conservative» attitude to treat uveal melanoma.

Experience with 3D printed model of the eye with intraocular tumor used by planning on linear accelerator LINAC based stereotactic radiosurgery.

Methods: Retrospective clinic-based study - clinical findings of patients with posterior uveal melanoma (choroid)
in stage T1/T3 who underwent stereotactic radiosurgery (SRS) at LINAC in Slovakia. Patients were not randomized either to radical or to “conservative” procedure, but the treatment was determined exclusively on a case-by-case basis. Tumor stage, volume, maximum elevation, localization presence of secondary retinal detachment, general status, age, gender, the functional tests were taken into consideration. The stereotactic frame was fixed to the head and the sutures were tied to the stereotactic frame. We used model Clinac 600 C/D Varian (system Aria, planning system Corvus version 6.2 verification IMRT OmniPro) with 6 MeV X by rigid immobilization of the eye to the Leibinger frame. The patient underwent CT and MRI examination with the fixed eye to the frame. The stereotactic treatment planning after fusion of CT and MRI was optimized according to the critical structures (lens, optic nerve, also lens and optic nerve at the contralateral side, chiasm).

The best plan was applied for therapy at C LINAC accelerator. The planned therapeutic dose was 35.0 Gy by 99 % of DVH (dose volume histogram).

In the software for segmentation (3DSlicer) created virtual 3D model of eye globe with tumorous mass based on tissue density from CT and MRI data. Virtual model was then processed in the slicing software (Simplify3D) and printed on 3D printer using FDM (fused deposition modeling) technology. Material used for printing was polylactic acid.

**Results:** In period 2001 - 2015 the group of 150 patients with uveal melanoma (139 choroidal melanoma, 11 ciliary body melanoma) was treated. The median tumor volume was 0.5 cm³ (0.2 - 1.6 cm³). The radiation dose was 35.0 Gy by 99 % of DVH (dose volume histogram). Since 2015 stereotactic planning scheme was optimized with help of 3D printed model of the patient's eye with intraocular tumor.

**Conclusion:** Our 3D printed model of eye with tumor was helpful in planning process to achieve the optimal scheme for irradiation which requires high accuracy of defining the targeted tumor mass and critical structures.

OSP19 - OCULAR TUMORS

#9942 : Radiosurgery for the treatment of choroidal melanoma: follow-up and size patterns of melanomas posterior to radiosurgery

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**Objectives:** To describe the general follow-up of patients and to analyze the evolution pattern of melanomas choroidal treated with radiosurgery.

**Material and methods:** A retrospective and descriptive analysis of 8 patients (4 men, 4 women, mean age of 58 years) diagnosed with choroidal melanoma who were treated with radiosurgery, from January 2015 to January 2017, was performed at the Radiosurgery Service of the Hospital Español, Mexico City. All patients were previously assessed with a complete ophthalmologic evaluation and with imaging studies to rule out metastases. A dedicated Novalis 600 N, 6 MV linear accelerator (BrainLab, Heimstetten, Germany) was used to impart doses ranging from 35 to 40 Gy (mean 35.75 Gy). Melanomas were located in the right eye in 87.5% of patients and the mean treated volume was 0.882 cc (0.202-1.819 cc). The main symptoms included a decreased visual acuity and quadrantanopsia. The mean follow-up was 12.8 months (4-22 months). Tumor size (area) was measured using ultrasound imaging during follow-up.

**Results:** After treatment, the percentage in tumor control, survival and metastasis was 87.5%, 100% and 0%, respectively. The TNM stage for choroidal melanomas of the patients was T2 and T2a. The evolution after radiosurgery was variable: 4 patients showed a progressive decline in tumor size, 3 patients had an initial tendency to increase tumor size followed by a significant reduction three months after treatment. Finally, one patient only had a 50% increase in tumor size and was considered as a disease progression. Visual acuity was reported to decrease 3 months after treatment. Complications: 50% developed retinopathy between 9 and 12 months, one patient had cataract/papillopathy and one patient showed no response to treatment. Follow-up of 7 functional patients continues.

**Conclusions:** Radiosurgery is a very minimal invasion alternative for the treatment of choroidal melanomas providing good tumor control and health-related quality of life. In our study some patients showed an initial increase in tumor size followed by a significant reduction. Thus, it is important to recognize tumor size changes after the radiosurgery to properly assess its efficacy. A larger number and longer follow-up periods of patients with choroidal melanomas treated with radiosurgery are required to better quantify the treatment success.

**Keywords:** Choroidal melanoma, radiosurgery
OSP19 - OCULAR TUMORS

#10035 : Preliminary results of fractionated Cyberknife radiosurgery for uveal melanoma.


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Keywords: eye, melanoma, hypofractionation, MRI

Aims: We report our clinical experience of a hypofractionated Cyberknife Radiosurgery schedule for uveal melanoma treatment.

Methods: Between April 2014 and March 2016 14 patients (pts), mean age 65 years (range 36 – 83 years) suffering from uveal melanoma (11 choroidal melanoma and 1 ciliary body melanoma) were treated at Cyberknife Center, Centro Diagnostico Italiano, Milan. All of the pts had received a diagnosis and referral from an ophthalmologist. Cyberknife radiosurgery was performed delivering a total dose of 54 - 60 Gy (mean 60 Gy) given in 3 or 4 fractions (mean 3) of 15 - 20 Gy (mean 20 Gy) prescribed to the 79 - 82% (mean 80%) isodose surface. All pts underwent orbit MRI with gadolinium for coregistration with the planning CT scans. The planning target volume (PTV) included the contrast-enhancing lesion on MRI plus a 2.5 mm margins in all directions. All pts underwent orbit MRI with gadolinium for coregistration with the planning CT scans. The planning target volume (PTV) included the contrast-enhancing lesion on MRI plus a 2.5 mm margins in all directions. All pts were irradiated eyelids closed, using a contention with a thermoplastic mask. The mean PTV volume was 2037 mm³ (range 701.82 – 5792 mm³), mean tumor base measured ultrasonographically 11.36 mm (range 7-15 mm), mean thickness 4.79 mm (range 2.5 – 10 mm), with a mean distance of 5.25 mm (range 0 – 15 mm) from fovea and 5.55 mm (range 0 – 13 mm) from optic nerve.

Results: After a mean follow-up of 17 months (range 7 – 30) local control was achieved in 100% of pts. No patient underwent enucleation and none developed distant metastases (all pts underwent abdomen ultrasound and liver blood examination once every six months and chest CT once a year). We observed a reduction of 13% in median base and of 44% in median thickness that were respectively 10 mm (range 4.8 – 13 mm) and 2.45 mm (range 0.5 – 5 mm) at last follow-up. Visual acuity was reduced in 64 % of pts, while in the others no change was found. Four pts suffered of radiation maculopathy, associated in one case with atrophy and in three cases with cystoids macular edema. Moreover radiation-induced optic neuropathy and radiation vasculopathy occurred respectively in 3 and 4 cases. 7 pts developed choroidal ischemia and 3 retinal detachment. At the last follow-up none had corneal anomalies.

Conclusions: These initial results of our Cyberknife schedule are consistent with data in literature and show a safe, minimally invasive and well tolerated method for treating uveal melanoma. Further follow-up is necessary.

OSP20 - ESTRO: SPINE

#10056 : Imaging-based outcomes for 24 Gy in 2 daily fractions for patients with de novo spinal metastases treated with spine stereotactic body radiotherapy (SBRT): An emerging standard

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Keywords: Spine SBRT, Spinal Metastases, SBRT Dose Fractionation

Objectives: Currently, there is no consensus fractionation scheme for spine SBRT. We report mature outcomes for a cohort of patients with no prior radiation (de novo) treated with 24 Gy in 2 daily fractions, which represents an emerging Canadian standard.

Methods: The cohort consisted of 279 de novo spinal metastases in 145 consecutive patients treated with 24 Gy in 2 SBRT fractions, between 2009 and 2015, identified from a prospective database. All vertebral segments were treated with an institutionally standardized linac-based approach using cone-beam CT image guidance and six degrees-of-freedom online setup correction. The endpoints were overall survival (OS), local control (LC), and the rate of vertebral compression fractures (VCF). OS rates were obtained...
using Kaplan-Meier methods and cumulative incidences of LC and VCF were obtained from competing risk analysis using death as a competing risk event. Evaluation of tumor control was based on serial spine magnetic resonance imaging (MRI) as per the SPIne response assessment in Neuro-Oncology (SPINO) criteria recommendations.

Results: The median follow-up was 17.0 months (range, 0.1–71.6 months). The 1-year and 2-year OS rates were 73.1% and 60.7%, respectively. Presence of epidural disease (p < 0.0001), lung (p = 0.0415) and renal cell (p < 0.0001) primary histologies and diffuse spinal metastatic disease as opposed to oligometastatic disease (p = 0.0034) were significant prognostic factors. The 1-year and 2-year LC rates were 90.3% and 82.4%, respectively, and the median time to local failure (LF) was 9.2 month (range, 0.4–31.3 months). Only the presence of epidural disease predicted for LF (p < 0.0001). The cumulative risk of VCF at 1 and 2 years were 8.5% and 13.8%, respectively. Lytic (p = 0.0143) or mixed lytic/blastic (p = 0.0214) lesions, spinal misalignment (p = 0.0121), and the dose to 90% of the planning target volume (PTVD90) (p = 0.0085) were significant predictors of VCF.

Conclusion: 24Gy in 2 daily fractions is safe and effective in achieving high tumor control rates for de novo spinal metastases. This fractionation scheme is currently the standard SBRT arm on an ongoing Phase 3 randomized Canadian national trial (CCTG-SC 24) comparing it to a conventional radiation dose of 20 Gy delivered in 5 daily fractions.

OSP20 - ESTRO: SPINE

#10357 : A retrospective analysis of factors affecting overall survival and outcome in the patients with metastatic spinal cord compression from NSCLCa following spinal SRS

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Keywords: Metastatic spine tumors, spinal cord compression, Non-small cell lung cancer, Stereotactic radiosurgery, survival, outcome

Introduction: Lung cancer is a leading cause of oncologic death in our country and commonly metastasize to spine which often resulted in spinal cord compression. Although recent advance in systemic therapeutic modalities including chemo- and targeted therapy, the prognosis of these metastatic disease is still poor and overall survival length is often less than 1 year. Recent radiosurgical treatment arm often provide better pain palliation and effectively durable local tumor control. Depending upon the patients' clinical status, therapeutic strategies should be tailored to improve quality of life for these patients with considering prognostic prediction and overall survival.

Method: Fifty-six patients with metastatic spinal cord compression from NSCLCa were treated with stereotactic radiosurgery between 2005 and 2014. Male to female ratio was 32 to 25. Median age was 66 year-old (range of 43 to 82 year). Pretreatment performance scale over 80 versus less than 70 was 25 versus 29. Cox regression model was utilized to analyze prognostic factors affecting overall survival including sex, age, KPS, No. of bone metastasis, No. of visceral metastasis, grade of metastatic epidural compression, history of prior radiation treatment and interval between initial diagnosis and spinal metastasis. In addition, based on the individual preradiosurgical scoring status and survival length, concordance rate were calculated by applying the three different prognostic systems such as Revised Tokuhashi, Tomita, and Van der Linden. By comparing the factors and outcome prediction of each system, useful relevant prognostic factors were evaluated.

Results: Average survival length was 8.5 months (range of 1–32 months). Concordance rates of predicting survival length with applying Tokuhashi, Tomita and Van der Linden scoring systems were 73%, 50% and 65% independently. Systemic oncologic statue and performance scale are the important parameters in evaluating tools to anticipate overall survival and outcome. Time to diagnosis of metastatic disease and primary lung cancer also showed significant predicting factor affecting survival length (< 2mos vs > 6mos, HR: 2.115, 95% CI 1.17–3.81, p=0.127).

Conclusions: The significant prognostic factors associated with survival after spinal SRS for metastatic NSCLCa are including pretreatment performance scale, primary disease control, and time between first metastasis and performance status. Relevant outcome factors should be carefully considered and evaluated in order to determine optimal therapeutic strategies including stereotactic radiosurgery.
OSP20 - ESTRO: SPINE
#10113 : Radiosurgery of high-grade spinal cord compression

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Keywords: Spinal cord compression, Radiosurgery/SBRT

Radiosurgical epidural decompression has been demonstrated with in 80% with complete or significant reduction of epidural tumor volume, indicating that these patients can be treated with non-invasive radiosurgery. In order to help a better communication and uniform decision-making of treatment, we also developed a dual grading system of spinal cord compression with grades 0 - V radiographic (anatomical), and grades a - e neurological (functional) grades. While open surgery is able to decompress the spinal cord immediately, radiosurgical spinal cord decompression occurs gradually and is suitable for patients with no neurological deficit. However, the current practice is to make such decision based on the MR imaging study rather than the patient's neurological status, and controversy exists whether high grade spinal cord compression can be safely treated with radiosurgery. Practitioners are indeed concerned about the presence of spinal cord compression. Therefore, the current study was performed to demonstrate the role of radiosurgery in patients with high-grade spinal cord compression on MRI imaging with grade IV (significant compression and displacement of spinal cord, T2-weighted CSF signal is still visible, aka partial block) and V (no visible T-2 weighted CSF signal, aka complete block on conventional myelogram). Total 33 patients with 35 lesions with radiographic grades IV-V were enrolled, with minimal or no neurological deficit (grade a-b) except one patient with neurological grade c (nonambulatory). The patients were treated with single dose spine radiosurgery 18-20 Gy, prescribed to the tumor margin. Spinal cord constraint was 10 Gy to the 10% cord volume defined 6 mm above and below the epidural tumor target. Median followup time of 6.4 months with MR imaging study and neurological examination every 2 months. Radiosurgery resulted in 75% spinal cord decompression at 2 months MRI scan post-radiosurgery, and 70% neurological improvement. One patient with neurological grade c became fully ambulatory. Only 2 patients required open surgery due to neurological decline, and 2 patients due to intractable pain. There was no other complication. Progression-free survival was improved in patients who responded to the radiosurgery treatment. Neurological grade was the only prognostic factor. Radiographic high grade did not affect the outcome. The results strongly support the use of radiosurgery for high grade spinal cord compression with no or minimal neurological deficit.

OSP20 - ESTRO: SPINE
#9839 : Stereotactic body radiotherapy for de novo spinal metastases: Systematic review and International Society of Stereotactic Radiosurgery (ISRS) Practice Guideline

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Keywords: spinal metastases, SRS, SBRT

Objectives: The aim of this systematic review is to provide an objective summary of the published literature pertaining to the use of stereotactic body radiation therapy (SBRT) specific to previously untreated spinal metastases.
Methods: A systematic review of the literature using PRISMA guidelines was performed up to March of 2015 from MEDLINE, PubMed, Embase, and the Cochrane Library. The search strategy was limited to publications in the English language.

Results: A total of fourteen full-text articles were included in the analysis. All studies were retrospective, except for two prospective studies. A total of 1,024 treated spinal lesions were analyzed. The median follow-up ranged from 9-49 months. A range of dose-fractionation schemes were utilized, with the most common ones being 16-24Gy/1fraction (fx), 24Gy/2fx, 24-27Gy/3fx, and 30-35Gy/5fx. For studies reporting crude results regarding in-field local tumor control, 346 out of 407 lesions (85%) remained controlled. For studies reporting actuarial values, the weighted average result demonstrated a 90% one-year local control rate. Only three studies reported data on complete pain response, and the weighted average of these results yielded a complete pain response rate of 54%. The most common toxicity was new or progressing vertebral compression fracture, which was observed in 9.4% of cases, and two cases (0.2%) of myelopathy were reported.

Conclusion: There is a paucity of prospective data specific to SBRT in patients with spinal metastases not otherwise irradiated. This systematic review demonstrates that SBRT is associated with favorable rates of local control of approximately 90% at one year, and rates of complete pain response of approximately 50%, with low rates of serious adverse events. Practice guidelines are summarized based on these data and ISRS consensus.

Keywords: spine surgery and radiation, SRS, tumor control toxicity

Material/Methods: An IRB approved retrospective review of patients treated with surgery followed by cEBRT or SRS for spinal metastases was performed. Local failure was defined as failure within the originally involved vertebral level(s). Surgical bed failure was any oncologic failure within the operative bed. Wound complications included post radiation infection or hematoma. Mechanical failure was defined as clinically significant hardware lucency or breakage, dynamic motion on imaging, loosening of bone-graft interface, or new pain not explained by oncologic progression.

Results: 63 patients were treated from 2006-2014: 37 received post-operative SRS; 26 received post-operative cEBRT. Instrumentation was performed in all 37 SRS patients and 18/26 (69%) cEBRT patients. Median follow-up post-SRS and cEBRT was 7.4 (range 1-39) and 4.4 (range 0-73) months, respectively (p=0.29). Karnofsky Performance Status ≥70 post-SRS and cEBRT was 86% vs 44%, respectively (p<0.01). The most common dose schedules were 16 Gy single fraction (SRS) and 30 Gy in 10 fractions (cEBRT). 1-year local failure was 9% vs. 30% (p=0.026) for SRS and cEBRT respectively, with 6/9 cEBRT patients demonstrating multilevel failure within and beyond the originally involved vertebral bodies; surgical bed failure at 1 year was 26.8% versus 30.0% (p=0.61). No mechanical failures were observed. Wound complications occurred in 2 SRS patients and 1 cEBRT patient; projected 1-year cumulative incidence rate of 2.8% and 6.3% respectively (p=0.91).

Conclusion: Post-operative SRS provides excellent LC in patients who have undergone surgery for spinal metastases. The 9% LF is less than that for SRS alone for patients with epidural disease, suggesting a benefit to post-operative SRS in carefully selected patients. The absence of significant complications in either group suggests that both SRS and cEBRT are safe approaches in this population.
OSP21 - RADIOBIOLOGY

#9990 : The risk of radiation-associated malignancy after Gamma Knife radiosurgery: A multi-institutional study

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Keywords: radiosurgery, secondary malignancy, tumor, cancer

Background: A major concern of patients undergoing Gamma Knife radiosurgery (GKS) for benign tumors is the risk of a separate secondary malignancy or malignant transformation. Long-term follow up studies are lacking and the exact incidence of radiosurgery-associated malignancy is not known. This study quantifies this risk and compares it to estimates of population risk based on the Central Brain Tumor Registry of the United States.

Methods: Data on all patients who have undergone radiosurgery for arteriovenous malformations (AVM), trigeminal neuralgia or benign intracranial tumors was collected through the International Gamma Knife Research Foundation (IGKRF). The incidence of malignant transformation and separate radiation-associated intracranial neoplasia was calculated in patient-years. Follow-up duration was defined as the time from radiosurgery to the time of death or last-follow up.

Results: To date, we have compiled data on 11,320 patients with a total of 59,200 patient-years of follow-up who under radiosurgery for meningioma (n=3141), AVM (n=2854), trigeminal neuralgia (n=1967), vestibular schwannoma (n=1914), pituitary adenoma (n=1182), other schwannoma (n=184) and hemangioblastoma (n=78). The overall median follow-up time was 3.97 years (0-24 years). Follow-up durations included 3928 patients with 2 to 5 years, 2018 patients with 5 to 10 years, 1462 patients with 10 to 15 years and 508 patients with greater than 15 years of follow-up.

Two cases of malignant transformation of vestibular schwannomas were reported at 8.7 and 11.8 years after radiosurgery, pathologically verified as malignant schwannoma. Two cases of presumed WHO grade1 meningioma transformed to an atypical meningioma and malignant meningioma at 3.5 years and 5.3 years respectively. No other cases of malignant transformation were reported. Three new malignant brain tumors were reported including one AVM patient and one meningioma patient, who developed radiographic features of distant intracranial malignancy at 4.3 and 8.7 years respectively. One patient with a pituitary adenoma developed pathologically verified osteosarcoma locally 12.8 years after radiosurgery.

Conclusion: The present analysis indicates that the incidence of malignant transformation after radiosurgery for benign tumors is approximately 1 in 14,800 patient-years. The incidence of a new malignancy after radiosurgery, either locally or distant, is 1 in 19,733 patient-years. These risks are not substantially higher than the CBTRUS (2009-2013) derived annual incidence rate of all primary malignant CNS tumors of 7.18 per 100,000. Patients can safely be counseled that the risk of malignancy after radiosurgery remains extremely low even at long-term follow-up of greater than 10 years.

OSP21 - RADIOBIOLOGY

#10372 : Risk of extracranial secondary cancer after radiosurgery: Comparison of different treatment platforms

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Keywords: secondary malignancy, extracranial,

Background: Secondary malignancy is a known complication of any radiation exposure. Though this risk is highest in the high dose treatment volume, it is clearly established that low dose radiation also results in a lifetime increased risk of cancer. Intracranial radiosurgery results in a small extracranial dose of radiation which therefore will increase a patient’s risk of cancer within the body. Different treatment platforms’
differing physical qualities result in small differences in this body dose delivered. This is of particular importance to young patients treated for benign conditions who have an otherwise normal life expectancy. The aim of this study is to compare the risk of extracranial secondary cancer after stereotactic radiosurgery (SRS) using different treatment platforms.

Methods: For an average sized 5 year old and adult the dose to the body to 14 female and 12 male organs received during treatment with SRS at 12.5Gy was calculated for four different radiosurgical treatment platforms using doses interpolated from literature and measurements. Lifetime risk of secondary cancer per 100,000 exposed was calculated for males and females exposed aged 5/15/25/35/45 years old utilising the National Cancer Institute RadRAT (v4.1.1) calculator. Chi squared statistical analysis.

Results: The platforms investigated were Gamma Knife Perfexion (Elekta, Stockholm), Linac (micro-multileaf collimator (mMLC) (Philips SL75-5 (Elekta) and cones (Radionics, Burlington, MA)), and Cyberknife (Accuracy, Sunnyvale).

The estimated excess number of extracranial cancers after treatment was:

Gamma Knife Perfexion 151-22 (0.43-0.06%) female 5-45yr/ 53-11 (0.14-0.03%) male 5-45yr per 100,000; Linac mMLC 1840-261 (5.3-0.78%) female 5-45yr/ 649-139 (1.7-0.36%) male 5-45yr per 100,000; Linac cones 3010-437 (8.6-1.3%) female 5-45yr/ 1080-235 (2.9-0.61%) male 5-45yr per 100,000; Cyberknife 6680-1270 (19.1-3.8%) female 5-45yr/ 2740-837 (7.3-2.2%) male 5-45yr per 100,000. At all ages/sex there was a statistically significant (p<0.001) difference in risk of secondary malignancy between Gamma Knife Perfexion, Linac and Cyberknife.

Conclusion: The extracranial dose of radiation that the body receives in radiosurgery results in an excess lifetime risk of secondary cancer which can only be estimated from extrapolated data from other ionising radiation exposure data. However these risks are potentially substantial for younger patients with normal life expectancy, so patients should be offered treatment utilising a radiosurgery platform which minimises this lifelong risk. Gamma Knife Perfexion results in the lowest estimated lifelong risk of secondary malignancy, with linac mMLC, linac cones and cyberknife progressively increasing risk.

OSP21 - RADIObIOLOGY

#9898 : Dose rate effect on Leksell Gamma Knife – in vitro study on medulloblastoma DAOY cells

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Keywords: radiobiology in Leksell Gamma Knife, dose rate effect

Objectives: In principle there are two reasons why dose rate on Leksell Gamma Knife (LGK) is being reduced during patient irradiation: 1) Co-60 sources decay with half-life of 5.26 years and 2) overall irradiation time is being extended by using multiple isocenters and conformal treatment plans (e.g. with blocked beams). It is thus important to study and evaluate effect of dose rate in LGK clinical conditions. This in vitro study is a pilot experimental work performed with medulloblastoma DAOY cells.

Methods and materials: Multiple experiments were performed with medulloblastoma DAOY cells irradiated on LGK by various dose rate (0.35 – 1.60 Gy/min). Currently, after Co-60 sources reloading in our center, experiments continue with dose rate up to 3.50 Gy/min. Irradiation was performed in a spherical Elekta ABS plastic phantom which was adapted to accommodate micro centrifuge tube (Eppendorf tube) containing cells. Leksell GammaPlan treatment planning software was used to plan cell irradiation. To produce different dose rate, sector blocking (0, 4 or 6 sectors blocked) was used together with 16 mm collimator to ensure cells homogenous irradiation. Plating efficiency and surviving fraction was determined for each experimental cell sample. Nine different doses in the range 0 – 6 Gy were used to have enough experimental points to obtain surviving curve. Linear quadratic model was used to fit experimental data. Surviving curves for different dose rates were plotted and compared.

Results: This is an initial pilot study with very preliminary data. However, based on so far obtained data it could be observed higher cell survival for dose rates lower than 0.40 Gy/min compare to higher dose rates over 0.75 Gy/
Conclusion: Very preliminary data from this study do show different cell survival for studied medulloblastoma DAOY cells based on a dose rate that was used for an irradiation. Higher survival is observed for a lower dose rate. However, to confirm this hypothesis and initial observation, more experimental work is needed.

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OSP21 - RADIOBIOLOGY

#10037 : Revisiting the risk of malignancy after gamma knife radiosurgery: with 10 years more experience, are the questions changing with changing practice?

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Keywords: malignancy risk, radiosurgery

Objectives: Ten years ago, we reported a retrospective cohort study. National health service numbers cross-referenced patients treated with radiosurgery against the national cancer database. This ascertained how many of our patients developed malignant tumours, and what the predicted background rate was. Then, with 30,000 patient-years of follow-up, no increased risk was identified. A criticism was the lack of long-term follow-up. We therefore revisited this study, with 10 years more data accrual and follow-up; but are aware that our practice and the resultant questions are changing.

Methods: The methodology was unchanged. UK patients were identified, and those with abnormal tumour suppressor genes (mainly type 2 neurofibromatosis) excluded. A vital status check corrected for loss of follow-up due to death. Patients were then stratified for sex, age and the year of follow-up data available. This generates, with national incidence rates, a background risk of developing different malignancies. This is compared with new reported malignancies in our treated patient cohort.

Results: Statistically, with 110,297 patient-years of follow-up, on an age, sex and time matched basis, we would have predicted 11.76 intracranial malignancies, and have identified 11. Eight of these were astro-glial, two were malignant transformations of vestibular schwannomas (VS) 9 and 10 years after the radiosurgery, and one malignant transformation of a meningioma. In interpreting this, the cohort includes 3012 VS patients, 4489 patients having more than 10 years follow-up, and 1132 more than 20 years.

Conclusions: This study supports the long-term safety of Gamma Knife radiosurgery. Overall there is no statistical increased risk of malignancy with a data set exceeding 100,000 patient years of follow-up. The two malignant VS transformations are of concern. The background risk of malignant nerve sheath tumours of the eighth cranial nerve without irradiation has been estimated at 1 in 1041 VS, so with 3012 VS patients treated, this may reflect the background rate rather than an increased risk related to radiosurgery. The more radiosurgery becomes the main primary treatment for VS, the more likely it is that any VS undergoing malignant transformation will have been irradiated.


OSP21 - RADIOBIOLOGY

#10252 : Impact of radiobiological models and their parameters on the individualized medical decision of proton vs photon radiotherapy

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Keywords: radiobiological models, medical decision, proton vs photon radiotherapy

Objectives: The use of appropriate radiobiological models to estimate the tumor control probability (TCP) and the normal tissue complication probability NTCP is an important step to rank and compare proton vs photon plans for cost effectiveness. The objectives of this study are to assess and quantify the uncertainties resulting from the choice of radiobiological models on the medical decision and to propose a new approach to estimate the real benefit from proton therapy.
Material and methods: clinical cases of cranio-spinal irradiations for pediatric patients were studied. The treatment plans were generated and calculated with photon and proton dose calculation algorithms to deliver the same prescription dose. The DVH metrics are the base of TCP/NTCP calculation. Two radiobiological models were used for TCP calculations: Poisson and equivalent uniform dose (EUD); and two NTCP models were used: Lyman-Kutcher-Burman (LKB) and EUD.

Results and discussion: proton and photon achieved close TCP values with both models. Regarding NTCP reduction, the choice of the NTCP model can deeply influence the medical decision since NTCP-LKB were higher than NTCP-EUD for most of the organs. Nevertheless, the proton plans offer NTCP reductions for most of the OARs. However, the magnitude of absolute NTCP reduction is sometimes very similar due to high TD50/5 values, initially proposed for grade > 2 and late toxicity from photon treatments. This gives the misleading impression that the proton does not show a real benefit in terms of NTCP reduction. Conversely, if comparing EUD values in Gy, it is obvious that proton offers the best and a significant dose reduction (EUD proton << EUD photon), especially for organs in thorax region as lung, heart, esophagus, with p < 0.05. Thus, our findings suggest, that Ramipril reduced the paralysis rate to 60 % at the high doses, and significantly delayed the onset of paralysis to 135±4 days post-radiation. Ramipril reduced the radiation rate to 60 % at the high doses, and significantly delayed the onset of paralysis to 135±4 days post-radiation. Ramipril reduced the paralysis rate and delayed the onset of paralysis. Ramipril reduced the radiation-induced neuroinflammation, and it may be a potential agent of mitigating radiation complication.

Conclusions: The considerable impact of radiobiological model on the radiotherapy outcomes urges to renew the reference toxicities to tune NTCP parameters’ The use of the recommended mean doses as TD50/5 in NTCP model could be a realistic approach to estimate low grade NTCP. In addition, EUD values translate the DVH data is a robust indicator be better estimate the dosimetric benefit. Moreover, further improvements of DVH, including secondary electrons, RBE variation and secondary neutrons are necessary.

Keywords: spine radio surgery, neuroinflammation, Ramipril

Spinal Cord is the most critical organ in spine radiosurgery. Once the spinal cord has been damaged, it can cause a serious neurological consequence leading to sensory and motor deficit and paralysis. Various mechanisms of radiation tissue reaction have been proposed, but with no therapeutic targets for mitigation of complication. To find a putative target of radiation-induced spinal cord damage, we explored neuroinflammation at the site of radiation to the spinal cord. Fisher 344 rats were irradiated to the spinal cord C4-T2 with a single radiosurgical doses of 23-33 Gy. The rats were randomized to sham treatment and Ramipril, ACE inhibitor, 1.5mg/kg/day until paralysis occurred. The spinal cord was then harvested and tested for neuroinflammation with immunohistochemical studies. There was a sharp curve causing no paralysis at 23 Gy to 100% paralysis above 28 Gy radiation at 125±4 days post-radiation. Ramipril reduced the paralysis rate to 60 % at the high doses, and significantly delayed the onset of paralysis to 135±4 days (p<0.05). The number of microglia (by anti-iba1 stain) on 40X filed by confocal microscopy was 2.5 ± 0.57 in control, 6.9 ± 0.89 in radiation group, and 4.12 ± 1.20 in radiation plus Ramipril-treated group. This was statistically significant (p<0.05) particularly in dorsal funiculus area. VEGF expression were increased in the sham-treated spinal cord, in contrast to the Ramipril-treated group. The finding indicates that Ramipril decreased the paralysis rate and delayed the onset of paralysis. Ramipril reduced the radiation-induced neuroinflammation, and it may be a potential agent of mitigating radiation complication.

OSP21 - RADIOBIOLOGY

#10174 : Radiosurgery-Induced Neuroinflammation of the Spinal Cord and Mitigation by Ramipril

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Keywords: spine radio surgery, neuroinflammation, Ramipril

OSP22 - BODY 1

#10007 : Early stage non-small cell lung cancer in the United States: Patterns of care and survival among elderly patients

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Keywords: lung cancer, NCDB, SBRT, SABR, lobectomy, radiation, NSCLC

Objective: To analyze the patterns of care of local therapies and their impact on overall survival (OS)
Abstracts

Methods: The National Cancer Database was queried for patients at least age 80 years with NSCLC diagnosed between 2004-2013 with clinical stage T1-3N0M0. Local therapy was analyzed over time and by age. Univariable and multivariable (MVA) models were performed to investigate the impact of prognostic factors on OS.

Results: Among 40,561 patients meeting inclusion criteria, 17,418 (43%), 13,008 (32%), and 10,135 (25%) of patients underwent surgical resection, radiotherapy, and observation, respectively, as their initial mode of local therapy. Overtime, while the utilization of surgical management generally remained stable, the utilization of conventionally fractionated radiotherapy and observation decreased in favor of stereotactic body radiotherapy (SBRT, p < 0.001). Among operable patients (n = 16,377), after MVA several factors were associated with OS including the choice of local therapy favoring resection over conventionally fractionated radiotherapy and observation (HR compared to lobectomy 1.362, and 2.656, respectively, each p < 0.001). In contrast, there was no statistical difference in OS between resection and SBRT among operable patients (HR for SBRT 1.128, p = 0.156).

Conclusions: The utilization of SBRT as the definitive local therapy in elderly patients with early-stage NSCLC is increasing in the U.S. Given its generally favorable toxicity profile, SBRT should be considered in the substantial proportion of elderly patients still not receiving any definitive local therapy. Among medically operable elderly patients, OS was similar between resection and SBRT.

#10005 : CyberKnife treatment of intraorbital metastases: A single center experience on 24 lesions

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Keywords: Cyberknife, stereotactic, radiosurgery, intraorbital metastases

Purpose: The aim of the study is to evaluate the feasibility, acute toxicity and symptoms control of CyberKnife (Accuray, Sunnyvale, CA)-based stereotactic radiotherapy (CBK-SRT) on intraorbital metastases.

Materials and Methods: This retrospective analysis included patients (pts) with symptomatic metastases located wholly within the orbit. Palliative radiation treatment was performed using CyberKnife image-guided technology (using skull-tracking technique). Gross tumor volume (GTV) volume was defined on a pre-radiotherapy magnetic resonance imaging (MRI) with Gadolinium. Treated volumes and dose-volume histograms (DVHs) are discussed. Acute toxicity was recorded according to Radiation Therapy Oncology Group/European Organization for Research and Treatment of Cancer (RTOG/EORTC) Scale.

Results: Between April 2012 and July 2016, 24 metastases (21 pts, 3 treated bilaterally) underwent CBK-SRT for intraorbital lesions (10 intraocular, 14 periocular) from different primary tumors (breast in 13 pts, lung in 3 pts, kidney in 2 pts, lymphoma in 1 pt, thyroid in 1 pt, trunk leiomyosarcoma in 1 pts). Patients were treated in 2 to 3 fractions (median 3 fractions), individual sessions of CBK-SRT were separated by 24 hours. Treatment dose was prescribed to a median isodose line of 75% (range 73 - 80%) normalized to an median maximum dose of 24 Gy (range 18.75 - 32 Gy). Median volume of GTV was 1.50 cubic centimetre (range 0.14-17.5), median maximal dose to ipsilateral optic nerve was 16.95 Gy (range 1.55-24.00), median mean dose to optic chiasm was 2.1 Gy (range 0.50-18.00), median mean dose to ipsilateral lens 1.35 Gy (range 0.30-9.00). At the end of the treatment, grade 1 toxicity according to RTOG/EORTC score was observed in 8 cases. No change in visual field or loss of vision was documented. 14 lesions of 24 had undergone post-radiotherapy MRI and after median follow-up of 5.5 months (range 2.0-26.5) no local progression occurred: 6 complete response, 6 partial remission and 2 stabilization of disease were observed. All of these patients reported decreasing pre-radiotherapy symptoms and improvement in quality of life. Longer follow-up (more than 12 months) is available in 4 lesions with complete radiological response in all cases.

Conclusions: In our experience, CyberKnife radiotherapy is a well-tolerated, safe and efficacious technique for palliative treatment of intraocular and periocular metastases.
OSP22 - BODY 1

#10216: Exploring the margin recipe for online adaptive radiation therapy for prostate SBRT: An intra-fractional seminal vesicles motion analysis

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Keywords: prostate, SBRT, motion, adaptive therapy

Purpose: To provide a benchmark for seminal vesicle (SV) margin selection to account for intra-fractional motion, and to investigate the effectiveness of two motion surrogates in predicting intra-fractional SV volumetric coverage.

Methods and Materials: 15 prostate Stereotactic Body Radiation Therapy (SBRT) patients were studied. Each patient has five pairs (one patient has four pairs) of pre-treatment and post-treatment cone-beam CTs (CBCTs). Each pair of CBCTs was registered based on fiducial markers in the prostate. All pre-treatment SV volumes were expanded with isotropic margins of 1, 2, 3, 4, 5 and 8 mm to form a series of PTVs, and their corresponding intra-fractional coverage to the post-treatment SV was used to calculate the “ground truth” for exact coverage with different margin recipes. Two commonly used motion surrogates, the center-of-mass (COM) and the border of contour, were evaluated using Pearson product-moment correlation coefficient and exponential fitting for predicting SV underdosage. Action threshold of each surrogate was calculated. For reference, the margin for each surrogate was also calculated based on a traditional margin recipe.

Results: 95% post-treatment SV coverage can be achieved in 9%, 53%, 73%, 86%, 95% and 97% fractions with 1, 2, 3, 4, 5 and 8 mm margin size, respectively. 5 mm margins provided 95% intra-fractional SV coverage in over 90% of the fractions.

The correlation between the COM and border was weak, moderate and strong in the left-right (LR), anterior-posterior (AP) and superior-inferior (SI) directions, respectively. Exponential fitting gave the underdosage threshold of 4.5 and 7.0 mm for the COM and border. The Van Herk’s margin recipe recommended 0, 0.5 and 0.8 mm margins in the LR, AP and SI directions based on the COM. For the border, the corresponding margin was 1.2, 3.9 and 2.5 mm.

Conclusions: 5 mm isotropic margins for the SV is the minimum required to mitigate the intra-fractional SV motion relative to the prostate. Both the COM and border are acceptable predictors for SV underdosage with 4.5 and 7.0 mm action threshold. Traditional margin calculation based on the COM or border underestimates the margin and should be avoided for this application.

OSP22 - BODY 1

#10341: Stereotactic body radiation therapy in the management of unresectable locally advanced pancreatic adenocarcinoma: Outcome and toxicity from a phase 2 study

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Keywords: sbrt, pancreas, unresectable

Purpose: Aim of the present study is assess efficacy and toxicity of Stereotactic Body Radiotherapy (SBRT) in patients affected by unresectable locally advanced pancreatic cancer.

Materials and Methods: All patients received a prescription dose of 45 Gy in 6 consecutive fractions. Delivery was performed with VMAT and flattening filter free beams (FFFs). Primary end point of the study was freedom from local progression (FFLP) while secondary end points were overall survival (OS), progression-free survival (PFS), and toxicity. Actuarial survival analysis and univariate or multivariate analysis were investigated. Toxicity was recorded according to the common toxicity criteria version 4.0.
Results: Forty-five patients were enrolled in a phase 2 trial with a median follow-up of 13.5 months. Two-year FFLP was 90% and both on univariate (P < .03) and multivariate analyses (P < .001), lesion size was statistically significant. Median PFS and OS were 8 and 13 months, respectively. On multivariate analysis, tumor size (P < .001) and FFLP (P < .002) were significantly correlated with OS. Chemotherapy before SBRT were administered in thirty-two (71%) patients with locally advanced pancreatic cancer. Median OS from diagnosis was 19 months. Tumor diameter (P < .002), FFLP (P < .035), and computed tomography SBRT (P < .001) were significantly correlated with OS from diagnosis, at multivariate analysis. No grade 3 or greater toxicity was observed.

Conclusion: Stereotactic body radiotherapy is a safe approach for patients with locally advanced pancreatic cancer and it fits efficiently in a multimodal approach.

OSP22 - BODY 1

#9871 : CyberKnife based stereotactic ablative radiotherapy (SABR) of prostate cancer patients – Preliminary results of 400 patient irradiation

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Keywords: SABR, SBRT, radioablation, prostate radiosurgery

Objectives: To evaluate the tolerance and effectiveness of SABR applied in the treatment of Low and Intermediate Risk (LR&IR) Prostate Cancer Patients (PCP).

To provide an evaluation of the level of risk group impact on the treatment results.

To assess Androgen Deprivation Therapy (ADT) usage on PSA decline after SABR.

Material and Methods: 400 PCP (213 LR and 187 IR, including T2c) irradiated with CyberKnife using the fd 7.25 Gy to the TD 36.25 Gy. At the start of treatment, 60.3% of patients used ADT and this percentage gradually decreased to 0% after 38 months. Follow-up median 15.0 months. Patients were monitored on SABR completion and subsequently 1, 4, 8 months later and then every 6 months. GI and GU acute and late adverse effects, PSA and ADT usage were evaluated.

Results: 9 patients (2.25%) failed (5 in LR and 4 in IR group) - 4 relapses and 4 nodal metastases. No G3/4 late adverse effects (EORTC/RTOG) were observed. 0.5% G3 GU and 0.3% G3 GI acute reactions, on SABR completion day and one month later, were noted respectively. The median of PSA declined 1.5 ng/ml during the first month and 0.6 ng/ml during the next three months. No impact of risk groups on treatment results was found. The only impact on ADT on PSA decline was confirmed for ADT&time points interaction.

Conclusions: SABR of LR and IR PCP is safe and effective treatment.

The inclusion of T2c patients and the low percentage of IR patient failure permit us to form the assumption that this procedure could be utilized in the treatment of more advanced cases.

The results do not let us define clearly the impact of ADT on radioablation results of LR and IR+T2c prostate cancer patients.

OSP22 - BODY 1

#9875 : Improvement of conformal arc plans by using deformable margin delineation technique for stereotactic lung radiotherapy

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Keywords: 3DCA, VMAT, Margin Delineation, SBRT, Lung

Purpose: Stereotactic body radiotherapy (SBRT) is an established technique in early stage lung cancer. Both volumetric modulated arc (VMAT) and conformal arc (3DCA) techniques can be used as a treatment method. Previously, we have shown that VMAT is superior to 3DCA technique in terms of plan evaluation parameters. In this study, we aimed to analyze whether deformable margin delineation technique (DMD)
improves the quality of the 3DCA technique and to compare it with VMAT plans.

Methods: Twenty stage I non-small cell lung cancer patients were included. VMAT and 3DCA non-coplanar plans were generated with 6MV FFF photons to conform planning target volume (PTV) according to RTOG 0915. As conventionally 3DCA plans have inferior target coverage compared to VMAT plans, we deformed PTV contour in order to get a better isodose coverage using DMD technique. Briefly, DMD technique is adaptation of isodose levels to the PTV by deforming margins. All techniques were compared in terms of dosimetric parameters; Ratio of prescription isodose volume (IV) to PTV (conformity index - CI), ratio of 50% prescription IV to PTV (Intermediate dose spillage volume - IDSV), maximum dose in % of dose prescribed at 2 cm from PTV (Intermediate dose spillage location - IDSL), and percentage of lung receiving 20 Gy (V20) respectively.

Results: All plans were acceptable and no deviation was observed according to RTOG criteria’s. CI ranged between 1.00–1.17 (Mean: 1.02); 1.04–1.25 (Mean: 1.06); 1.04–1.39 (Mean 1.15) for 3DCA-DMD-FFF, VMAT-FFF and 3DCA-FFF, respectively. 3DCA-DMD have significantly better CI compared to others (p<0.001, p<0.001). IDSV values ranged between 3.22–4.74 (Mean: 4.00); 3.24–5.92 (Mean: 4.15); 3.27–5.30 (Median: 4.17) for 3DCA-DMD, VMAT-FFF and 3DCA-FFF, respectively. 3DCA-DMD have significantly lower IDSV which indicates superior falloff gradient (p<0.013, p<0.001). IDSL values ranged between 35.7%–67.0% (Mean: 53.2%); 42.1%–79.2% (Mean: 57.8%); 38.8%–75.8% (Median: 57.4%) for 3DCA-DMD, VMAT-FFF and 3DCA-FFF, respectively. 3DCA-DMD have significantly lower IDSL values which shows a better falloff gradient 2 cm away from PTV (p=0.011, p<0.001). V20 for lung ranged between 8.6%–11.9% (Mean: %4.19); 8.0%–14.51% (Mean: 4.31%); %0.80-%10.88 (Mean: %4.06) for 3DCA-DMD, VMAT-FFF and 3DCA-FFF, respectively. No difference was found between 3 techniques for V20 (p=0.881, p=0.079).

Conclusion: Our results have shown that 3DCA plans can be ameliorated by using DMD method and can be even better than VMAT in terms of CI, IDSV and IDSL. We believe that 3DCA-DMD is a novel, simple and effective technique for a better SBRT plan.
### Results:
131 eligible patients were identified with a total of 226 different SRS treatments, some patients being treated several times for different metastases. Symptomatic radionecrosis developed in 21 patients (9.29% of the 226 irradiated targets, 16.03% of the whole population surviving more than 6 months).

Multivariate logistic regression analysis identified V12 as the only risk factor ($P = 0.004$) and history of previous whole-brain irradiation as a protective factor ($P = 0.026$). These were the only independent variables that correlated significantly with the occurrence of symptomatic radionecrosis. None of the other tested factors did.

We used logistic regression to design a risk prediction model for symptomatic radionecrosis, integrating V12 and WBRT history. This formula estimates the probability of occurrence:

$$\text{Probability} = \frac{e^{\beta}}{1+e^{\beta}}$$

with $\beta = -2.50 + 0.66(V12) - 1.2(WBRT)$.

### Conclusion:
Symptomatic radionecrosis from brain metastases radiosurgery can be individually predicted by a statistical model according to the 12 Gy treatment volume. The apparent protective effect of previous whole-brain irradiation is a surprise and should be further investigated.

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### OSP23 - ESTRO: METASTASES 4

#### #9601 : Evaluation of dynamic changes large metastases in deep brain structures after hypofractionation stereotactic radiotherapy

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**Keywords:** metastases, MRI, hypofractionation stereotactic radiation therapy

**Purpose:** To assess by MRI the dynamic changes of deep brain large metastases after hypofractionation stereotactic radiation therapy.

**Methods and Materials:** In retrospective analysis, 146 patients (mean age 55 y.o.) with 215 brain metastases, treated by hypofractioning radiotherapy were included (dose 8-10 Gy, mean metastasis volume 1.5 cm$^3$). 1.5 and 3.0T scanners were used with T13D sequences 1mm before and after contrast enhancing, T2 WI tra 2mm, flair tra 1-3mm, T2 WI cor 2mm, DWI. In 21 patients SWI was added. In 30 patients CT or MRI PWI and PET with 11C methionine were added. Tumour volume control was performed by GammaPlan 10.1 station. Patients were assessed before treatment, after 1 month, then, every 3 months.

**Results:** We have detected 6 radiologic patterns: tumour dimensions changes (68%), structural necrosis (28%), metastasis contrasting decreasing (64%), contour changes (83%), perifocal swelling area reduction (97%), intratumour haemorrhage (14%). The most variable were dimensions and volume changes: volume reduction or stabilisation, volume increasing by necrosis or disease progression, volume increasing on 1st control, then decreasing on 2nd control (necrosis), then increasing by haemorrhage. According PET with 11C methionine and PWI continued tumor growth was detected in 4% of cases.

**Conclusion:** Brain metastases reaction after radiotherapy characterised by heterogeneity. Imaging results (volume and contour changes, haemorrhage) are non-specific and may be signs of local disease progression or postradiation reactions. To process these data in the future and to avoid misinterpretation of the results when pseudo-progression and to determine the optimal dose/volume/fractionation need well-designed prospective, multicenter clinical trials with strict inclusion criteria of patients in the study with a standardized MRI Protocol, timely re-examination as MRI and PET and PWI.

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### OSP23 - ESTRO: METASTASES 4

#### #9999 : Freedom progression, risk of adverse radiation effect, and prognostic variables for repeat SRS for brain metastases

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**Keywords:** Brain metastases, Radiosurgery, Reirradiation, Toxicity

**Objectives:** To evaluate freedom from progression (FFP) and risk of adverse radiation effect (ARE) among brain metastases re-treated with stereotactic radiosurgery (SRS) after prior SRS.
Method: Brain metastases retreated with SRS were identified within a cohort of 4365 brain metastases with available follow-up imaging treated with single-fraction Gamma Knife SRS at our institution from September 1998-December 2013. FFP and ARE were measured from the date of repeat SRS with censoring at last follow-up imaging.

Results: A total of 136 brain metastases in 74 patients had repeat SRS at a median of 13.3 months (interquartile range, 7.1-22.4 mo) after prior SRS with or without history of prior whole brain radiotherapy. The most common primary sites were breast (50), lung (25), and melanoma (42). The median imaging follow-up after repeat SRS was 16.3 months among these lesions with at least one follow-up scan. The median quadratic mean diameter (QMD) was 1.4 cm (range, 0.3-4.4 cm; interquartile range, 0.9-1.9 cm) and median target volume 1.1 ml (range, 0.03-26.9 ml; interquartile range, 0.3-2.9 ml). The median dose was 18.0 Gy (range, 12.0-20.0 Gy; interquartile range, 17.5-18.5 Gy). Overall, the 1-year FFP probability was 81% (95% confidence interval, 72-87%). The 1-year probability of ARE by imaging was 31% (24-43%) with a 13% (8-22%) 1-year probability of symptomatic ARE. The 1-year FFP probabilities were 91% (76-97%), 83% (69-91%), and 58% (36-74%) for QMD ≤1 cm, 1.01-2 cm, and >2 cm, respectively, with corresponding 1-year ARE probabilities of 0%, 18% (9-34%), and 23% (10-48%). On Cox proportional hazards multivariate analysis, both longer interval from prior SRS to repeat SRS by quartile and smaller QMD (≤1 cm vs. 1.01-2 cm vs. >2 cm) were significantly associated with higher FFP probability (p = 0.003 with HR 0.616 and p < 0.001 with HR = 2.71, respectively). Only QMD was significantly associated with risk of symptomatic ARE (p = 0.008).

Conclusion: Repeat SRS for brain metastases with QMD ≤2 cm yielded good local control with acceptable risk of symptomatic ARE. Longer interval from prior SRS was associated with higher control probability.

#9755 : Results of radical local treatment of oligometastatic stage IV disease of non-small cell lung cancer patients with synchronous oligo-metastases.

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Keywords: NSCLC, Oligometastases, SBRT, radiotherapy, ARE.

Background: Patients with stage IV non-small cell lung cancer (NSCLC) are considered incurable and mainly treated palliatively. In contrast, a radical treatment approach is increasingly recommended in patients with oligometastatic stage IV disease. The purpose of this study was to investigate progression free survival (PFS) and overall survival (OS) of NSCLC patients diagnosed with synchronous oligometastatic disease who underwent radical treatment.

Methods: Patients with NSCLC and oligometastatic disease at diagnosis, who were treated with radical intent between 2008 and 2016, were included. Treatment consisted of systemic treatment and radical/stereotactic radiotherapy or resection of the intrathoracic disease. Treatment of the metastases consisted of radical/stereotactic radiotherapy, surgical resection or radiofrequency ablation (RFA).

Results: Ninety-one patients (52% men, mean age 60 years), were included with a median follow-up of 35 months. Almost all patients (98%) were in good condition (WHO=0-1). The intrathoracic tumor stage, ignoring M-status, was: IA (11%), IB (3%), IIA (12%), IIB (11%), IIIA (36%) and IIIB (28%). Seventy-seven patients (85%) presented with a solitary metastasis, mostly occurring in the brain (32%), bone (25%) or adrenal gland (14%). Fourteen patients presented with 2 or more metastases (9 patients (10%) with 2 metastases, 2 patients (2%) with 3 metastases and 3 patients (3%) with 4 metastases, respectively).

Eighty-one patients (89%) were treated with radiotherapy for the primary tumor of whom 75 patients (93%) received either concurrent (N=9 (12%)) or sequential (N=66 (88%)) systemic therapy. Eight patients (9%) underwent surgery for the primary tumor; 2 patients (2%) received only systemic treatment.

The metastases were treated with ablative/stereotactic radiotherapy (72 (79%)), surgical intervention (5 (6%)), only systemic treatment (6 (6%)), a combination of surgical intervention and radiotherapy (6(6%)), gamma knife (2(2%)) and RFA (1(1%))

Thirty-eight patients (42%) died during follow-up. The cause of death was lung cancer in all patients, except one. Sixty-three (69%) patients developed recurrent disease. Eleven recurrences (17%) occurred within the irradiated area. Most recurrences where brain (16(25%)) and pulmonary metastases (13(21%)).

For the whole group, the median PFS was 14 months (range 2-89, 95% CI 12-16) and the median OS was 32 months (range 3-89, 95% CI 25-39). The 1- and 2-year
OS rates were 85% and 58% and the 1- and 2-year PFS rates were 55% and 27%, respectively.

**Conclusion:** Radical local treatment of a selected group of NSCLC patients in good condition presenting with synchronous oligometastatic stage IV disease resulted in favorable long-term PFS and OS.

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**OSP23 - ESTRO: METASTASES 4**

#9845 : Salvage whole brain radiotherapy after stereotactic radiosurgery for brain metastases: a prospective study (JLGK0901)

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**Keywords:** brain metastases, stereotactic radiosurgery, whole brain radiotherapy

**Purpose:** Little is known about the results of post-stereotactic radiosurgery (SRS) salvage whole brain radiotherapy (WBRT) in brain metastasis (BM) patients.

**Methods:** Using our prospectively accumulated database including 1194 consecutive patients undergoing SRS alone for initially-diagnosed BMs during the 2009-2012 period (JLGK0901 Study, Lancet Oncol 2014;15: 387-95, UMIN ID; 000001812), we studied the 127 patients (10.6%, 55 females, 72 males, mean age; 62 [range; 36-83] years) who underwent salvage WBRT. Competing risk analysis was applied, as appropriate.

**Results:** Cumulative incidences of WBRT were 6.3%, 8.8%, 10.2%, 10.8% and 11.0% at the 12th, 24th, 36th, 48th and 60th post-SRS month. Patient age <65 years, SCLC and 2-4 tumors correlated significantly with WBRT. Post-WBRT MST was 4.2 (95% CI; 3.0-5.0, IQR; 2.1-9.5) months. Actuarial survival rates were 34.0%, 17.3%, 6.9%, 2.6%, 1.3% and 1.3% at the 6th, 24th, 36th, 48th, 60th and 72nd post-WBRT month. The crude incidence of neurological death was 31% (37 patients) and actuarial neurological death rates were 19.8%, 26.5%, 27.4%, 30.0%, 30.0% and 30.0% at the 6th, 24th, 36th, 48th, 60th and 72nd post-WBRT month. MRI-confirmed leuko-encephalopathy occurred in 11 patients (9%) and WBRT was a significant factor impacting a higher incidence of leuko-encephalopathy (HR; 0.008, 95% CI; 0.001-0.081, p<0.0001). SRS-related complications occurred in 25 patients (18%). Age >65 years, neurological symptoms and WBRT (HR; 0.560, 95% CI; 0.365-0.861, p=0.0081) correlated significantly with higher complication rates.

**Conclusions:** To our knowledge, this is the first prospective study demonstrating the results of post-SRS salvage WBRT in BM patients.

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**OSP23 - ESTRO: METASTASES 4**

#9794 : Treatment plan quality comparison of normal tissue objective vs. customised stereotactic radiosurgery normal tissue objective for multiple target radiosurgery

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**Keywords:** radiosurgery, stereotactic, multiple metastases, treatment planning, radiotherapy, normal tissue objective

**Purpose or Objective:** To evaluate the effects of Normal Tissue Objective (NTO) and Stereotactic Radiosurgery Normal Tissue Objective (SRSNTO) in radiotherapy treatment planning to reduce dose to normal brain and surrounding OARS whilst maintaining PTV coverage.

**Materials and methods:** Twenty patients, previously treated, for multiple cranial metastases in a single fraction were retrospectively planned using the Eclipse Treatment Planning System [Varian Medical Systems, Palo Alto, CA, USA]. In each case, NTO and SRSNTO were compared as means of controlling dose fall off from the PTV. The cohort of patients included one 4 lesion case, three 3 lesions cases and sixteen 2 lesions cases. PTV volumes varied from 0.5cc to 15.4cc. Plans included 5 non-coplanar arcs with a single isocentre placed at the centre of mass of the total target volume. All plans were normalized such that 99% of the target volume received 80% of the prescribed dose. Plan quality was evaluated by; volume of brain receiving 4Gy, volume of brain receiving 12Gy, mean dose to brain, dose to OARS and PTV coverage.
Results: PTV coverage was comparable amongst the techniques. D2% to PTV increased by 1% when planning with SRSNTO compared to NTO. SRSNTO with no upper objectives results in increased D2% by 13% compared to with standard objectives.

V12Gy to brain was not significantly different (p = 0.1) between NTO and SRSNTO but was significantly reduced (p = 0.01) with SRSNTO with no upper objectives. Mean dose to brain was significantly reduced when optimized with SRSNTO (p = 0.01). Plans optimized with SRSNTO and no upper objectives saw a further decrease in mean dose to brain (p=0.01).

V4Gy to brain was reduced by an average of 38cc (range 5cc-259cc) representing an average 28.7% reduction when planning with SRSNTO compared to NTO (p = 0.01). SRSNTO with no upper objectives resulted in a further significant decrease of V4Gy to brain (p=0.01).

OAR doses were not significantly changed when planning with NTO or SRSNTO and were all clinically acceptable.

Conclusion: Multiple target radiosurgery planning with SRSNTO can result in significantly decreased V4Gy and mean dose to normal brain with no reduction in PTV coverage. SRSNTO optimised with no upper objectives and no OAR constraints offers an uncomplicated planning solution to reduce brain dose further with little optimizer interaction.

OSP24 - VASCULAR 2

#9974 : Gamma Knife Radiosurgery for Arteriovenous malformations in pediatric and adolescent patients.

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Keywords: Gamma Knife, AVM, Pediatric.

Object: To determine the efficacy and safety of gamma knife radiosurgery for arteriovenous malformations of paediatric and adolescent patients.

Methods: Between May 2008 and August 2016 more than 2300 patients were treated using 201 source cobalt 60 Leksell gamma Knife 4c at Pakistan gamma Knife center Karachi. It included 372 patients with AVMs. There were 93 pts which were 18 yrs or younger. Seventy one patients (72.4%) had hemorrhage at the time of presentation. Fifteen patients had multiple hemorrhages (15.3%).Mean target volume was 3.7cc (range 0.32-31.8cc).Mean prescription margin dose used was 18.9 Gy (range 14-22 Gy).

Results: Out of 93 patients, radiological follow up for more than 03 years was available for 52 patients. Complete Obliteration on angiography/MRI images was found in 32 patients (61.5 %). Partial or ongoing obliteration is described in 20 patients. No acute morbidity is noted within 48 hours of treatment. Two patient (post embolisation) with partial obliteration with evidence of rebleed was retreated at 02 years. The incidence of hemorrhage at 03 years after gamma knife was 4%. Post gamma knife odema was noted around the obliterating AVM in 5% cases without new neurological deficits. One patient with SM grade IV in Rt. thalamic region had increase in left hemiparesis. One patient with left occipital AVM developed visual field defects.

Conclusions: Gamma Knife Radiosurgery for paediatric AVMs offers a safe and effective treatment option, with low permanent complication rates during early follow up.

OSP24 - VASCULAR 2

#10328 : Stereotactic radiosurgery for hemorrhagic brainstem cavernomas: what to expect?

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Keywords: cavernoma, brainstem, radiosurgery, Gamma Knife

Objectives: Stereotactic radiosurgery represents a consistent therapeutic option in the management of hemorrhagic brainstem cavernomas (BCs). Its long-term efficacy and related morbidity need to be precised.

Methods: We included 28 patients with hemorrhagic brainstem cavernomas treated by Gamma Knife radiosurgery (GKRS) in our University Hospital between 2007 and 2014. We retrospectively analyzed clinical data and imaging follow-up in order to assess the annual haemorrhage rate and patient functional outcomes.

Results: The mean age at treatment was 40.6 years. Mean follow-up was 3.32 years (range 1-6). Patients harbored a mean of 2.1 bleeds before GKRS. The BCs’ location was: 7 in the medulla oblongata, 17 in the pons, and 4 in the midbrain. Median target volume was 137 mm³.
(IQR, 89-327 mm³). Median dose was 15 Gy at the 50% isodose. No morbidity related to treatment was reported. Two patients rebleeded after GKRS. The overall annual haemorrhage rate (AHR) before GKRS was 34.9% (30 hemorrhagic events reported during a cumulated time of “diagnosis to treatment” of 86 years). After GKRS the AHR was 2.3% (p<0.001). 92% of patients had a modified Rankin Scale ≤2.

Conclusions: GKRS is an effective treatment for hemorrhagic brainstem cavernomas to significantly reduce the AHR, with no related morbidity.

OSP24 - VASCULAR 2

#9960 : Enlargement and progression of pediatric cerebral arteriovenous malformations after Gamma Knife radiosurgery: a report of 5 cases and discussion of treatment strategies

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Keywords: cerebral arteriovenous malformation; progression; pediatrics; GammaKnife; stereotactic radiosurgery

Introduction: It is believed that arteriovenous malformations (AVMs) are dynamic lesions with ongoing morphological and hemodynamic changes. Enlargement and progression of pediatric cerebral AVMs following Gamma Knife Radiosurgery (GKRS) is a rare phenomenon. Herein, we report 5 cases of pediatric AVMs who presented progression of AVM nidus years after GKRS and discuss their treatment strategies.

Methods: We performed a retrospective review of 5 pediatric patients treated with GKRS for cerebral AVMs at our institution from January 2004 up to and including September 2015. Patient demographics, AVM characteristics, GKRS parameters and AVM responses were recorded.

Results: All 5 patients were treated with GKRS at least twice and followed up both clinically and radiologically. The median age was 7 years (range 5-11 years), with 3 being boys (60%). The median AVM volume were 3.8 cm³. The median Spetzler-Martin (SM) and Pollock grades of the treated AVMs were 2 and 0.86 respectively. The median follow-up was 63 months (range 42-122 months) after first GKRS. The parameters for median and range in first GKRS planning were prescription isodose 55% (50%-59%), prescription dose 16 Gy (15-18 Gy), maximal dose 29.1 Gy (25.4-36.0 Gy), and number of shots 7 (4-14). Dynamic enlargement and progression of AVMs were confirmed based on angiography in 4 patients and magnetic resonance imaging (MRI) in one patient during a median latency period of 5 years (range 3-9 years). 3 of 5 (60.0%) AVMs treated demonstrated a response on follow-up MRI and displayed obliteration based on angiography. But recurrent nidi occurred adjacent to the obliterated nidus 3-8 years (median 5 years) after GKRS. Enlargements of AVM nidus were seen in the other 2 patients 5 and 9 years after GKRS respectively. After progression 4 patients were treated with second GKRS and the other one received a combined treatment of embolization and GKRS. No patient developed post-GKRS edema or other major complications.

Conclusions: The findings from this study suggest that GKRS is a safe and effective treatment for pediatric AVMs, yielding an acceptable obliteration rate with minimal permanent severe morbidity and no mortality. Sporadic case reports of AVM nidus progression after GKRS in children with a long latency warrant further investigation and call for continuous follow-up of the pediatric AVM patients even after radiographic confirmation of nidus obliteration.

OSP24 - VASCULAR 2

#10374 : Cyberknife radiosurgery of unruptured avms: The experience of 220 cases.

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Since January 2003 until December 2016, in our Institution 500 patients harbouring AVMs have been irradiated with Cyberknife; 220 patients had unruptured AVMs.

Material and methods: 105 patients were females and 115 males; the age ranged from 12 to 81 years (mean 39 yrs; median 38); The nidi were localized in the temporal lobe in 52 cases, 48 in parietal lobe, 38 in occipital, 23 in frontal lobe, 16 in the basal ganglia; 15 in the cerebellum. The assessment of the volume was made on MRI and AGF images. Range of lesion volume was 1-23 ml (mean 2.3 ml, median 1.6 ml). Deep venous drainage was identified in 31 cases and in 35 cases the drainage was both superficial and deep; 116 pts presented Spetzler-Martin grade III, 66 pts grade II,
27 grade IV and 8 grade V; only 3 patients presented grade I. Pollock-Flickinger score range was 0.23-4.63 (mean: 1.35).

Clinical aspect was characterized by epilepsy in 70 patients (32%), headache in 26 patients (12%) visus deficits, paresthesia etc... in 22 patients (10%). For 42 patients the AVMswas an accidental finding. Before treatment all patients were investigated with 3D cerebral angiography and then image-fusion technique with CT images was performed. After treatment MRI was scheduled every 6 months and three years after radiosurgery angiography was performed in 152 patients. 47 patients undergone only MRI and 1 patient performed only CT scan.

The peripheral dose ranged from 10.5 Gy to 22.5 Gy (mean: 18.9 Gy); the maximum dose from 15 Gy to 30 Gy (mean 25.25 Gy). The follow up range was 6-152 months (mean 51 months).

Results: The nidus was no longer recognizable in 84/200 (42%) patients with FU of at least 36 months. In 91/200 (45.5%) the nidus was reduced and in 25 nidus was unchanged; 20 patients are lost at FU. After the first treatment we observed 12 cerebral bleeding and three of them were fatal. 51 patients undergone second radiosurgery: among them we observed 9 cases of cerebral bleeding and no death. Only one bleeding was noted among 12 cases that required a third radiosurgery.

In 97 patients the symptoms present before treatment disappeared during the follow up and in 20 of them the clinical aspect improved.

Conclusion: Preliminary data of our study seem to indicate Cyberknife radiosurgery is helpful in the control of AVMs without previous bleeding.

Keywords: arteriovenous malformations; radiosurgery; dose-staged; stereotactic radiosurgery

Objective: To describe our experience in treating large brain arteriovenous malformations (AVMs) with dose-staged (DS) stereotactic radiosurgery (SRS).

Methods: We treated 28 patients with large AVMs from September 2008 to January 2014 with a minimum follow up of three years, median 61 months. Patients mean age was 26 years, with no difference in number of patients for each gender, 14 males and 14 females. Seven were classified with Spetzler-Martin grade V, 13 with Spetzler-Martin grade IV and 7 with Spetzler-Martin modified by Oliveira as grade 3A. All patients were treated with 5 fractions from Monday through Friday. Five patients received the dose of 650 cGy a day, 16 received 600 cGy a day, 5 patients received 550 cGy a day and 2 patients received 500 cGy a day.

Results: The mean obliteration rates for DS-SRS was 21.43%. One patient had a post-SRS hemorrhage and died. We could not observe any alterations in angiographies of three patients. The initial treatment fractions were 5 x 650 cGy, but due to motor complications we considered to decrease to 600 cGy each fraction. Even with lower doses, it was observed alterations in magnetic resonance image (MRI) as hyper signal in T2 and some transient motor deficits but excepting our major bleeding complication, all patients recovered to their pre-treatment functional status.

Coclusions: Large brain AVMs are a challenge to any method of treatment and considering SRS it is needed a long term follow up, but in our small experience DS-SRS seems to be a reasonable treatment approach.

OSP24 - VASCULAR 2

#10053 : Multisession Cyberknife radiosurgery for cerebral arteriovenous malformations: outlining of the radiosurgical target and obliteration

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Keywords: Cerebral arteriovenous malformation, Radiosurgery, Cyberknife, Gamma knife, Embolization
Objective: We analyzed the outcomes of 65 patients with intracranial AVM treated by multi-session cyberknife radiosurgery (CKR) and compared the rate of obliteration with outlining the content of the AVM nidus.

Methods: Between January 2008 and February 2011, sixty-five patients underwent multi-session CKR for cerebral AVMs. Among 65 patients, 20 had prior embolization, 4 patients underwent embolization combined with gamma knife, 2 had prior gamma knife. Thirty-nine patients underwent cyberknife as their initial treatment. Delineation of the AVM targets were as follows: AVM with prior embolization, the radiosurgical targets include AVM nidus and embolization areas and some draining veins, but low radiation dose was delivered to embolization parts and veins. According to Spetzler-Martin grading, 13 patients was classified as grade I, 24 patients as grade II, 15 patients as grade III, 8 patients as grade IV and 5 patients as grade V. The mean target volume was 8.8 cm³ (range, 1.2-27.0 cm³). Seven patients with small volume AVM were irradiated by cyberknife in a single session, the rest patients had 2 sessions (n=35) or 3 sessions (n=23). The mean marginal dose was 23Gy (range 15-28Gy).

Results: AVM obliteration was confirmed by MRI or angiography in 51 patients at a mean follow-up of 46 months (range 36-70 months). The rates of total obliteration were 78% at 3 years. Marked reduction of the size of AVM has been obtained in 14 patients who were not obliterated completely. Among these 14 patients, 3 had the second CKR, 1 had embolization, 1 had gamma knife, the rest were followed up further. The patients were treated by embolization combined with CKR, the rate of AVM obliteration was 83% (20/24). In Spetzler-Martin grade I and II, 34 of 37 (92%) AVMs was obliterated. The higher rate of obliteration of AVM was related to small volume of AVM located in non-critical areas, prior embolization, in which the radiation target including the embolization area and high dose was also associated with a higher obliteration. Eighteen patients had brain edema in the follow-up MRI, 10 of them needs medication and resolved later. Three patients had a hemorrhage during the follow-up period and recovered partially. A permanent neurological deficit due to adverse radiation effects developed in 2 patients.

Conclusions: CKR proved to be most effective for patients with smaller AVMs located in non-critical areas. Delineation of AVM target including the embolization area in patients who had prior embolization was key point to higher rate of obliteration.

OSP25 - BODY 2

#10061: Salvage focal cyberknife stereotactic radiotherapy to dominant intra-prostatic lesions using [11C]choline PET/CT

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Keywords: prostate, hypofractionation,

Purpose: We investigated the role of integrated [11C]choline PET/CT for target volume selection and delineation in patients with recurrent prostate cancer following External beam radiotherapy (EBRT) for a salvage focal Cyberknife Stereotactic Hypofractionated Radiotherapy (SBRT) treatment.

Methods and Materials: From December 2012 to December 2016 a cohort of 33 patients with initial disease category defined as low (7), intermediate (8), high (18), in accordance to NCCN 2008 guidelines, a median age of 74 years (range 62-89) and an history of locally-recurrent prostate cancer following EBRT were referred to our Department for salvage Cyberknife SBRT. The diagnosis of a clinically evident prostate cancer recurrence was based on biochemical progression and imaging studies (CT Scan, Bone Scan and [11C]choline PET/CT). Median iPSA was 19.6 ng.ml⁻¹ (4.9-88 ng.ml⁻¹), EBRT doses ranged from 74 to 79.2 Gy (median 76 Gy) and the median interval time between diagnosis of relapse and salvage focal Cyberknife treatment of 66 months (range 12-187). The median pre-reirradiation PSA was 4.84 ng/ml (range 2.23-21.04 ng/ml). To reconstruct CTV and organ at risk, CT scan and MRI with T1-T2 sequences were performed and [11C]choline PET/CT images were fused. Nine patients received 3 fractions of 10 Gy (total dose 30 Gy), 24 patients received 3 fractions of 12 Gy (total dose 36 Gy) delivered to the PET positive prostate node (median volume of 14.3 cc - range 5.75-65.04).

Results: Salvage Focal Cyberknife treatment was well tolerated without any RTOG grade 3 acute or late toxicity. With a median follow up of 26 months (range 7-49) we observed the following results: no in field recurrence, resulting in a local control of 100%. In 6 pts, a [11C]choline PET/CT detect the presence of a local recurrence (median time 15 months; range 8-22 mts) with the evidence of a
new positive prostate node outside the irradiated field requiring a second Cyberknife salvage treatment. 3 patients develop lymph nodes or bone metastases 6, 9 and eleven months after Cyberknife treatment.

**Conclusions:** Cyberknife Hypofractionated stereotactic radiotherapy using \(^{11}C\)choline PET/CT fusion for image guidance is a suitable technique for partial prostate dose escalation. According to available literature, \(^{11}C\)choline PET/CT is not clinically recommendable to plan target volume, nevertheless our promising data suggest a potential role of \(^{11}C\)choline PET/CT as an image guide tool for the irradiation of focal prostate cancer relapse. Prospective trials are needed to better define the role of differential prostate treatment on imaging defined targets.

**OSP25 - BODY 2**

**#9913 : Feasibility of SBRT for patients with locally advanced pancreatic cancer: a single center experience.**

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**Keywords:** Pancreatic carcinoma; SBRT; image guided radiotherapy

**Introduction:** Despite advances in treatment, notably in systemic therapy, the prognosis of pancreatic adenocarcinoma (PADC) remains dismal. Stereotactic body radiotherapy (SBRT) is an emerging tool in the complex management of PADC. We review outcomes of SBRT for PADC at our institution.

**Methods:** We reviewed patients treated with SBRT for either unresectable advanced PADC or locally recurrent PADC after surgery. Eligible patients were treated as part of a prospective trial and received chemotherapy after SBRT. Treatment was delivered using the Cyberknife® tumor tracking system with markers. The median prescribed dose was 30 Gy (30–35 Gy), delivered in 5–6 fractions. Toxicities were reported as per CTCAE v4.0. Survival outcomes were estimated using the Kaplan-Meier method.

**Results:** Between October 2010 and March 2016, 21 patients were treated at our center, among them 6 were part of a prospective trial. The median follow-up was 7 months (range: 1–28). The 6-month and 1-year local control rates were 94% and 57%, respectively. The 1 year overall survival was 25% for locally advanced patients and 67% for those with local recurrences. Eighty percent of cancer related deaths were due to metastatic progression. Five patients (24%) had Grade I-II gastrointestinal acute toxicity; one patient had grade V gastrointestinal bleeding 6 months after SBRT.

**Conclusion:** SBRT for unresectable and recurrent PADC is feasible and provides reasonable local control. Modest dose schedules may be preferable due to the relationship of the pancreas to dose-limiting organs. More work should be done to integrate SBRT with modern systemic therapy in the management of PADC.

**OSP25 - BODY 2**

**#9910 : iTV – A new concept of internal target definition for radiation treatment of CA lung**

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**Keywords:** inverse ITV, 4D dose calculation, DICOM-RT toolbox, Lung radiation therapy, Deformable image registration.

**Purpose:** The purpose of this study was to define a more effective internal target volume, namely iTV than the classical internal target volume (ITV) for radiation treatment of lung cancer.

**Methods:** The ITV takes into account only the geometrical aspect but not the temporal nature of the tumor motion, continuous irradiation the whole trajectory of the GTV defined by the ITV will inevitably lead to excessive irradiation of the neighboring healthy tissue. The iTV defined in this study was on the basis of 4D dosimetry which allows the target volume to be determined in both spatial and temporal domains, with the aim to obtain optimal target coverage by completely eliminating excessive irradiation. The 4D dose distribution over the moving target was calculated using deformable image registration (DIR), which tracks the displacement of each CT voxel during the respiratory cycle. The sum of the dose along the trajectory of each voxel presents the accumulated doses receiving by the target. The lowest dose of the GTV therefore indicates
the location of the extremity of target’s extension, and
the enclosed isodose volume delineates the boundary
of the internal target volume. In contrast to the classical
ITV which is determined before dose calculation, the
iITV was derived as a result of 4D dose calculation. It is
therefore denoted as the inverse ITV (iITV).

Results: Our results suggest that 1) iITV reduced the
target dose volume by an average of 16.5% compared
with that determined by the ITV, 2) optimal dose
planning was generally (but not always) achieved
with the planning CT performed at the temporal mean
tumor position, 3) the degree of target coverage
maximization strongly depends on the nature of tumor
movement.

Conclusions: By considering both geometric and temporal
factors, the 4D dose planning based on DIR allows ITV
to be estimated in a more effective approach. The iITV
optimizes the internal target volume which can be applied
as an indicator for selecting utmost dose plans.

OSP25 - BODY 2
#10400 : Cost-effective implementation of
lung SBRT in a developing country

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Keywords: cost-effective SBRT, Lung SBRT, Developing
Country, Myanmar

Stereotactic body radiation therapy (SBRT), has become
an integral component of the management of early-stage
non–small cell lung cancer (NSCLC). Unfortunately,
SBRT is not readily available in developing countries
where the cost of advanced radiation equipment prevents
widespread availability of this modality. In addition,
experience and expertise in modern techniques is scarce.
We describe the onsite implementation of a cost-effective
complete lung SBRT solution using deep inspiratory
breath-hold (DIBH) technique with the Abches System
(Apex Medical), delivered by an entry level Varian IX
with on-board portal imaging in one of only few linear
accelerator equipped hospitals in Myanmar.

Materials and Method: Abches is a respiration-monitoring
device developed by Onishi et al. for facilitating
precise irradiation of a target by assuring a stable breath
hold. To simulate the breath-hold technique, we used the
MOBIUS QUASAR phantom at different amplitudes (from
1-1.5cm) with designed breathing curve to simulate the
breath-hold scenario. We designed a lung SBRT protocol
using the above equipment taking into account motion
management and image-guidance procedures essential
for safe delivery of SBRT. The local team of physicists and
radiation oncologists with little or no prior experience in
SBRT underwent a 3-day hands-on, onsite course on the
basis and application of the protocol, including QA proce-
dures and targets. Planning was done with Varian Eclipse
v13.6. After the course, an audit was conducted on the
entire SBRT process delivered by the local team on the
phantom. Participants were ‘blinded’ to various ‘errors’
and assessed with a checklist. TLDs were used to validate
the dose that was delivered within the “tumor”.

Results: Checklist items were scored 90% and above. The
physicist was able to scan and plan the phantom accord-
ing to the protocol after 3 days of training and manage dif-
ferent scenarios of breath holding. The radiation oncolo-
gist was able to make treatment decisions and contour
the target effectively. The RTTs were able to monitor and
coordinate the machine beam on timing effectively as well
as using the onboard imager to localize correctly. The TLD
dose results from the delivery of the plan on the MOBIUS
QUASAR was within tolerance of 3%, and the gamma
analysis 3%/3mm were above 97% using array detectors.

Conclusion: Our study showed that by adhering closely
to a standardized protocol through structured onsite
training, SBRT for early lung cancers can be safely
delivered in a developing country cost-effectively, using
a base model linear accelerator.

OSP25 - BODY 2
#10161 : Disparities in and utilization of
stereotactic body radiotherapy (SBRT)
in the management of primary and
metastatic lung cancer: A national cancer
database study

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Stereotactic body radiation therapy (SBRT), has become
an integral component of the management of early-stage
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breath-hold (DIBH) technique with the Abches System
(Apex Medical), delivered by an entry level Varian IX
with on-board portal imaging in one of only few linear
accelerator equipped hospitals in Myanmar.
Keywords: Lung, SBRT, NCDB, Race

Purpose: To evaluate the utilization of SBRT in the management of primary and metastatic lung cancer and to evaluate factors associated with SBRT utilization, and disparities in SBRT utilization by race.

Materials/Methods: The National Cancer Database (NCDB) is a comprehensive national database that captures approximately 70% of newly diagnosed cancer patients in the USA. Data for patients meeting eligibility criteria for our study (receiving radiotherapy to the lung or chest, utilizing a stereotactic treatment modality, and completing treatment in 1-5 fractions) were extracted from the NCDB 2013 PUF data file (encompassing years 2004-2013). Race was defined as White (Wh), Black (Bl), American Indian (AI), and Asian (As). Because there were only 6 patients coded as Hawaiian/Polynesian, this group was included with the As group. Descriptive statistics were used to summarize variables. Univariate analysis (UVA) was used to evaluate for disparities in SBRT use by race and ethnicity. Association between RT use and covariates was assessed using univariate Chi-square test and multiple logistic regression (MVA).

Results: There were 369,072 patients diagnosed with lung cancer in the PUF database, of whom 22,556 patients (6.1%) met eligibility criteria. Median age was 75 years, 46.4% were male and 53.6% were female. Only 4.1% of patients had stage IV disease, and 2.9% had unknown stage. Median tumor size was 22 mm. The most frequently used dose regimen was 50Gy in 5fx followed by 48Gy in 4 fractions or 60Gy in 3 fractions. Overall, SBRT utilization steadily increased from 0.3% in 2004 to 12.9% of all lung cases in 2013 (p < 0.001). When evaluating by race, SBRT utilization varied from 3.7% for As patients to 6.5% for AI patients (p < 0.001). Asian patients tended to be older and had a higher percentage of stage IV disease. AI patients tended to be younger and had smaller median tumor size. Factors that were statistically significant for SBRT use on UVA and MVA included age, facility type, year of diagnosis, analytic stage, crowfly, and lymph node status. Race was significant on UVA but not on MVA.

Conclusion: This analysis demonstrates an increased utilization of lung SBRT from 2004 to 2013. Numerous factors associated with SBRT utilization including facility type, crowfly distance, and lymph node status were identified. However, race did not appear to be a significant factor for SBRT use on multivariate analysis.

OSP25 - BODY 2

#9996 : Quantification of ITV volume consistency during lung SBRT

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Keywords: ITV, Lung Cancer, SBRT

Purpose: Lung SBRT has reported excellent local control rates of over 90%. A 4DCT scan is recommended by RTOG 0915 for intelligent definition of an ITV. At most institutions a single 4DCT scan is acquired at simulation, and slow-scan CBCT's are acquired for daily alignments. This approach assumes that the ITV volume is relatively consistent over 1-2 weeks of treatment, and/or that the blurred CBCT representation of the target is sufficient to allow for visualization of ITV changes that might compromise the quality of target coverage. In this study we utilize 4DCT's acquired prior to each treatment fraction to accurately quantify the consistency of the ITV throughout treatment.

Method: 18 patients who underwent lung SBRT treatment with three fractions were randomly chosen from our institutional database. Each patient received a 4DCT scan at simulation, and prior to each treatment fraction (4 total 4DCTs) using BodyFix immobilization and RPM on a GE RT16. ITVs were semi-automatically defined for each 4DCT dataset (threshold/edge detection plus expert user edit). For each patient, all 4 ITV's were compared to each other for volumetric and geometric consistency. A PTV=ITV_{sim} + 3,4,5mm was used to determine what PTV margin was sufficient to cover the ITV/target for all 3 treatment fractions.

Results: ITV_{sim} volumes ranged from 2.59 to 54.11 cc (mean=11.56cc), and treatment day ITV volume differences from ITV_{sim} ranged from –48% to +65%. 5/18 cases showed ITV volume changes ≥ 40%. For 4/18 patients the ITV_{sim} volume was the largest (leading to ‘over treatment’ of healthy tissue for all treatment fractions); 3/18 cases the ITV_{sim} volume was the smallest (leading to ‘under treatment’ of the ITV for all treatment fractions). For each patient, if we assume a worst case scenario of the smallest ITV volume occurring on simulation day, 5mm and 4mm PTV margins were sufficient to cover the largest ITV. However, a 3mm margin would have been insufficient...
for full ITV coverage. And this assumes an ideal image registration and perfect application of corrective shifts, which probably does not occur each day.

Conclusion: Non-trivial changes in ITV volume occur during SBRT of lung, predominately due to changes in patient breathing patterns. 5mm and 4mm PTV margins were sufficient for the patients studied here, if we assume a perfect image guided setup correction. A 3mm margin was insufficient for full ITV coverage.

OSP26 - ESTRO: METASTASES 5

#10072 : Better understanding the patient selection for Gamma Knife Radiosurgery for synchronic brain metastasis from non-small cell lung cancer

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Keywords: Brain metastasis, NSCLC, Gamma Knife radiosurgery, Stereotactic radiosurgery

Introduction: We have little understanding of referral patterns of patients with brain metastasis (BM) from non-small cell lung cancer (NSCLC) for treatment of BM in a third line treatment center with Gamma Knife radiosurgery (GKRS). To gain more insight in referral patterns, the characteristics of patients with synchronically diagnosed BM from NSCLC who are treated with GKRS were compared to a general population of patients with BM from NSCLC from the same region.

Material and Methods: 1129 patients with synchronic BM from NSCLC diagnosed between 2008 and 2014 were selected from the population-based Netherlands Cancer Registry, of which 242 patients were treated with GKRS in our center (GKRS-group). All patients treated with GKRS received a dose of 18-25 Gy prescribed to the isodose covering 99-100% of the tumor volume, had a Karnofsky index ≥70 and had no prior treatment to the brain.

Results: Patients in the GKRS-group were younger (62y vs 64y p=0.0016) while gender and histology did not differ. They had lower tumor burden: presence of T2 was higher (43% vs 33%, p=0.0158), and of T4 (19% vs 28%, p=0.0044) was significantly lower in GKRS treated patients. Also, they had more often N0 disease (32% vs 19% p=<0.0001), less often N3 disease (18% vs 29% p=0.0004) and less metastatic sites when compared to the patients that were not treated with GKRS (n=887, noGKRS-group). No significant differences were observed in number of comorbidities, socio-economic status and country of birth. In multivariable logistic regression analysis, GKRS treatment was associated with an age of 60 years and less and N0 status. Gender, T stage, histology, number of comorbidities, country of birth as proxy for ethnicity and socioeconomic status were not associated. All GKRS-patients received treatment, either systemic treatment (69%) or local treatment of their primary lung cancer (86%). Median survival in the GKRS-group was 9.7 months vs 4.0 months in the noGKRS-group (p-value Log Rank=<0.0001). 80% of patients in the GKRS-group had at least one follow-up MRI, local tumor control of the treated BM was achieved in 94% at last follow-up.

Conclusion: Patients with synchronic BM from NSCLC that are referred to a third line treatment center for GKRS have favorable factors, such as low age and absence of local lymphatic spread. In these selected patients median survival rates of 9.7 months and high local tumor control were achieved with GKRS.

OSP26 - ESTRO: METASTASES 5

#9949 : Interinstitutional plan quality assessment of two LINAC based single isocenter multiple metastasis radiosurgery techniques

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Keywords: multiple metastasis, single isocenter, radiosurgery

Introduction: Recent data have increasingly highlighted the cognitive benefits of stereotactic radiosurgery (SRS) in comparison with WBRT±SRS. Several treatment planning systems (TPS) are available for linear accelerator (linac) based SRS for multiple brain metastases. Two of the most advanced are Brainlab Elements™, an automated single isocenter dynamic conformal arc (SIDCA) based approach, and Varian RapidArc™, a volumetric modulated arc (VMAT) based approach. The purpose of this work was to compare the plan quality between the two techniques.

Methods: Twenty-two five to ten brain metastases (170 total) patients were planned with both Varian RapidArc (v13.5) at University of Alabama at Birmingham (UAB) and BrainLAB Multi-mets Elements™ (v1.0.2) at Thomas Jefferson University (TJU). Twelve were UAB patients and ten were TJU patients. UAB plans used a single isocenter, four non-coplanar VMAT arcs with 10MV flattening filter free (FFF) beam. TJU plans used a signal isocenter, varied number of non-coplanar dynamic conformal arcs (4~9) with 6MV beam. Case characteristics were as follows: target number (n_min=5, n_max=10; n_median=8), individual target volume (TV_min=0.014cc, TV_max=17.73cc; TV_median=0.35cc), plan target volume (TV_min=0.49cc, TV_max=27.32cc; TV_median=7.87cc). Prescription doses ranged from 14~24 Gy in single fraction, and were selected based on individual target volume. Planning goal is to cover at least 99% volume of each target with its prescription dose. Plans were evaluated based on RTOG conformity index (RTOG_CI), Paddick conformity index (PCI) for each target, 12Gy isodose volume (V12SI) as a surrogate of radionecrosis risk, 5 Gy isodose volume (V5SI) as a surrogate for low dose spill, and mean brain dose (Dmean_brain) for each plan. Dosimetry parameters were compared using two-tailed Wilcoxon signed-rank test.

Results: Conformity was favorable among the VMAT plans (median: RTOG_CI_SIDCA= 1.39, RTOG_CI_VMAT= 1.23; p <0.0001 ; PCI_SIDCA= 0.69, PCI_VMAT= 0.76; p < 0.0001), and so does the twelve gray isodose volume (median: V12SIDCA= 30.6 cc, V12VMAT = 25.0 cc; p = 0.0003). Five gray isodose volume was favorable among the Element plans (mean: V5SIDCA= 178.7 cc, V5VMAT = 205.1 cc; p = 0.006), and so does the mean brain dose (mean: Dmean_brain_SIDCA= 2.81 Gy, Dmean_brain_VMAT= 3.22 Gy; p = 0.0001).

Conclusion: For single isocenter LINAC based multiple (5~10) metastasis SRS, VMAT based RapidArc plan facilitates favorable conformity and twelve gray isodose volume compared to SIDCA based Element plan, while it has less favorable mean brain dose and low dose spill. Further work and clinical correlate are required to understand the consequence of these dosimetric results.

OSP26 - ESTRO: METASTASES 5

#10253 : Single-isocenter, image-guided stereotactic radiosurgery (SRS) in the management of multiple brain metastases: Retrospective and prospective studies

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Keywords: SRS, Single-Isocenter Multi-Target SRS, Brain Metastases

Background: Brain metastases (BM) are common in cancer patients and SRS is often the treatment of choice for patients with 1-3 small, discrete BM. Whole-brain RT (WBRT) continues to be employed for treating multiple (>3) BM, despite its proven neurocognitive deficits versus SRS, largely due to the excessive length of time to treat multiple BM with separate isocenter plans. Utilizing single-isocenter, multi-target (SIMT) volumetric-modulated-arc-based for SRS planning and delivery, multiple BM can be treated simultaneously. Clinical outcome data on this approach are limited and we summarize our institutional experience using SIMT SRS for multiple BM, along with our newly opened prospective study on these patients.

Materials and Methods: Patients treated at our institution from 2013-2015 with SIMT SRS to 4 or more BM were included in this IRB-approved retrospective study. All patients were treated using a linear-accelerator-based image-guided SRS system (Novalis Tx or TrueBeam ST.)

Results: 59 consecutive patients with a median follow-up time of 15.2 months (mo) were evaluated. Average age was 61.8 years. The most common primary
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histology was non-small cell lung cancer (35.6%). More than half had previous WBRT or SRS. Median number of treated lesions per patient was 5 (range 4-23). Per patient, the mean PTV was 7.4cc. Dose per lesion ranged from 7-20Gy, with a PTV average dose of 19.4Gy. The median overall survival (OS) for the entire cohort was 5.8mo. While the number of treated lesions did not influence OS, longer OS was associated with a total PTV < 10cc vs ≥10 cc, 7.1 vs 4.2mo (p=0.0001). Mean dose >19Gy for the entire PTV also correlated with increased OS(6.6 vs 5mo, p=0.017). When the volume of normal brain receiving > 12Gy exceeded 10cc, poorer overall survival was observed (5.1 vs 8.6mo, p=0.003.)

Conclusions: In SIMT SRS for patients with multiple BM, lower total lesion volume, higher total dose and lower volume of normal brain receiving >12Gy were associated with increased OS, but the total number of BM was not significant. In January 2017, we opened a prospective trial of SIMT SRS for patients with 4-10 BM. Endpoints include, overall survival, local and distant brain recurrence, neurocognition, quality of life and radionecrosis.

OSP26 - ESTRO: METASTASES 5

#10043 : Assessment of dosimetric predictors and impact of whole-brain radiotherapy on the incidence of radionecrosis after stereotactic radiosurgery for brain metastasis

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Keywords: Brain metastasis, stereotactic radiosurgery, radionecrosis, whole brain radiotherapy

Background: Stereotactic radiosurgery (SRS) and whole-brain radiotherapy (WBRT) are commonly used for treatment of brain metastasis (BM). Radiation-induced necrosis (RN) is the main late toxicity of SRS and may cause considerable morbidity. Several dosimetric parameters of SRS have been suggested to correlate with RN, but the associations are not consistent, and the impact of WBRT remains undefined.

Materials and Methods: All patients 18 years or older who received SRS with or without WBRT for BM from January 1, 2008 to December 31, 2013 in a single institution with at least 6 months follow up were included from a prospectively-collected database. Dosimetric variables for each separate lesion were gathered from the treatment planning software. Serial consecutive post-SRS MRI images were reviewed for RN, using standard imaging definitions.

Results: 767 lesions were treated in 294 patients. Patients were 61% female, and had a median age of 59 years. Most common primary sites were lung, breast, melanoma (50%, 18%, 10%, respectively). 207 patients (70%) were treated with both WBRT and SRS, and 87 (30%) with SRS only. 606 lesions (80%) were supratentorial. 66 patients (23%) developed RN, 32 of whom were symptomatic (11%), corresponding in total to 111 lesions (14% of lesions) (2y RN-free survival per lesion: 82%). At the time of analysis, 203 patients (69%) were dead, with a median survival of 14.7months.

On univariate analysis, WBRT retreatment, WBRT before SRS, supratentorial location, SRS prescription dose, prescription isodose, lesion volume, lesion mean dose, V12 (volume receiving 12Gy), conformity index (CI) and patient’s performance status were significantly correlated with RN occurrence. On multivariable analysis, only V12 (HR 1.04, 95%CI 1.02-1.06, p=0.0008), mean dose (HR 0.93, 95%CI 0.89-0.98, p=0.003), prescription isodose (HR 0.92, 95%CI 0.89-0.96, p=0.00008), ECOG3-4 (HR2.37, 95%CI 1.35-4.14, p=0.0025) and supratentorial location (HR 2.80, 95%CI 1.35-5.81, p=0.005) were significant, and there was a trend of significance for WBRT before SRS as compared to after (HR1.67 95%CI 0.99-2.83 P=0.054). Adding WBRT to SRS and various WBRT fractionations were not associated with risk of RN.

Conclusion: Our study suggests that RN is associated with lesion location, higher SRS doses to larger volumes and patient’s performance status. The addition of WBRT to SRS and its sequence and/or dose fractionation does not appear to increase the incidence of RN.

OSP26 - ESTRO: METASTASES 5

#10060 : The validation of melanoma GPA and Chowdhury overall survival score in patients with melanoma brain metastases treated with Gamma Knife surgery

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Keywords: Melanoma, Gamma Knife Radiosurgery, Brain metastases

Introduction: Nearly half of the patients with stage IV melanoma develop brain metastases (MBM) with a median survival of 4-5 months after diagnosis of brain metastases. Among current treatment options for local management is Gamma Knife Radiosurgery (GKRS). Median overall survival after GKRS is 5.6 months. Several risk scores have been defined to identify prognostic subgroups in patients with MBM such as the Melanoma Graded Prognostic Assessment (M-GPA). Recently, Chowdhury et al. defined a new overall survival risk score in patients treated with GKRS.

In this study, we validated both the Melanoma GPA and Chowdhury overall survival score in our patient cohort.

Methods: We retrospectively included 104 patients treated with GKRS alone for MBM between 2002 and 2014 in our institution. Patients were divided in categories based on M-GPA and the Chowdhury overall survival (OS) score. The M-GPA included Karnofsky Performance Status (KPS) and number of brain metastases. The Chowdhury OS score included gender, KPS, number of brain metastases and presence of any extracranial disease. The Kaplan-Meier method was used to estimate overall survival.

Results: Median inclusion time was 80 months and the median overall survival (mOS) after GKRS was 6 months. Regarding the M-GPA 9 patients (8.7%) had a score of 0-1.0 with a corresponding mOS of 2 months. Forty-five patients (43.3%) scored 1.5-2.0 points resulting in 6-month mOS. An mOS of 6 months was observed in 27 patients (26 %) with 2.5-3.0 points. Twenty-three patients (22.1%) scored 3.5-4.0 points with an mOS of 9 months. Regarding the Chowdhury OS score 27 patients (26.0%) had a high-risk score (6.5-10 points) with a mOS of 3 months. Moderate-risk (4-6 points) was scored in 47 patients (45.2%) resulting in a mOS of 7 months. Thirty patients (28.8%) were scored as low-risk (0-3 points) and appeared to have a mOS of 13 months. In contrast to the M-GPA differences in mOS were statistically significant between all three risk groups of the Chowdhury OS score.

Conclusion: In this study, we validated both the M-GPA and Chowdhury OS score. The Chowdhury OS score proved to be the most accurate score to categorize patients with MBM in risk groups with corresponding statistically significant mOS time. Contrary to Chowdhury et al. the follow-up time in our study was sufficient for the low-risk group to reach the median overall survival time which was 10 months.

#9868: Impact of two-staged stereotactic radiosurgery (2-SSRS) treatment for brain metastases ≥ 2 cm

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Keywords: Large brain metastasis, two-stage radiosurgery, 2-SSRS, hypo-fractionated radiosurgery, gamma knife, radiosurgery, local control, radiation necrosis

Introduction: Stereotactic radiosurgery (SRS) is the primary modality for treating brain metastases. However, effective radiosurgical control of brain metastases ≥2cm (BM≥2cm) is associated with suboptimal local control (LC) rates of 37–62% and an increased risk of treatment-related toxicity. To enhance LC while limiting adverse radiation effects (AE) in these patients, a dose-dense treatment regimen using 2-staged SRS (2-SSRS) was utilized. Study objective was to evaluate the efficacy and toxicity of this treatment strategy.

Methods: IRB-approved retrospective review 54 patients (63 BM≥2cm) treated with 2-SSRS was performed. Volumetric measurements at first stage radiosurgery (1st SSRS) and second stage radiosurgery (2nd SSRS) treatments and at follow-up were determined. The study evaluated three primary outcomes: i) response at first follow-up MRI, ii) local time to progression (TTP) and iii) overall survival (OS) in response to 2-SSRS. Response was analyzed using methods for binary data, TTP analyzed using competing risks methods and OS was analyzed using conventional time-to-event methods.
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Results: Of 54 patient, 46 (85%) had one BM ≥2cm treated with 2-SSRS, 7 patients (13%) had two BM ≥2cm concurrently treated with 2-SSRS and 1 patient underwent 2-SSRS for three concurrent BM ≥2cm. Median age was 63 y (23-83), 23 patients (43%) had NSCLC, and 14 patients (26%) had radio-resistant tumors (renal or melanoma). Median doses at 1st and 2nd SSRS were 15Gy (12-18) and 15Gy (12-15) respectively. Median duration between stages was 34 days; median tumor volumes at 1st and 2nd SSRS were 10.5 cm³ (range 2.4-31.3) and 7.0 cm³ (range 1.0-29.7). 3-month follow-up imaging was available for 43 lesions; median volume 4.0 cm³ (range 0.1-35.9). Median change in volume compared to baseline was 54% decreased (range -98.2–66.1%), p<0.001. Overall, 9 lesions (14.3%) demonstrated local progression, median time 5.2 months (range 1.3–7.4) and 7 (11.1%) demonstrated AEs (6.4% Grade 1/2 toxicity; 4.8% Grade 3). Estimated cumulative incidence of local progression at 6-months was 12% (95% CI: 0.01-0.23). Shorter TTP was associated with greater tumor at baseline (p=0.01) and smaller absolute (p=0.006) and relative (p=0.05) decreases in volume from baseline to 2nd SSRS. Estimated OS rates at 6/12-months were 65% and 49%, respectively.

Conclusion: 2-SSRS is an effective treatment modality resulting in significant reduction of BM ≥2cm with excellent 3-month (95%) and 6-month (88%) LC rates and overall AE rate of 11%. Prospective studies with larger cohorts and longer follow-ups are necessary to assess durability and toxicities of 2-SSRS.

OSP26 - ESTRO: METASTASES 5

#10267 : Cumulative intracranial tumor volume (CITV) augments the prognostic value of disease-specific graded prognostic assessment (dsGPA) model for survival in patients with melanoma cerebral metastases

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Keywords: Brain metastases, net reclassification index, prognostic model, radiosurgery, ds-GPA, melanoma

Background: The diagnosis-specific Graded Prognostic Assessment scale (ds-GPA) for patients with melanoma brain metastasis (BM) utilizes only two key prognostic variables: Karnofsky’s Performance Score (KPS) and the number of intracranial metastases. We wished to determine whether inclusion of cumulative intracranial tumor volume (CITV) into the ds-GPA model for melanoma augmented its prognostic value.

Objective: To determine whether or not CITV augments the ds-GPA prognostic scale for melanoma Methods: We analyzed the survival pattern of 344 melanoma patients with BM treated with stereotactic radiosurgery (SRS) at separate institutions. The prognostic value of ds-GPA for melanoma was quantitatively compared with and without the addition of CITV using the net reclassification improvement (NRI>0) and integrated discrimination improvement (IDI) metrics.

Results: The incorporation of the cumulative intracranial tumor volume (CITV) into the melanoma-specific ds-GPA model enhanced its prognostic accuracy. Addition of CITV to the ds-GPA model significantly improved its prognostic value, with NRI>0 of 0.366 (95% CI: 0.125-0.607, P=.002) and integrated discrimination improvement of 0.024 (95% CI: 0.008-0.040, P=.004).

Conclusion: The prognostic value of the ds-GPA scale for melanoma brain metastasis is enhanced by the incorporation of CITV. Running title: CITV augments ds-GPA for Melanoma

OSP26 - ESTRO: METASTASES 5

#10054 : White matter changes between patients with and without local progression following SRS treatments

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Keywords: DTI, Brain metastasis, SRS, local progression

Background: Recent technological advances, especially in advanced MR imaging techniques, have endowed physicians with the ability to further interpret subtle structural variations and physiological alterations. Diffusion tensor imaging (DTI) is the most sensitive technique to detect structural alterations and potential pathologies of white matter. It is a specific diffusion-weighted imaging (DWI) technique that provides quantitative measurements of the mean diffusivity and distribution of diffusion orientation of the white matter tracts. Stereotactic radiosurgery (SRS) is a very effective treatment technique for brain tumors by delivering ablative dose in a single fraction. However, SRS could also result in neurological complications by inducing neurotoxicities such as white matter injury. This ablative dose-induced white matter changes after SRS treatments has yet to be elucidated, especially with the potential impact from the growth of recurrent lesion. Purpose: The present study aims to evaluate the white matter changes following SRS using DTI for patients with or without local progression.

Materials and Methods: Ten patients who were treated with brain SRS at UNMC were collected retrospectively. Five patients had local progression occurred between 6 to 12 months following the treatments, the other five patients without local progression were matched based on treatment volume (PTV range: 0.2cc ~ 3cc). All the DTI images acquired before and 6 months after SRS treatments were registered to the high-resolution contrast enhanced T1-weighted MR images and CT images used for SRS planning in BrainLab iPlan treatment planning system (iPlan). Diffusion tensors were generated, and fiber tractography was implemented in iPlan. The volume receiving doses greater than 12Gy (V12) was generated for each patient, with a control volume created in the contralateral brain that mirrored the location, size and shape of V12. Mean diffusivity, represented by apparent diffusion coefficient (Dav), and fractional anisotropy (FA) were calculated in iPlan for the V12 volumes, and normalized by the corresponding values of the counterpart control volumes on the contralateral side. The post-treatment changes of these metrics were compared among patients.

Results: The mean diffusivity (Dav) of the V12 volume decreased with a large variation (0.96 ± 0.38) for patients with local progression, whereas that increased slightly (1.02 ± 0.13) for patients without local progression 6 months after the treatments. FA varied significantly among patients, and no correlation was observed.

Conclusion: The mean diffusivity in the high dose volume (V12) varied between patients who developed local progression and the patients without local progression following SRS treatments.

OSP26 - ESTRO: METASTASES 5

#9923 : Hypofractionated stereotactic radiosurgery for pituitary metastases

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Keywords: hypofractionation; pituitary metastases; stereotactic radiosurgery

Pituitary metastases (PMs) are uncommon, representing only 1% of pituitary lesions. The diagnosis of PMs can be challenging and an optimal management remains to be determined. Here, we present a pilot clinical study on the efficacy and safety of hypofractionated stereotactic radiosurgery (SRS) with an optimized dosimetric plan in treating PMs. Between June 2013 and December 2014, seven consecutive patients (4 men and 3 women; median age 62 years) had been diagnosed with PMs based on their characteristic clinical and radiological features and subsequently treated using hypofractionated SRS. Primary cancers originated from the lung (n = 5) or the breast (n = 2). All patients presented with diabetes insipidus (DI). Anterior pituitary and visual dysfunction were combined in 4 and 3 patients, respectively. On magnetic resonance imaging (MRI), PMs involved the pituitary stalk and/or the posterior lobe in all patients. SRS of a cumulative marginal dose 31 Gy with dose-volume constraints for the optic apparatus was delivered in 5 daily fractions. As results, tumor was locally controlled in all patients with substantial responses on MRI (including complete remission in 4 patients). The median survival time was 14 months (range, 6-24 months) after SRS. DI and visual dysfunction improved in all patients, although anterior pituitary dysfunction did not recover. No patients experienced any deterioration in visual, pituitary, or other cranial nerve functions. These results suggest a promising role of hypofractionated SRS in treating PMs in terms of both tumor control and functional outcomes.

OSP26 - ESTRO: METASTASES 5

#10264 : Improving the prognostic value of disease specific graded prognostic assessment (ds-GPA) model for renal cell carcinoma by incorporation of cumulative intracranial tumor volume (CITV)

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Abstracts

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Keywords: Brain metastases, net reclassification index, prognostic model, radiosurgery, ds-GPA, renal cell carcinoma

Background: We tested the prognostic value of cumulative intracranial tumor volume (CITV) in the context of ds-GPA model for renal cell carcinoma (RCC) patients with brain metastasis (BM) treated with stereotactic radiosurgery (SRS).

Method: Patient and tumor characteristics were collected from 360 RCC BM patients treated with SRS. Univariable logistic regression model was used to test the prognostic value of CITV, Karnofsky Performance Score (KPS), and the number of BM. Net reclassification improvement (NRI) and integrated discrimination improvement (IDI) were used to assess whether CITV improved the prognostic utility of RCC ds-GPA.

Results: In univariable logistic regression models CITV, KPS, and the number of BM independently associated with RCC patient survival. In a multivariable Cox proportional hazard model, the association between CITV and survival remained robust after controlling for KPS and BM (P=.042). The incorporation of the cumulative intracranial tumor volume (CITV) into the RCC ds-GPA model (consisting of KPS and number of BM) improved prognostic accuracy with NRI>0 of 0.3156 (95% CI: 0.0883-0.5428, P=.0065) and integrated discrimination improvement of 0.0151 (95% CI: 0.0036-0.0277, P=.0183).

Conclusion: CITV is an important prognostic variable in SRS-treated RCC patients with BM. The prognostic value of the ds-GPA scale for RCC brain metastasis was enhanced by the incorporation of CITV.

OSP26 - ESTRO: METASTASES 5

#10009 : CyberKnife based stereotactic ablative radiotherapy (CK SABR) of prostate cancer patients with oligometastatic lymph nodes.

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Keywords: prostate cancer, oligometastases, oligorecurrence, stereotactic ablative radiotherapy

Objective: Evaluation of effectiveness of CyberKnife based stereotactic ablative radiotherapy (CK SABR) in treatment of prostate cancer patients (PCP) with oligometastatic lymph node (LN). Identification of prognostic and predictive factors.

Material and methods: 32 patients with PC (age 49-79) treated in 2013 – 2016 with CK SABR due to 51 oligometastatic LN. 7 were diagnosed primarily with oligometastasis disease, 19 (59.4 %) had high risk, 11 (34.4%) intermediate risk and 2 (6.2%) low risk PC. Primary treatment consisted of hormonal therapy (HT) in 21 (62.6%), surgery in 13 (40.6%) and radiotherapy in 30 (93.8%). Median time from diagnosis of PC to development of oligometastases was 45.5 months. 17 (53.1%) had 1 oligometastatic LN, 11 (34.4%) two LN and 4 (12.5%) three LN. 65.5% had HT. CK total dose ranged from 12 to 45 Gy (median 36) delivered in 2 – 5 (median 3) fractions of 6 to 15 Gy (median 12). Biologically equivalent dose (alfa/beta ratio of 1.6) ranged from 96 to 506.9 Gy (median 306). GTV and PTV varied from 0.27 to 7.92 cc (median 1.08) and from 1.58 to 24.2 cc (median 5.65), respectively. In statistical analysis Kaplan Meier method and log rank test were used.

Results: All patients had at least one control visit after CK SABR. Follow-up (FU) ranged from 3.9 to 62.5 months (median 12). During that time 3 patients died (1-, 2-, and 3-year overall survival (OS) of 92%, 74% and 74%). None of treated LN progressed during FU – local control (LC) of 100%. Progression of the disease (metastases to other LN or bones) was observed in 12 cases – 1- and
2-year progression free survival (PFS) of 63% and 40%. Progression of PSA concentration was observed in 8 patients and median biochemical PFS (bPFS) was 24 months. Only PFS and bPFS have statistically significant impact on OS in log rank test (p=0.02 and 0.007, respectively). PFS was better in patients with primarily oligometastatic LN PC than in those with LN oligorecurrence (p=0.03). PFS was worse in those with GTV over 1 cc (p=0.02), progression of PSA during FU (p=0.0003), modification of HT (p=0.0008) and those who developed castrate resistant PC (p=0.001). Interestingly, those who did not received HT during LN CK had better bPFS (p=0.04).

**Conclusion:** CK of oligometastatic LN PC provides satisfactory LC. PCP with primarily oligometastatic LN have better outcome than those with LN oligorecurrence.

OSP27 - ORGANS AT RISK

#10464 : VIM Gamma Knife Perfexion radiosurgery: Dynamic mono-isocentric shielding for internal capsule sparing

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**Keywords:** VIM Gamma Knife Perfexion Radiosurgery, Tremor

When treating tremor by VIM (Ventral Intermediate Nucleus) radiosurgery with Gamma Knife Perfexion (GKP), we face the difficulty of improving the gradient to the internal capsule while limiting the number of beam plugging in order to maintain a good overall gradient.

We intend here to evaluate in VIM radiosurgery the efficacy of an original dynamic plug shaping method designed to improve the versatility of sector plugging with GKP.

This method consists in putting two 4 mm shots at the same coordinates but with a different pattern of plugs and weights. Our in-house method is to plug sectors 6 and 7 with a weight of 1 for the first isocenter and to plug sectors 2 and 3 with a weight of 0,4 for the second.

Pros and cons of this method are compared to a selection of four other ballistic strategies that could represent an alternative as applied to VIM targeting:

- 4 mm shot with four sectors plugged (sectors 2-3-6-7 for a left VIM and 3-4-7-8 for a right VIM),
- 4 mm shot with two “external” sectors plugged (sectors 2-3 for a left VIM and 7-8 for a right VIM),
- 4 mm shot with two “internal” sectors plugged (sectors 3-4 for a left VIM and 6-7 for a right VIM).

The comparison was led retrospectively on 20 patients treated by Gamma Knife for a radiosurgery of the VIM (8 for left VIM, 12 for right VIM).

For each patient, and for each of the proposed methods, we measured the gradient index, the V90, V12, maximal dose to the internal capsule (D<sub>10mm3</sub>), volume of 12 Gy of the internal capsule (V<sub>12</sub><sub>10mm3</sub>) and mean dose of the internal capsule (D<sub>mean</sub> IC).

The dosimetric comparison between our in-house method and four other alternatives for VIM targeting shows that our in-house method is a good compromise between sparing the internal capsule and keeping a good gradient of dose fall off over the other surrounding tissues.

OSP27 - ORGANS AT RISK

#10359 : Dizziness following stereotactic radiosurgery for vestibular schwannoma – Is vestibular system radiation dose related to post treatment changes in symptoms?

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**Keywords:** dizziness, vestibular, schwannomma,

**Objective:** Dizziness is a major factor affecting quality of life in patients with vestibular schwannoma (VS), but treatment of this is unsatisfactory. Identification of methods to reduce dizziness is required. The aim of this study is to investigate if severity or changes in dizziness symptoms after stereotactic radiosurgery (SRS) relate to vestibular system dosimetry.

**Methods:** The patient cohort consisted of consecutive patients with VS treated with SRS at the Bristol Gamma Knife Centre between October 2013 and March 2016. Patients who previously underwent surgical treatment were excluded. Dizziness symptoms were measured...
using the Dizziness Handicap Inventory (DHI) pre-treatment and at 3, 12 and 24 months post SRS.

The semicircular canals (SSC), vestibule (including the areas of the saccule and utricle) and length of vestibular nerve treated were retrospectively contoured on all treatment plans with treatment dose measured. Dosimetric data collected from this was related to change in DHI scores utilising Pearson correlation for statistical analysis.

Results: Follow up data were available for 86 patients who recorded their DHI at pre-treatment and 3 months post SRS and for 69 at 1 year and 38 at 2 years. The VS treated was mean 1.8cc [0.07-8.9], received a mean 12.3Gy to 50.1% isodose SRS with the Perfexion/Icon Gamma Knife. Coverage mean 0.99, gradient index mean 2.83 and Paddick Conformity Index mean 0.82. The mean cochlea dose (all hearing grades) was 4.7Gy; vestibule mean 5Gy [1.3-8.7Gy] and maximum to 1mm² mean 7.36Gy [1.5-16.1Gy]; SSC mean 3.3Gy [1-6.2Gy] and maximum to 1mm³ mean 5.9Gy [1.8-9.5Gy]; and length of nerve receiving treatment dose mean 18.5mm (6.9-28.2mm). No significant correlation was demonstrated between any of the dose measurement and changes in DHI at 3, 12 or 24 months post SRS.

Conclusion: Unlike the relationship between hearing loss and cochlea dose, there are no dose parameters within the cochlea, SCC, vestibule or length of vestibular nerve treated that relate to changes in dizziness.

OSP27 - ORGANS AT RISK

#10356 : Cohort comparison study of late 5th & 7th cranial nerve neuropathy following Gamma Knife or linear accelerator radiosurgical treatment of vestibular schwannomas

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Keywords: late, neuropathy, vestibular, schwannoma

Objectives: Multiple platforms are used to treat vestibular schwannomas (VS) with stereotactic radiosurgery/radiotherapy (SRS/SRT). These platforms have different physical qualities which result in different levels of conformity and gradient index, but it is unclear if those differences affect patient outcomes. At University Hospitals Bristol (UHBristol) patients with VS were treated with SRS/SRT using a linear accelerator X-knife [Radionics] cones (linac) between 2006 and 2013. From 2013 all SRS was delivered using Perfexion/Icon Gamma Knife (GK) [Elekta, Stockholm]. All patients were managed by the same multidisciplinary team. The aim of this study was to compare these two cohorts of patients regarding the late side effects of treatment to see if the differing platforms’ physical qualities equated to different side effect profiles.

Methods: All patients treated at UHBristol with SRS/SRT using linac or GK for VS with a minimum 1 year follow up were included in the 2 cohorts. Data collection was retrospective review of case notes for linac and prospective data collection for GK cohort. All side effects, excluding those relating to 8th cranial nerve, including severity, date of onset and resolution were recorded, plus any required neuro-surgical intervention. Side effects relating to trigeminal and facial nerve were categorised according to effect and permanence. Statistical analysis used chi-squared test.

Results: 302 patients with VS were treated with SRS/SRT in UHBristol 2006-2016. 136/198 (69%) linac and 103/104 (99%) GK patients had follow up >=1 year. Overall total permanent side effects (barring 8th cranial nerve) occurred in 25% (34) linac v 12.6% (13) GK (p=0.029). Most late side effects occurred in the first 2 years. New/worsened objective trigeminal neuropathy occurred in 9.6% (13) permanently/2.2% (3) transiently with linac and 1.9% (2) permanently (0 transient) with GK (permanent p=0.0162; all p=0.0044). New trigeminal neuralgia occurred in 4.4% (6) permanently/1.5% (2) transiently with linac and 1% (1) permanently with GK (all p=0.048). There was no statistical difference in facial nerve palsy: linac 3.7% (5) permanent /3.7% (5) transient; GK 1% (1) permanent/1.9% (2) transient, but hemi-facial spasm differed: linac 3.7% (5) permanent/1.5% (2) transient versus 2.9% (3) transient with GK (permanent p=0.0492; total p=0.39).

Conclusion: Serious late effects of treatment regarding trigeminal and facial nerve were significantly reduced in patients treated with SRS/SRT with GK compared to linac, likely related to the improved dose conformity with GK reducing radiation dose to these nerves.

OSP27 - ORGANS AT RISK

#10332 : Reirradiation of brainstem: Clinical evaluation and its radiobiological correlation

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**Keywords:** brainstem; re-irradiation; normal tissue tolerance; radiation-related toxicity; radiosurgery; staged radiosurgery.

**Objective:** The main studies focused on radiosurgery-induced injury to the brainstem are only five. The largest study by Foote et al. analyzed 149 patients and found that the dosimetric factors predictive of cranial nerve palsy included Dmax $\geq 17.5$ Gy, prescribed dose $\geq 12.5$ Gy, length of irradiated cranial nerve $\geq 16$ mm and tumor volume $\geq 1.7$cc. Based on this data, the authors concluded that doses $\geq 15$Gy to the brainstem conferred a significant increase in risk for cranial nerve complications. However, there are not clear clinical evidences and indications about re/irradiation of brainstem.

The objective of the study was to analyze the radiation-related toxicity of the brainstem re-irradiation and its correlation with radiobiological parameters.

**Methods:** We analyzed 12 patients who underwent re-irradiation for progression or relapse of tumors of the brainstem or close to it. The clinical results were correlated with radiobiological parameters through the linear-quadratic model to express the re-irradiation tolerance in cumulative equivalent total doses when applied in 2Gy fractions (EQD2cumulative). We used $\alpha/\beta$ values of 2.1 and 3.3Gy.

**Results:** The histology was high-grade glioma in 4 patients, metastases in 5, meningioma in 2 and unknown in 1 patient. Three patients underwent 5 radiation treatments (1 3Dconformal RT, 4 SRS), 1 patient received 4 RT treatments (1 3DCRT and 3 SRS), 1 patient received 3 RT treatments (3 SRS), 6 patients received one 3DCRT and 1 SRS course, 1 patient received two SRS treatments. The cumulative EQD2 (3,3) ranged 26.5–116.2Gy (mean ± S.D. 73±26.9Gy). The cumulative EQD2 (2,1) ranged 30.5–130Gy (mean ± S.D. 79.5±29.4Gy). The mean time interval between radiotherapy courses was 18.7 ± 20 months (range 0-72 months; median 12 months; n = 23). The mean PTV was 119.9±369.5cc (range 0.1–1455.6). The mean follow-up was 44 months (range 10-145 months). At the time of analysis 7 patients were alive. No radionecrosis was reported. Only 1 patient developed G1 ataxia and dysphagia and only 1 patient developed a G2 ataxia. Both patients showed a neurological improvement after 1 month of corticosteroid therapy.

**Conclusion:** The overall outcome in the twelve described patients seems to be encouraging. Modern irradiation systems make it reasonable to administer successive irradiation treatments. Involving only 12 patients, this analysis cannot be expected to provide ground for us to draw definitive conclusions. However, the retrospective EQD2 values reported in this study can be used as starting point for a study focused on dose-reference for safe re-treatments.

## OSP27 - ORGANS AT RISK

**#9007 : Dosimetric comparison of sector-blocked and non-sector-blocked Gamma Knife Perfexion treatment plans for trigeminal neuralgia**

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**Keywords:** Gamma Knife, Sector Blocked, Trigeminal Neuralgia

**Purpose:** To compare the dosimetry of sector-blocked and non-sector-blocked treatment planning techniques for patients with trigeminal neuralgia (TN).

**Methods:** Thirteen cases of TN were evaluated in this IRB approved retrospective study. Gamma Knife treatments were performed using a single 4mm shot placed at/or near the DREZ. Thin-slice MRI images (SPGR or T2) were used for contouring and treatment plans were generated on GammaPlan v10. All MRI contour sets and prescription doses (range 75-80 Gy) used for sector-blocked (mixing blocked collimators with 4 mm collimator diameters) treatment plans were reused to generate non-sector-blocked (all sectors 4mm) treatment plans. All treatment plans were evaluated by a single radiation oncologist. A paired t-test was used to statistically compare sector-blocked and non-sector-blocked treatment plans.

**Results:** In sector-blocked plans, a median of 3 sectors were blocked (range 1-4 sectors). The average volumes of normal brain tissue receiving 10, 8, 5, 2, and 1 Gy for sector-blocked vs. non-sector-blocked treatment plans were (0.94±0.25 vs. 0.90±0.28 cc, p=0.07), (1.36±0.32 vs. 1.28±0.40 cc, p=0.02), (2.76±0.67 vs. 2.49±0.79 cc,
p<0.01), (12.05±2.89 vs. 10.16±3.15 cc, p<0.01), and (43.58±13.07 vs. 32.57±12.74 cc, p<0.01), respectively. Sector-blocked plans had a slightly higher average maximum dose to the normal brain tissue than non-sector-blocked treatment plans (47.2±16.0 vs. 46.5±16.9 Gy, p=0.65). The average volumes of brainstem receiving 10, 8, 5, 2, and 1 Gy were 29%, 17%, 17%, 25%, and 52% higher in non-sector-blocked treatment plans, when compared to corresponding sector-blocked treatment plans respectively. The average maximum doses to the brainstem for sector-blocked vs. non-sector-blocked treatment plans were (37.0±22.8 vs. 41.0±23.3, p<0.01). Sector-blocked treatment plans had a higher average maximum dose to the cerebellum than non-sector-blocked treatment plans (10.5±6.8 vs. 7.5±4.7 Gy, p<0.01). The average volumes of ipsilateral temporal lobe receiving 10, 8, 5, 2, and 1 Gy were 29%, 4%, 14%, 33%, and 38% higher in sector-blocked treatment plans when compared to non-sector-blocked treatment plans, respectively. The average maximum doses to ipsilateral temporal lobe for sector-blocked vs. non-sector-blocked treatment plans were (26.8±20.1 vs. 27.8±20.8 Gy, p=0.24). The mean beam-on times for sector-blocked vs. non-sector-blocked treatment plans were (57.8±12.8 vs. 37.4±6.5 minutes, p<0.01).

Conclusions: Treatment plans utilizing a sector-blocked shot were capable of achieving greater brainstem sparing than those using a non-sector-blocked shot, but at the cost of delivering higher doses to the cerebellum and temporal lobes, and with significantly longer treatment times.

OSP27 - ORGANS AT RISK

#10441 : The role of infundibulum in preventing hypopituitarism after stereotactic radiosurgery for functional pituitary adenomas

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Keywords: Stereotactic radiosurgery, functional pituitary adenomas, secretory adenomas, hypopituitarism, gammaknife, pituitary stalk, infundibulum

Objectives: The most common side effect of stereotactic radiosurgery (SRS) for pituitary tumors is the development of pituitary dysfunction. Secretory adenomas require higher radiation doses to achieve cessation of excess hormone production. The aim of this study was to identify the role of maximum radiation dose delivered to the infundibulum and to find a cutoff value which could predict the development of hypopituitarism in secretory pituitary adenomas.

Methods: In this retrospective study, patients with secretory pituitary adenomas, who were treated with SRS at All India Institute of Medical Sciences, New Delhi from January 2010 to June 2013 and had minimum radiological and hormonal follow-up of 2 years were enrolled. Radiological follow-up by means of contrast MRI done annually and ophthalmological follow-up by means of 6 monthly visual field charting were also done. Complete hormone analysis was done immediately before SRS and at 6 monthly intervals in follow-up. Good endocrinologic outcome was defined as decrease or normalization of hormone levels following SRS.

Results: A total of 45 patients satisfied the study criteria and were included in the study. The incidence of new or worsened hypopituitarism was 40% with a mean follow-up in these patients of 41+/−12 months (range 24 to 66 months). Maximum infundibulum dose delivered was found to be an independent predictor of development of post-SRS hypopituitarism (p=0.001). The average maximum dose received by infundibulum in patients without hypopituitarism was 14.4 ± 6 Gray (Gy) and in those with hypopituitarism was 23.5 ± 9.2 Gy, which was found to be statistically significant (p=0.001). Based on the ROC curves, a cutoff value of ≥18.4 Gy was obtained which could predict development of post-radiosurgical hypopituitarism, with a sensitivity of 77.78% and specificity of 74.07%. Tumor control rate was 95.6% at a mean radiological follow-up of 40.3+/−11 months (range 24-66). Following SRS, 86.7% patients showed similar or improved vision from before SRS. Good endocrinologic outcome was achieved in 80.6% for acromegaly patients (25/31), 71.4% for patients with prolactinomas (5/7), and 90% for Cushings disease patients (9/10).

Conclusion: Our study shows that maximum radiation dose delivered to the infundibulum is an independent risk factor for development of postradiosurgical hypopituitarism. The study also shows that keeping the maximum radiation dose received by the infundibulum below 18.4 Gy significantly reduces chances of development of new onset hypopituitarism in secretory pituitary adenomas.

OSP28 - WFSBS: SKULL BASE

#9907 : Upfront hypofractionated frameless stereotactic radiotherapy for large petroclival meningioma

Alfredo Conti (1), Antonio Pontoriero (2), Giuseppe Iatì (2), Federica Midili (3), Carmelo Siragusa (3), Anna Brogna (3), Stefano Pergolizzi (2)
The paradigm of treatment of skull base meningioma. Hypofractionated stereotactic radiation therapy may change quality of life. Even though further studies are necessary, tumor control was achieved in 87.5% of patients without impairment of neurological status or of the skull base. Tumor control was achieved in 87.5% of patients without impairment of neurological status or of the skull base. Tumor control was achieved in 87.5% of patients without impairment of neurological status or of the skull base. Tumor control was achieved in 87.5% of patients without impairment of neurological status or of the skull base.

**Methods:** A series of 32 patients with a petroclival and sphenopetral meningiomas with a volume >8cc were treated with upfront hypofractionated radiosurgery between 2007 and 2016 at the CyberKnife Center of the University of Messina, ITALY. Patients received a dose of 25-45 Gy in 5-15 fractions. Outcome measures included progression-free survival, neurological and quality of life outcome.

**Results:** At mean follow up of 56 months (range 6-114), tumor volumes increased in 12% of patients, remained stable in 44%, and decreased in 44%. Kaplan-Meier actuarial progression free survival rates at 3, 5, 8, and 10 years were 100, 89, 82, and 80% respectively. No complications were recorded except from medically controlled trigeminal neuralgia that occurred in 15.6% of patients. At last clinical follow-up, 90.6% of patients demonstrated no change or improvement in their neurological condition and quality of life.

**Conclusions:** In our series, we used upfront frameless stereotactic radiotherapy for the most challenging tumor of the skull base. Tumor control was achieved in 87.5% of patients without impairment of neurological status or quality of life. Even though further studies are necessary, hypofractionated stereotactic radiation therapy may change the paradigm of treatment of skull base meningioma.

**Keywords:** Petroclival meningioma; large tumors; skull base; radiosurgery; cyberknife

**Background:** Large petroclival meningiomas are extremely challenging tumors because of their intimate location with critical neurovascular structures. Microsurgical resection is often associated with significant morbidity. For this, combined surgical/radiosurgical treatment is advocated. In this study, we evaluate the outcomes of petroclival meningiomas treated with hypofractionated CyberKnife SRS as a primary treatment modality.

**Objective:** To assess efficacy and safety of Leksell Gamma Knife Radiosurgery (LGKRS), in terms of tumor control (TC) and permanent symptomatic adverse radiation effects (AREs) (end points); to identify some prognosticators significantly influencing the end-points in patients affected with glomus jugular tumors (GJTs).

**Methods:** Between April 1996 and December 2013, 51 consecutive patients with GJTs underwent LGKRS at our Department and were followed up for at least 3 years. Males/females ratio was 10/40; mean age was 56.6 years (20-82). In 21/50 (42%) patients, an endovascular embolization was performed and 19/50 (38%) cases underwent one or more surgical procedures before LGKRS. At the time of treatment, GJTs were classified according to the Glasscock–Jackson (G-J) grading as follows: Grade I 11 patients (23%), Grade II 23 (46%), Grade III 6 (11%), and Grade IV 10 (20%). Mean and range dose planning parameters were as follows: gross target volume (GTV: 0.22 mL, 0.06-0.70), prescription dose (PD: 16.8 Gy, 12.0-24.0), prescription isodose (PI: 49.70 %, 40-55), maximum dose (MD: 32.62 Gy, 24-48) and shot number (13.3, 2-33). On GK day, stereotactic localization was performed using volumetric and T1 fat saturated MRI sequences. Univariate logistic regression analysis was performed to evaluate which of the following independent variables – G-J grading, pre-LGKRS endovascular treatment, pre-LGKRS surgery, GTV and PD, adjusted for age and sex – could potentially influence the end points.

**Results:** Median survival was 53.9 months (37.7-183.50). At last clinical follow-up, an improved or stable neurological examination was observed on the whole series with no symptomatic AREs. TC was achieved in 96.0% of cases (48/51) with an actuarial progression-free survival rate of 97% at 10 years. No malignant

**Keywords:** glomus jugular tumors, gamma knife radiosurgery, prognosis

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**OSP28 - WFSBS: SKULL BASE

#10239 : Gamma Knife radiosurgery for glomus jugular tumors. Results on 51 treated patients followed-up for al least 36 months

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transformation or radiation induced tumors were observed. Statistical analysis showed that G-J Grade II \((p=0.043)\) was the only prognosticator positively affecting the probability of TC in such patients.

**Conclusion.** Despite the particularly critical location of GJTs, long-term outcomes show that LGKRS reveals to be an extremely effective and safe primary or adjuvant treatment in such tumors, as well.

OSP28 - WFSBS: SKULL BASE

**#9965 : Long-term outcome of low dose \((\leq 12 \text{ Gy})\) gamma knife radiosurgery for skull base meningiomas**

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**Keywords:** meningioma, skull base, gamma knife, radiosurgery

**Objective:** The optimal doses of radiosurgery for skull base meningioma have been reported 13 - 15 Gy. We have been intended to perform low dose radiosurgery for treating close to critical structure of skull base. We evaluate long-term efficacy of low dose \((\leq 12 \text{ Gy})\) gamma knife radiosurgery (GKS).

**Methods:** 295 patients treated with GKS (median treatment volume: 6.9 cm³, median prescribed marginal dose: 12 Gy, range 8 - 12 Gy) were followed for a mean of 104 months (range 6 - 252 months). 22 patients with large volume tumors were treated by two-staged radiosurgery (volume fractions).

**Results:** Local tumor growth control was 85%, Actuarial rates of progression-free survival at 5, 15, and 15 years were 90%, 82%, and 74%, respectively. 6% were malignant transformation of tumors. Univariate analysis revealed only without preGKS surgery was positive factor and age, sex tumor volume, treatment dose, staged surgery were not significant for tumor control. The clinical outcome was improved in 15% and unchanged in 64% of patients. The radiation induced neuropathy occurred 7.8% (22 patients). The trigeminal neuralgia considering most devastating symptoms was improved or disappeared in 60% (6/10 patients), but new trigeminal neuralgia was occurred in 3.7% (11 patients).

**Conclusion:** The low dose GKS \((\leq 12 \text{ Gy})\) for skull base meningiomas can achieve long-term tumor growth control with low morbidity with a long-term follow-up period of > 8.5 years. But the malignant transformation was still difficult to control; this not related radiosurgery however this may be natural course.

OSP28 - WFSBS: SKULL BASE

**#9939 : Long term follow up of jugular glomus treated with radiosurgery.**

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**Keywords:** Radiosurgery, Glomus, long term

The treatment of paraganglioma of the jugular foramen remains controversial due to its high morbidity, given the anatomical position, the presence of major vessels and cranial nerves that are often found within the lesion.

Although benign, these tumors sometimes present rapid growth and the neurological symptoms that accompany are hearing loss, cerebral nerves palsies and tinnitus.

For many years surgery, with or without previous embolization has been the treatment of choice, but the inability to do a complete resection, and complications have made surgeons think of alternative treatments such as radiotherapy and most recently radiosurgery. One of the major uncertainties that have always accompanied radiosurgery as treatment for jugular glomus is its effectiveness and long-term results. We present a series of 29 patients treated with radiosurgery, over 50% of patients had undergone surgery, with a mean of 73 months (> 6 years), a symptomatic tumor control 96.5%, and morbidity post irradiation of 13% (Grade I RTOG). According to our data and that found in contemporary literature, radiosurgery has replaced surgery as the primary treatment of jugular foramen paragangliomas.

OSP28 - WFSBS: SKULL BASE

**#10451 : Gamma Knife radiosurgery for recurrent WHO grade 2 meningiomas**

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The treatment of paraganglioma of the jugular foramen remains controversial due to its high morbidity, given the anatomical position, the presence of major vessels and cranial nerves that are often found within the lesion.

Although benign, these tumors sometimes present rapid growth and the neurological symptoms that accompany are hearing loss, cerebral nerves palsies and tinnitus.

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Keywords: Gamma knife, radiosurgery, grade 2 meningioma

Objectives: WHO grade 2 meningiomas are aggressive tumors associated with a high recurrence rate leading to repeated surgical procedures, which can seriously worsen a patient’s neurological status. Although radiosurgery is an increasingly popular technique, its role in the management of grade 2 meningiomas has yet to be defined. In this study, the authors aimed to evaluate radiosurgery in achieving control of proven tumor progression occurring after resection of grade 2 meningiomas.

Methods: This retrospective study included consecutive patients, between 2000 and 2015, treated by gamma knife radiosurgery (GKRS) for radiologically proven progression of a previously surgically treated grade 2 meningioma.

Results: Thirty patients were eligible for analysis. There were 10 men and 20 women with a mean age of 59 years. The mean radiation dose was 15.2 Gy (range 12–21 Gy), and the mean target volume was 5.4 cm³ (range 0.194–14.2 cm³). Thirty-eight radiosurgical procedures were performed in the 30 patients. The mean progression-free survival after radiosurgery was 32.4 months among those with progression in a target irradiated volume and 26.4 months among those with progression in any intracranial meninges. With a mean follow-up of 56.4 months (range 12–108 months), the 12-, 24-, and 36-month actuarial local control rates for all patients were 75%, 52%, and 40%, respectively, and the regional control rates were 75%, 48%, and 33%. A single case of transient hemiparesis completely resolved without sequelae.

Conclusions: Radiosurgery appears to be a safe and effective treatment for the local control of delayed progression after resection of a WHO grade 2 meningioma. Higher radiation doses similar to those applied for malignant tumors should be recommended when possible.

OSP28 - WFSBS: SKULL BASE

#9966: Current and future for treatment strategy of skull base hemangiopericytoma in stereotactic radiosurgery: Advantage of use pathological micro-anatomy

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Keywords: Gamma knife, hemangiopericytoma, anatomy

Rationale: Hemangiopericytoma (HP) is well known as one of very rare intracranial tumors, and especially skull base one which is very close to the cavernous sinus should be too difficult to be cured by microsurgery alone because of much abundant feeding arteries. If there is residual tumor, it will have often opportunity to develop extracranial metastases. In addition, we should do stereotactic radiosurgery to prevent tumor regrowth. In our institute, we have tried to install and investigate pathological micro-anatomy in Gamma plan to grasp relationship between the tumor and surround vital structures, and hope to prevent tumor shrinkage without any neurological deficit.

Materials and Methods: We already treated 11 HP cases with Gamma knife surgery (GKS) after surgical resection, and median prescribed dose was 12 (10-25) Gy. Among of them, 36.4% (4/11) could be controlled, but 54.5% (6/11) experienced extracranial metastases. The clinical results were failure, and then we have investigated micro-anatomy to detect tumor origin and its extension much more precisely to make complete dose planning. In detail, we irradiated higher dose (80% isodose area) to the tumor origin as a priority target, and also cover the tumor as much as possible to make tumor necrotizing due to feeding arterial occlusion pathologically.

Result: We experienced another case whose tumor was located in the Meckel’s cave which was looked like trigeminal schwannoma, but the onset was very progressive abducens nerve palsy. At that moment, we investigated micro-anatomy in Gamma plan, but didn’t make clear diagnosis. So we decided to do surgical resection to define pathology with maximal volume reduction. We couldn’t remove sufficiently because of terrible bleeding from the tumor, and did GKS for residual with 24Gy as prescribed peripheral dose according to the micro-anatomical simulation. The patient experienced no deficit with tumor disappearance at 6 months later to GKS, and has to be observed much longer follow-up.

Conclusion: We will progress the knowledge and clinical experiences of GKS based on pathological micro-anatomy to establish heavy particle microsurgery system to provide patients complete remission to prevent extracranial metastases.
**OSP29 - GLIOMAS**

#9938: A phase I/II trial of 5-fraction stereotactic radiosurgery with 5mm margins with concurrent and adjuvant temozolomide in newly diagnosed glioblastoma: quality of life and updated outcomes

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**Keywords:** radiosurgery, glioblastoma, glioma, phase I trial, quality of life

**Objectives:** We determined the maximum tolerated dose (MTD) of 5-fraction stereotactic radiosurgery (SRS) with concurrent and adjuvant temozolomide (TMZ) in glioblastoma (GBM).

**Methods and Materials:** Patients received 5 consecutive days of SRS in a 3+3 design with 25, 30, 35 or 40 Gy targeting the GTV with a 5 mm CTV and 0 mm PTV (maximum size 150 cm³). A dose limiting toxicity (DLT) was Grade 3-5 CNS toxicity within 30 days, with life-long assessment for late SRS-related adverse radiation effect (ARE). Secondary endpoints included progression free survival (PFS), overall survival (OS), and health-related quality of life (HRQOL). Changes from baseline for 9 HRQOL measures were calculated at baseline and in follow-up.

**Results:** From 2010 to 2015, 30 patients were enrolled. Median age was 66 years (range 51-86) with median KPS of 80 (range 50-100). Median GTV was 26.8 cm³ (range 3.8–81.0) with a PTV of 60.2 cm³ (range 14.7–137.3). DLTs occurred in 2 patients and ARE in 12 patients: 5 developed pseudoprogression at a median of 3.0 months and 7 developed grade 1/2 radionecrosis (RN) at a median of 8.0 months after SRS. RN was not associated with dose (p=0.8) or PTV size (p=0.09). With a median follow-up of 14.0 months, median OS and PFS were 14.9 (95%CI 10.9-21.4; range 1.7 - 62.4) and 8.2 (95%CI 4.6-10.5; range 1.7-55.8) months, respectively. RN was associated with improved median survival (33.0 vs. 11.3 months; p=0.05). HRQOL assessment compliance was 76% at 12 months. Communication deficit worsened over time (-1.7 points/month, p=0.008), with no significant changes in the other 8 HRQOL scales. While RN was not associated with a significant decline in any HRQOL scale, disease progression was associated with communication deficit (p=0.01).

**Conclusion:** Five-fraction SRS with 5mm margins with TMZ for newly diagnosed GBM has similar OS and HRQOL compared to conventional fractionation. Patients with radiation necrosis, the primary ‘toxicity’, had longer survival with no decline in HRQOL.

**OSP29 - GLIOMAS**

#9892: Treatment results for patients with glioblastoma treated on Leksell Gamma Knife

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**Keywords:** Leksell Gamma Knife, glioblastoma,

**Objectives:** Main purposes of this study was to analyze treatment results for a group of glioblastoma patients treated in our center on Leksell Gamma Knife (LGK) over past more than twenty years.

**Methods and materials:** Altogether 126 patients were treated for glioblastoma during 1992-2014 in our institution and analyzed in this study. There were 69 (55%) male and 57 (45%) female with median age of 56 years (range 17-80 years). From this group 123 (98%) underwent surgery, 126 (100%) radiotherapy and 116 (92%) chemotherapy before the LGK radiosurgery. Median Karnofsky score before the LGK radiosurgery for patients in this group was 90 (range 50-100), median time from diagnosis of glioblastoma to the LGK radiosurgery was 12 months (range 1-96 months). Median tumor volume was 3.75 cm³ (range 0.04 – 37.10 cm³) and location: 45 (36%) temporal, 31 (25%) frontal, 21 (17%) parietal, 12 (9%) occipital and 17 (13%) other location. All patients in this study were treated by the LGK radiosurgery performed in one single fraction with median minimal tumor dose of 12 Gy (range 10 – 25 Gy) on median 50% (range 40 – 86%) isodose line. Two and more LGK radiosurgeries were performed in 19 (15%) cases. Median patients’ survival since glioblastoma
diagnosis was 20 months (range 6 – 237 months) and median patients’ survival after the LGK radiosurgery was 7 months (range 1 – 223 months).

**Conclusion:** Treatment on the LGK was well tolerated by all patients. It appears a good final therapeutic option for glioblastoma after previous surgery, radiotherapy and chemotherapy for a small residual volume.

**OSP29 - GLIOMAS**

**#10302 : CyberKnife treatment for progressive supratentorial malignant glioma: single institution study.**

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**Keywords:** glioblastoma, radiosurgery, hypofractionation, CyberKnife, brain, malignant glioma progression

Study objective: retrospective analysis of results of CyberKnife radiosurgery and hypofractionated irradiation for small to medium-size progression of supratentorial malignant glioma in 61 selected patients treated in Burdenko Neurosurgical Institute in 2009-2016.

Patients and methods: 32 men and 29 women was included, mean age was 47,2 years. 39 patients had primary glioblastoma, 5 - secondary glioblastoma, 6 - anaplastic astrocytoma, 7 - anaplastic oligoastrocytoma and 4 had anaplastic oligodendroglioma. 60 patient underwent tumor removal and 1 stereotactic biopsy. 57 patients received postoperative radiotherapy with 58-60 Gy in 29-33 fractions and other 4 had shorter courses (33-45 Gy in 12-18 fractions). Patients with glioblastoma and anaplastic astrocytoma received temozolomide 75 mg/m² during radiotherapy. After completion of radiotherapy 54 patients received adjuvant chemotherapy (35 had temozolomide-based regimen and 19 - other regimens). Mean time from completion of radiotherapy to first progression was 8,2 months in glioblastoma group (44 patients) and 16,3 months in anaplastic glioma group (17 patients).

First progression as single growing lesion in primary tumor region (local type of «monofocal» progression) was observed 31 of 44 (70%) glioblastoma and 14 of 17 (82%) anaplastic glioma patients. 6 glioblastoma and non of anaplastic glioma patients had distant type of monofocal progression (single new distant lesion with absence of progression in primary tumor region). Other 12 patients had «multifocal» progression (2 had several local growing foci, 2 had several distant foci and 8 had at least 1 growing local lesion and 1 new distant lesion).

Lesions with volume less than 11 cm³ was treated with single median dose of 20 Gy, bigger lesions (up to 58 cm³, median volume - 12,7 cm³) were irradiated with 3 to 7 fractions up to total dose of 21-39,5 Gy (every day or every other day). Mean follow-up was 13,9 months after CyberKnife salvage irradiation.

**Results:** mean time from salvage irradiation to second progression was 8,2 months in glioblastoma group and 17,2 months in anaplastic glioma group; overall survival after salvage irradiation was 16,5 and 31 month respectively. In 6 of 92 irradiated lesions (6,5%) clinically significant adverse radiation effect developed, all were treated successfully with bevacizumab. In primary glioblastoma group (39 patients) addition of more than 3 infusions of 400 mg bevacizumab to CyberKnife treatment was statistically significant associated with better overall survival (p=0.01).

**Conclusion:** CyberKnife irradiation with bevacizumab is an effective option for monofocal and multifocal forms of supratentorial glioblastoma progression.

**OSP29 - GLIOMAS**

**#10067 : Hypofractionated stereotactic radiotherapy for the treatment of recurrent high-grade gliomas: radiological response and survival outcomes**

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**Keywords:** high-grade gliomas, recurrences, hypofractionation

**Objectives:** The study aimed to analyze radiological responses of recurrent high-grade glial tumors treated with hypofractionated stereotactic radiotherapy (HSR) and to
Methods: We retrospectively analyzed 104 patients managed with HSR for recurrent high-grade gliomas between 2011 and 2016. All patients had experienced progression after a complex treatment with surgery and chemo-radiotherapy. 49% of patients were diagnosed with glioblastoma and 51% with grade III glioma. The indications for HSR were locally progressing tumors in 77% or new distant tumors in 23% of patients. Tumor recurrence was determined and localized with MRI matched against C11-methionine PET/CT. The mean target volume was 36.4 cm³, ranging from 2.8 to 127.2 cm³. The prescription dose was volume-dependent from 18 to 30 Gy delivered in three fractions with interfraction intervals from 2 to 10 days. HSR was performed with Cyber Knife (Accuray, Sunnyvale, CA, USA) and linear accelerator TrueBeam STX (Varian Medical Systems, Palo Alto, CA). After treatment, the patients underwent follow-up imaging examination (contrast-enhanced MRI and/or PET/CT with C11-methionine) every 2 months. Post-treatment MR and PET images were fused with initial pre-treatment images and volumetrically analyzed with Gamma Plan software (Elekta AB, Stockholm, Sweden). Radiological response was evaluated using RANO criteria. PFS and OS were calculated using the Kaplan-Meier method. The median follow-up time was 11 months.

Results: We found that patients with recurrent glioblastoma and grade III glial tumors demonstrated a similar pattern of radiological response to HSR: none of the patients achieved a complete response, 9% of patients with glioblastoma and 11% with grade III glioma showed a partial response, 32% and 42% stable disease, 23% and 19% progressive disease, 36% and 28% pseudo-progression. Median progression-free survival from the date of HSR was 8.6 months for patients with glioblastoma and 13.6 months for patients with grade III glioma (p=0.001). The invasion of the tumor into deep brain structures appeared to be a crucial factor affecting OS (HR=6.18, p<0.001).

Conclusion: Recurrence often means a fatal outcome for the patient, as standard treatments are no longer effective. This is why HSR may be considered an effective salvage treatment for patients with recurrent high-grade gliomas. A precise determination of recurrent active parts of the tumor is essential for the success of this approach.
Introduction: Glioblastoma (GBM) is the most malignant form of astrocytoma with a dismal outcome. Despite advances in treatment, the average survival in patients with recurrent GBM remains 6-10 months. In this study we evaluated the role of stereotactic radiosurgery (SRS) in the management of recurrent GBM.

Materials and Methods: A retrospective review of the Cleveland Clinic brain tumor database (1997-2016) was performed following IRB approval. Overall survival (OS) and progression free survival (PFS) from salvage SRS were the primary and secondary end points, respectively. Molecular analysis was performed using standard techniques. Response to SRS was assessed on T1 with contrast and T2-FLAIR MRI images. The log rank test and Cox proportional hazard models were used for analysis.

Results: Fifty-three patients with 75 lesions underwent salvage SRS. Eleven patients (21%) had multiple lesions and one patient (1.8%) underwent treatment in three stages for a single lesion (12 Gy each). The median age at diagnosis and SRS was 58.9 years and 60.5 years, respectively. Overall, 68% (n=36) of patients were male and the majority (70%, n=34) had good performance status (KPS>80). Most patients (74%, 56/75) had either gross total tumor resection (57%, 43/75) or subtotal resection (17%, 13/75) and all surgery was followed by chemoradiotherapy prior to salvage SRS. Most lesions were treated with at least two additional procedures, following index procedure prior to salvage SRS (56%, 42/75). Majority (85%, n=11/13) of patients had wild type IDH, 53% (n=10/19) had extensive Ki-67 staining (>30%) and 71% (n=10/14) were MGMT unmethylated.

Median OS post SRS was estimated to be 11.0 months (95% C.I. 7.1-12.2) and median per-lesion PFS was 4.1 months (95% C.I. 2.6-4.4). Median tumor diameter and volume were 2.55 cm and 3.80 cm³, respectively. Median prescription dose was 18 Gy (12-24 Gy) and homogeneity index was 1.90 (1.11-2.02). KPS>80 was independently associated with longer PFS (HR: 2.38, CI: 1.02-5.56, p=0.04).

Conclusions: Good performance patients with smaller tumor volumes and treated at higher homogeneity index were associated with longer OS/PFS despite multiple prior treatments for recurrent GBM. SRS for recurrent GBM is reasonable salvage treatment option for these patients.

PHYSIQUE

#9957 : A novel index for assessing radiosurgery treatment plan quality

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Keywords: radiosurgery, plan, quality, gradient, conformity, index

One of the hallmarks of intracranial radiosurgery is a steep dose gradient from the periphery of the target into surrounding brain. Clinical studies have consistently backed up the importance of steep dose fall off through evidence from symptomatic complications (Flickinger, Korytko, Blonigen, Minniti). The available data suggests that there are threshold doses, above which, the risk of symptomatic radionecrosis increases with volume irradiated. It therefore makes sense to concentrate on limiting doses above these thresholds, ignoring lower doses that may be clinically irrelevant.

Several metrics have been proposed to quantify dose fall off. The Gradient Index (GI) (Paddick and Lippitz) remains the most commonly used metric, serving as a practical volumetric assessment of dose fall off. Upon the formulation of the GI the authors identified the limitation that this metric is not suitable for comparing plans of incongruent conformity. In order to overcome this limitation, Thomas et al proposed the AUC metric, as an alternative for comparative plan evaluation. The AUC metric is the integral area under the dose-volume histogram (DVH) between the 50% of the prescription dose (PD) and the prescription isodose (PI). This metric provides a useful dose-volume product (Energy in Joules) that quantifies dose fall off outside the target, which the authors have previously used as a predictor for normal tissue complications. This metric, however, still suffers from dependence to conformity and prescription dose whilst not accounting for dose deposition inside the target.
To overcome limitations of currently used metrics, we propose a novel metric, the **Efficiency Index** (EI), based on the same principle of integrating areas under differential DVHs:

$$EI = \frac{D_{\text{minTV}} \cdot TV \cdot \text{dose}}{\text{PD} \cdot V \cdot \text{dose}}$$

where $D_{\text{minTV}}$ is the minimum dose in the target, $D_{\text{max}}$ is the maximum dose, PD is prescription dose, TV is target volume and $V$ is the volume occupied by the 50% PD isodose line.

The EI can be easily calculated using differential DVHs of the TV and of volume $V$. The value is effectively the proportion of energy deposited inside the target within the 50% of PD isodose line. It has theoretical limits of 0 and 1, with 1 being perfect. It combines conformity, gradient and a high mean dose to the target into a single value.

The EI has been calculated for 40 clinical SRS plans (mean TV of 3.8 cc) with a GI range of 2.49 – 3.03 and a mean of 2.74. The calculated EI values ranged from 0.403-0.551 with a mean of 0.496.

**SKULL BASE**

**#9994 : Stereotactic radiosurgery for newly diagnosed and recurrent chordomas of the skull base and spine**

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**Keywords:** Chordoma, Radiosurgery, Skull Base, Spinal

**Purpose/Objectives:** With conventionally fractionated radiotherapy, local failure typically occurs in over 30% of chordomas by 3 years. Given that the alpha/beta ratio for these slowly growing tumors is likely low, we investigated if dose escalation through hypofractionated stereotactic radiosurgery (SRS) may improve local control.

**Methods/Materials:** An IRB-approved retrospective review identified 35 consecutive patients with new or recurrent chordoma treated to 36 sites (n=25(69%) in skull base, n=11(n=31%) in spine) with SRS (in 1 to 5 fractions) from 2000 to 2016. SRS treated 22 newly diagnosed tumors (61%) following surgery and 14 (39%) tumors recurrent after radiotherapy (n=11) or surgery alone (n=3). The median SRS dose for newly diagnosed tumors was 40 Gy in 5 fractions (range, 20-45 Gy in 1-5 fractions) for a median EQD2 (equivalent dose in 2 Gy fractions, assuming an alpha/beta of 4) of 80 Gy4 (range, 64-134 Gy4) and 29 Gy in 5 fractions (range, 18-50 Gy in 1-5 fractions) for a median EQD2 of 51 Gy4 (range, 24-117 Gy4) to recurrent tumors. Local control (LC) within or adjacent to the SRS field, regional control (RC) within the surgical corridor or in the draining lymph nodes, distant control of metastatic disease (DC) and overall survival (OS) were estimated with the Kaplan-Meier method, censored at last follow-up. Acute and late toxicity were assessed via CTCAE V4.0.

**Results:** Newly diagnosed chordomas had a median follow-up of 32 months (range, 8-142 months) and a 3-year LC of 88% (95% confidence interval (CI), 59-97%), RC of 92% (CI, 56-98%) and DC of 89%. With a median follow-up of 24 months (range, 5-193 months), recurrent tumors had a 3-year LC of 92% (CI, 54-97%), RC of 54% (CI, 24-76%) and DC of 86%. At last follow-up, 20 of 22 newly diagnosed patients were still alive (91%), but 7 of 13 recurrent patients (54%) were deceased, for a median OS of 94 months. Late toxicities occurred in 6 patients (17%): cranial neuropathy (grade 2 in three patients and grade 3 in one patient), vertebral body compression fracture (grade 2), and treatment induced trigeminal neuralgia (grade 2).

**Conclusions:** With a 3 year overall local control of 88%, these early data suggest that dose escalation through hypofractionated SRS provides rates of local control comparable or higher than historical series of fractionated radiotherapy for selected, smaller tumors, and supports a low alpha/beta ratio for chordoma. Measures to improve regional control for recurrent tumors are warranted.
SKULL BASE

#10178 : Multicenter study for the treatment of meningioma close to anterior optic-pathways or involving the optic nerve sheath with Gamma Knife: Preliminary results with stereotactic hypo-fractionation approach on a series of 180 patients with at least 2-year-FU

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Keywords: gamma knife radiosurgery, optic pathways meningiomas, hypofractionation

Objective: Gamma Knife Radiosurgery (GKRS) has proved to be an outstanding technique while treating skull base (SB) meningiomas (MNs) inferior to 15-20 mL. However, single session GKRS seems sometimes hazardous in cases of anterior optic pathways (AOP) close-fitting lesions or larger tumors, due to potential risks of radiotoxic effects. In order to lower this risk of damage to AOP and keep treatment efficacy, many Centers adopted hypofractionation protocols using either G-frame or relocatable Extend system. Objective of this multicenter study is to describe results obtained with those techniques evaluating the following end-points: local tumor control, ophtalmological outcome (visual acuity and visual field), permanent adverse radiation effect rate and other radiosurgery-related neurological deficits.

Methods: Our protocol consists of a 3 GKRS daily hypo-fractionating treatments (1 session/24 hours; 5-7 Gy/session). Stereotactic imaging (routinely an 1.5 Tesla MRI) is performed the first day. Indications for stereotactic hypo-fractionation approach were as follows: histopathology or clinical and neuroimaging features consistent with MNs close to the AOP or with direct optic sheath invasion or anterior SBMNs exceeding 15-20 mL. From February 2006 to December 2014, 272 patients underwent stereotactic hypo-fractionation treatment in five Centers and 180 of them were followed-up for at least 2 years. Females were 142 and 38 males (ratio 3.7:1), mean age was 50.02 years (range 10-85). There were 110 (61%) primary lesions and 70 (39%) residual meningiomas (G1/GII, 63/7). Location was classified as close to AOP 159 (88%) or involving the optic nerve sheath 21 (12%). Mean gross target volume (GTV) was 6.29 mL (0.1-30.2 mL). Mean prescription isodose was 50% (47-60%). Mean cumulative prescription dose was 19.49 Gy (15-21 Gy), according to GTV and AOP involvement. Follow-up schedule included complete neuro-ophtalmological assessment and contrast-enhanced MRI every six months for the first year and annually thereafter.

Results: Mean follow-up was 37.5 months (25.3-114 months). 155 (86%) patients were stable (no pre-GK deficit) or improved; 17 (9.5%) showed an unchanged outcome while 8 (4.5%) worsened. Radiological outcome can be summarized as follows: 11 lesions (6%) showed a >50% shrinkage, 74 (41%) an <50%
shrinkage; 87 (48.5%) were unchanged and 8 (4.5%) progressed.

Conclusion: Our multicenter study suggests that GKRS stereotactic hypo-fractionation approach seems to be a safe and effective therapeutic option in selected patients with AOP close-fitting lesions and with optic nerve sheath MNs and in cases larger than 15-20 mL. Visual preservation seems to be associated with a more favourable clinical-radiological outcome.

Poster Display - Beginin tumors /Skull Base

P000 : Combined approach for large vestibular schwannomas: planned subtotal resection followed by Gamma Knife surgery in a series of 40 consecutive cases

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Keywords: vestibular schwannoma, radiosurgery, microsurgery, combined approach

Background: The surgical management of large vestibular schwannomas (VS) yields a high risk for the facial and cochlear nerve functions. Gamma Knife radiosurgery (GKRS) allows optimal functional results in small- and medium-size VS, but cannot be used upfront in large VS because of the high rate of volume-related side effects.

Methods: To develop of a new treatment paradigm of combined approach with microsurgery and GKS, aiming at optimal functional outcome for the facial and cochlear nerves in patients with large VS (i.e. Koos grade IV). To perform planned subtotal resection followed by GKRS in a consecutive a series of patients with large VS. All patients were operated via a retrosigmoid approach in the lateral decubitus position with intraoperative neuromonitoring (IOM). Data pertaining to patient characteristics, surgical and dosimetric features and outcome were collected prospectively at time of treatment and during the follow-up course.

Results: A consecutive a series of 40 patients was treated between 2010 and January 2017. The mean presurgical tumor volume was 12 cm³ (1.47-34.9). All cases had normal facial nerve function (HB I) before surgery, except for one who was in HB IV. Postoperative status showed normal facial nerve function (House-Brackmann grade I) in all patients. In a subgroup of 22 patients in which cochlear nerve preservation was attempted at surgery (patients with residual hearing before surgery), 21 of them (95.4%) retained residual hearing. Among them, 16 patients had normal hearing (Gardner-Robertson class 1) before surgery, and 13 (81.2%) retained normal hearing after surgery. The mean duration between surgery and GKRS was 6.2 months (4-13.9, median 6 months). The mean tumor volume at the time of GKRS was 3.6 cm³ (0.5-12.8), which corresponds to a mean residual volume of 31.4% (range 3.6-50.2) of the pre-operative volume. There was a tendency towards larger postoperative residual volume in patients with attempt to cochlear nerve preservation. The mean marginal prescription dose for GKS was 11.9 Gy (range 11-12, median 12 Gy). Following GKRS, there were no new neurological deficits, with facial and hearing functions remaining identical to that after surgery. The mean follow-up after surgery was 31 months (range 3-72).

Conclusion: Our data suggest that the management of large VS with planned subtotal resection followed by GKRS may yield an excellent clinical outcome with respect to retaining facial and cochlear nerve functions. Our results with this approach are comparable to those obtained with GKRS alone in small- and medium-size VS.

Poster Display - Beginin tumors /Skull Base

P001 : Multi-fraction stereotactic radiosurgery for large cavernous sinus hemangiomas with minimum 3-year follow-up: Long-term outcomes of 40 cases

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Keywords: stereotactic radiosurgery; cavernous sinus hemangiomas
Objective: Stereotactic radiosurgery (SRS) has emerged as a principal alternative to microsurgical resection for small and medium-sized cavernous sinus hemangiomas (CSH). However, large CSH management remains a challenge for the neurosurgeon. Although preliminary studies have demonstrated that multi-fraction SRS for large CSHs is both safe and effective, the number of patients in the clinical series and the length of follow-up were limited. This study aimed to clarify the long-term outcomes of multi-fraction SRS for the treatment of large CSHs with minimum 3-year follow-up.

Methods: Between January 2008 and June 2012, forty patients with large CSHs underwent multi-fraction SRS. Thirty-seven patients underwent radiosurgery as primary treatment modality based on clinical and imaging criteria. Three patients had previous operation. The mean volume of the CSHs was 48.6 ± 12.1 cm³ (range, 11.3-140.1 cm³). Multi-fraction SRS was delivered in 2 to 4 fractions (median, 3 fractions). The median marginal dose was 21 Gy (range, 17.8–22 Gy) prescribed to a median 64% isodoseline. Dose sculpting technique is used to focus high radiation dose within the tumors and the base of the tumors.

Results: The median follow-up period was 53 months (range, 36–90 months). Tumor control was achieved in all patients (100%) during the follow-up period. At 12 months after multi-fraction SRS, MRI revealed a mean of 70% tumor volume reduction (range, 40%-99%). The last MRI showed a mean of 85% tumor volume reduction. At the last follow-up, one patient with marked tumor shrinkage died of stroke, unrelated to CSH. All patients demonstrated improvements in their neurological deficits post radiosurgery. The only observed side effects were mild headache during treatment in 4 patients with giant tumor and mild, asymptomatic brain edema in the follow-up MRI. One patient reported seizures which were controlled after antiepileptic drugs administration. There were no radiation induced neuropathies during the follow-up period.

Conclusion: Our extended experience confirms that multi-fraction SRS is a safe and an effective management strategy for large CSHs. Considering the risk involved in microsurgery, multi-fraction SRS may serve as the primary treatment option for patients with large CSHs.

Keywords: Acoustic Neuroma, Race, Treatment Utilization

Purpose: To evaluate the treatment modalities utilized in the management of patients with acoustic neuroma (AN) and the potential disparities in the management of AN by race.

Materials and Methods: The NCDB is a comprehensive national database that captures approximately 70% of newly diagnosed cancer patients in the USA. Patients diagnosed with AN were identified in the 2013 Participant Use File (PUF) encompassing years 2004-2013, using ICD-O-3 codes. The utilization of observation, surgery, radiation therapy, and types of radiation therapy (stereotactic (SRS) vs standard-fractionated RT (SFRT)) were evaluated. Race categories were identified as White, Black, American Indian (AI), Asian, or Hawaiian/Polynesian (HP). Categorical data were summarized using descriptive statistics. Chi-square and ANOVA univariate analysis (UVA) and multinomial logistic regression multivariate analysis (MVA) was performed for the types of treatments utilized. This study was reviewed by our institutional IRB.

Results: A total of 40,292 patients meeting the ICD-O-3 criteria for AN were identified in the 2013 PUF data file (90.7% white, 5.3% black, 0.3% AI, 3.6% Asian, and 0.2% HP). Of these, 8367 patients did not undergo surgery or radiation therapy (RT), 22,926 patients underwent surgical resection and 9,727 patients underwent radiation therapy (with some patients receiving combined modality treatment). Of the patients receiving RT, 89.1% underwent SRS (55.0% gamma knife, 8.9% Linac based and 25.2% SRS NOS) and 10.9% underwent standard fractionated radiation therapy. Treatments utilized by race (for Observation, Surgery, SRS, SFRT, Combination treatment) were: White: 20.8%, 55.1%, 20.0%, 23.2%, 1.8%; Black: 24.0%, 53.8%, 17.5%, 2.1%, 2.6%; American Indian: 11.4%, 61.0%, 21.0%, 1.9%, 4.8%; Asian: 18.6%, 60.1%, 15.6%, 2.5%, 3.3%; Hawaiian/Polynesian: 20.8%, 55.2%, 19.7%, 2.3%, 1.9% (p < 0.001). In general, black patients had the highest rate of observation, AI patients had the highest proportion of surgical resection and the highest rate of SRS treatment and Asian patients had the highest rate of combined surgery and SRS treatment. Factors significantly associated with treatment utilization on UVA and MVA included age, tumor size, year of diagnosis, CDCC score, crowfly distance, and the geographic region of the facility location. Race was significant for the type of treatment utilized on UVA but not on MVA.

Conclusion: The statistical analyses in this study showed differences in the types of treatments utilized in the management of AN based on patients age, race, and tumor size among other factors. Further studies are needed to better evaluate potential disparities in treatments utilized for patients with AN.

Poster Display - Benign tumors /Skull Base

P002 : Treatment modalities utilized in the management of acoustic neuromas by race

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**Poster Display - Beginin tumors /Skull Base**

**P003 : Low-dose linac radiosurgery for cavernous sinus meningiomas: Short-term results in 30 patients**

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**Keywords:** cavernous sinus meningiomas, radiosurgery, low-dose, linac

**Introduction:** Stereotactic radiosurgery (SRS) is an important treatment option for patients with cavernous sinus meningiomas. The purpose of clinical study was retrospective analysis of the efficiency of linac SRS for cavernous sinus meningiomas with using lower prescription doses (≤12.5 Gy).

**Materials and methods:** Linear accelerator «Trilogy + BrainLab» stereotactic radiosurgery was performed in 30 patients (8 males and 22 females; mean age - 52 years) with cavernous sinus meningiomas. 23 patients (76.7%) received SRS alone, and 7 patients (23.3%) had undergone surgery before SRS.

**Results:** The marginal doses for the tumors were 11 Gy to 12.5 Gy (median, 12.1 Gy). Tumor volume ranged from 2.8 cc to 20.9 cc (median, 9.1 cc). Median tumor coverage 95.5%. Median follow-up of patients was 10 months (range, 2-39 months).

20 patients (66.7%) before SRS had visual disturbances and 4 patients (13.3%) had facial pain or numbness. Six (20%) patients demonstrated improvement in their neurological condition after SRS. Other 24 (80%) patients also had no worsening of their neurological status. None of the patients experienced optic neuropathy caused by radiation injury or any new neurological deficits after radiosurgery. Follow-up images showed a reduction in tumor size in 14 patients (46.7%), no further growth in 16 (53.3%) cases. The overall tumor control rates 100%.

**Conclusions:** SRS - is an effective method of treatment for cavernous sinus meningiomas, providing high rate of tumor control and ensuring safety of patient's neurological status. SRS with using lower marginal doses (≤12.5 Gy), allows reducing frequency and severity of both transient and permanent neuropathy. Further study is needed to determine the tumor control and complication rates 5 years or more after low-dose linac radiosurgery.

**Poster Display - Beginin tumors /Skull Base**

**P004 : Stereotactic radiosurgery of vestibular schwannomas and neuroimaging evaluation of its efficacy**

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**Keywords:** vestibular schwannoma, stereotactic radiosurgery, postradiational neuroimaging monitoring.

**Introduction:** This study is dedicated to actual scientific problem of improvement results of stereotactic radiosurgery (SRS) and neuroimaging monitoring of vestibular schwannomas.

**Materials and methods:** Linear accelerator «Trilogy + BrainLab» stereotactic radiosurgery was performed in 143 patients (53 males and 90 females; mean age - 49.6 years) with 145 vestibular schwannomas, 38 patients had undergone surgery before SRS. It was used original method of SRS treatment Dyn Arc + IMRT significantly increased its efficacy (p=0,022).

The feasibility of neuroimaging data application and dose regimen as predictors of response to radiosurgical treatment in patients with VS was also proved. New predictors of local control were investigated. It was established, that data of perfusion CT (gap(MTT) х gap(CBV)) are the strongest predictive factor influencing median tumor growth control ratio.

**Conclusions:** SRS with using original method of treatment is providing high rate of tumor control - 96.3% and ensuring safety of patient's. New mathematical model of response prognosis of vestibular schwannomas on SRS treatment was carried out. It allows to calculate the optimal time periods for postradiational neuroimaging monitoring during which decreases the frequency of imaging procedures during follow-up.
**P005 : Relatively low dose Gamma Knife radiosurgery for remnant pituitary adenoma after surgical treatment**

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**Keywords:** Gamma knife radiosurgery, Pituitary adenoma

**Object:** The purpose of this study is to evaluate the efficacy of gamma knife radiosurgery (GKRS) in the management of remnant pituitary adenoma (PA) under underwent surgical treatment.

**Materials and Methods:** Data of 25 patients who were treated with GKRS were reviewed between June 2006 and December 2012. All included patients underwent surgical resection via trans-sphenoidal approach or craniotomy. Endocrinological, ophthalmological, and radiological responses were investigated. The duration of follow-up varied from 48 to 96 months. To analyze radiological response we did rating of tumor control by 6 grade (-1: enlarged, 0: no volume change, 1:1-25% of volume reduction, 2: 25-50%, 3: 50-90%, 4:90-100%).

**Results:** Average marginal dose was 15.76Gy (range of 9-22Gy). Fifty percent isodose line was used. Nine patients (36%) among 25 patients showed that tumor was disappeared (grade 4). Four patients (16%) showed grade 3. Eleven patients (44%) showed between grade 0 and 2. One patient showed regrowth of tumor (grade -1). There was no significant difference of controllability between non-hormone-secreting pituitary adenoma and hormone-secreting pituitary adenoma. There was no aggravation of endocrinological or ophthalmological symptom during follow-up period. The limitations of this study were that number of patient was small and there was no control group.

**Conclusion:** GKRS can achieve tumor control in remnant PA without adverse effect by relatively low dose selection (non-hormone-secreting PA, average 14.76Gy; hormone-secreting PA, average 16Gy) after surgery.

**P006 : Five-year follow-up result of Gamma Knife radiosurgery (GKRS) for intracanalicular vestibular schwannoma (iVS)**

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**Keywords:** Gamma knife radiosurgery, Vestibular schwannoma

**Object:** The purpose of this study is to evaluate the long-term efficacy of gamma knife radiosurgery (GKRS) in the management of intracanalicular vestibular schwannoma (iVS).

**Materials and Methods:** Data of five patients who underwent GKRS for iVS were reviewed between February 2008 and December 2011. Radiological responses, auditory functions and adverse effect were investigated. Planned marginal dose was 12Gy (50% isodose line). The duration of follow-up was more than 5 years.

**Results:** At last follow-up date two patients who visited hospital due to dizziness was improved and hearing functions were in normal range after GKRS. In other three patients who suffered from hearing impairment their hearing functions were not improved after GKRS. Two patients (40%) out of 5 patients were showed that tumors were shrunken and three patients (60%) showed stable status on final brain MRI. In aspect of adverse effects all patients complained different intensity of tinnitus after GKRS. The limitations of this study were that number of patient was small and there was no control group.

**Conclusion:** GKRS can achieve good tumor control in iVS. However, clinicians have to consider a possibility of occurrence or aggravation of tinnitus.

**P007 : Evaluation of linear accelerator radiosurgical treatment of vestibular schwannomas based on their volumetric dynamics in the first two years after radiosurgery**

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Abstracts

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Keywords: vestibular schwannomas, LINAC radiosurgery, volumetric evaluation

Purpose: Evaluate the efficacy of linear accelerator radiosurgical treatment of vestibular schwannomas (VS) based on the observed changes in the tumor volume.

Methods: 121 patients with VS were treated with linear accelerator (LINAC)-based radiosurgery (SRS) in the period from 2006 to 2014. Average patient age was 57.5 years with an average volume of VS tumors of 2ml. Mean marginal dose of the irradiation comprised 12.3 Gy.

In the first 2 years after SRS patients underwent an MRI examination with a volumetric assessment of the VS (3-6 months, 1 year, and 2 years post SRS). Based on the observed volumetric changes patients were stratified in the following groups: volumetric “Progression of VS”, “Stabilization”, and “Partial regression”.

Results: After 3-6 months post SRS volumetric progression of VS (range 3.2 - 150%) was observed in 56.4% of cases (57 patients). Unchanged VS volume was observed in 39.6% of cases (40 patients), while a partial regressions (4 - 29% of the pre-SRS volume) - in 4% of patients.

One year follow-up post SRS: 9.4% (8 patients) had a VS volumetric progression (ranging 4.8 - 142.1% in comparison to the previous MRI). Stabilization of tumor growth was observed in 35.5% of cases (30 patients), while in 55.3% of all cases (47 patients) a partial VS regression (ranging 2.9 - 70% compared to the previous MRI results) was confirmed.

A 2-year follow-up after the SRS revealed a volumetric stabilization in 49.4% of cases (39 patients), partial regression of the tumor volume (ranging 9.1 - 80%) - in 46.8% (37 patients), and an increase in the tumor volume (ranging 10 - 71.4% of the previously observed volume) was documented in 3.8% of cases (3 patients).

Conclusions: 1) Most changes in VS volumes were observed in the first year after SRS. An increase in VS volume accompanied by regressive structural changes was believed to be a reaction of the tumor tissue to irradiation and perceived as “pseudo-progression”.

2) In the 2-year follow-up VS volume stabilization or its partial regression were confirmed in 96.2% of patients, in contrast to a volume progression in 3.8% of cases. A volumetric increase following a 2-year period after SRS was perceived as a true tumor progression.

3) The efficacy of the treatment should not be assessed earlier than 2 years after the irradiation.

4) LINAC-based SRS is a highly effective method of treatment for patients with vestibular schwannomas.

Poster Display - Beginin tumors/Skull Base

P008: Stereotactic radiosurgery for vestibulocochlear nerve schwannomas: vestibular function outcome and quality of life assessment

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Keywords: radiosurgery, schwannoma, vHIT

Objective: Stereotactic radiosurgery (SRS) is the method of precise delivery of high doses of radiation for the benign cranial nerves tumors with limited radiation exposure to surrounding healthy tissue. The CyberKnife M6™ delivers SRS, with extreme accuracy over a minimum number of treatments, reducing side effects and preserving patients’ quality of life.

Materials and Methods: 18 patients had CyberKnife M6™ radiosurgery (SRS) treatment in SRC «Sigulda» from December 2015 till January 2017 for vestibulocochlear nerve schwannomas. Each patient receives from 1 to 3 fractions of radiosurgical treatment. Most patients (12 patients) had 1 fraction stereotactic radiosurgery with
a single dose range from 12 Gy (8 patients) to 14 Gy (4 patients). Six patients with tumor recurrence after surgery had 3 fractions SRS with total dose 18 Gy. Treatment was with 130-180 non-complanar beams using 1-2-collimators (7.5-10mm), isodose curve was from 67 - 86%, coefficient conformity was 1.15-1.25, homogeneity factor was 1,1-1,3. All patients received a standardized neuro-ophtalmological examination, pure-tone audiometry. 8 patients received video head impulse test (vHIT) for vestibular function assessment before SRS. 3 patients in this group had medial reduction of vestibular function.

**Results:** At this stage of research, we can evaluate the safety of the treatment and the absence of early complications after SRS radiosurgery. There were not acute post radiation complications, no severe postradiation neurological deficit and no local progression for 6 month. All patient had postradiation n.facialis deficit. Moderate hearing decrease was detected in 8 patients after SRS. 4 patients in group which received vHIT before SRS, had moderate deterioration of vestibular function at the first follow-up 3 month after SRS.

**Conclusions:** Stereotactic radiosurgery is a highly effective and safe treatment for patients with vestibulocochlear nerve schwannomas, which allows to avoid the risk of severe neurological complications and keep a high level of quality of life after treatment.

**Poster Display - Benign tumors /Skull Base**

**P009 : Long term follow-up of cavernous sinus meningiomas after stereotactic radiosurgery**

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**Keywords:** Meningeoma, skull base tumors, radiosurgery

**Objective:** Microsurgical resection of cavernous sinus meningiomas (CSM) is challenging with a high percentage of recurrence due to incomplete resection (>10% reported recurrence rate after Simpson Grade II and >20% after Grade III resections) and/or permanent, partly severe cranial nerve deficits. Stereotactic radiosurgery (SRS) has evolved as alternative first-line treatment for CSM. Here, we report about the long term clinical and radiological follow-up of an unique cohort of patients with CSM treated with LINAC based SRS.

**Methods:** In this single center retrospective analysis we included all patients with CSM who underwent single fraction LINAC SRS between 1993 and 2012 and had a minimum follow-up of 3 months. We evaluated tumor control (no further intervention needed) by the Kaplan-Meier method. Additionally, patient data were analyzed in terms of clinical symptom control and incidence of complications or unexpected side effects rated by Common Terminology Criteria for Adverse Events (CTCAE; v4.03).

**Results:** 82 patients with 83 tumors (f/m =62/20, median age 53 ± 11, range 33-81 years) were identified. Mean tumor volume was 5.8 ± 3.5 cm³ (range, 0.6-16 cm³), the mean marginal dose was 12 ± 2 Gy (range, 7.0-18.75 Gy) at isodose levels of 64 ± 17% (range, 30-85%). Median follow-up (FU) was 57 months (range, 3-226 months).

Tumor control was 100% after 6 and 12 months, 97% after 5-years and 94% after 10 years. Symptoms prior to SRS remained stable in 88% (n=73), improved in 3.6% (n=3) and deteriorated in 2.4% (n=2) at last follow-up. Four patients (4.8%) report about adverse events CTCAE grade 1 (headache n=2, somnolence n=1, trigeminus disorder n=1).

**Conclusion:** SRS for SCM provides reliable long term tumor control without considerable permanent side effects. Thus, SRS should be taken into account when counselling patients harbouring CSM.

**Poster Display - Benign tumors /Skull Base**

**P010 : Long term results of acoustic neurinoma treated with LINAC- and Cyberknife® based stereotactic radiosurgery: a follow-up of 335 patients**

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**Keywords:** Meningeoma, skull base tumors, radiosurgery

**Objective:** Microsurgical resection of cavernous sinus meningiomas (CSM) is challenging with a high percentage of recurrence due to incomplete resection (>10% reported recurrence rate after Simpson Grade II and >20% after Grade III resections) and/or permanent, partly severe cranial nerve deficits. Stereotactic radiosurgery (SRS) has evolved as alternative first-line treatment for CSM. Here, we report about the long term clinical and radiological follow-up of an unique cohort of patients with CSM treated with LINAC based SRS.

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Tumor control was 100% after 6 and 12 months, 97% after 5-years and 94% after 10 years. Symptoms prior to SRS remained stable in 88% (n=73), improved in 3.6% (n=3) and deteriorated in 2.4% (n=2) at last follow-up. Four patients (4.8%) report about adverse events CTCAE grade 1 (headache n=2, somnolence n=1, trigeminus disorder n=1).

**Conclusion:** SRS for SCM provides reliable long term tumor control without considerable permanent side effects. Thus, SRS should be taken into account when counselling patients harbouring CSM.
Abstracts

Keywords: acoustic neuroma, Cyberknife, LINAC, radiosurgery

Objective: Tumor control and functional hearing preservation are the main goals to be reached in the treatment of acoustic neuroma (AN). Stereotactic radiosurgery (SRS) has evolved as alternative first-line treatment for AN. Here, we report the clinical and radiological long term follow-up of patients with AN treated with LINAC or Cyberknife® based SRS.

Methods: In this single center retrospective analysis we consecutively included all patients with AN who underwent single fraction LINAC or Cyberknife® based radiosurgery between 1991 and 2015 with a minimum follow-up of 2 months. Patient data were analyzed in terms of tumor control (defined as no further intervention required), preservation of functional hearing and incidence of early and late treatment related complications (rated by using the Common Terminology Criteria for Adverse Events, CTCAE; v4.03).

Results: 335 patients (f:m = 176:159, median age = 58 years) were treated either with LINAC (n=270) or Cyberknife® (n=65) -based SRS. Median tumor volume was 1.1ml ± 2.6ml (0.1-23.7). The median radiation dose was 12 Gy (range 11-20) at a median isodose level of 72% (31.9-86.21). Median follow-up was 30 months (2-224 months). According to the Koos classification we identified 53 (15.8%) Koos I, 180 (53.7%) Koos II, 42 (12.5%) Koos III and 60 (17.9%) Koos IV tumors. 70 patients had surgery prior to SRS.

The 2-, 5- and 10-year tumor control rate was 99%, 89% and 88%, respectively. The Kaplan-Meier estimated an objective hearing preservation rate of 89% after 12 months, 80% after 24 months and 57% after 50 months. Treatment failure was observed in 6.3% (n=21). Re-treatment included re-radiation in 43% (n=9/21) and microsurgery in 57% (n=12/21). Denovo permanent adverse events (CTCAE grade I and II) were objectively observed in 8.9% (n=30) cases.

Conclusion: SRS for AN leads to very good long term tumor control with a considerable rate of hearing preservation and a low rate of permanent side effects. SRS can be proposed as safe and effective first line treatment alternative to - or in combination with - microsurgical resection.

Poster Display - Begnin tumors /Skull Base
P011 : Stereotactic radiosurgery for Pituitary adenomas: Analysis of its efficacy, safety at Kuwait gamma knife center.

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Keywords: Pituitary adenomas, Radiosurgery, Prolactinoma, Cushing’s disease, Acromegaly, Gamma Knife.

Objective: Gamma knife radiosurgery has become an important tool in the management of pituitary adenomas. We have reported our treatment results, managed with this novel technology at Department of Neurosurgery, Ibn Sina Hospital, Kuwait.

Subjects and Methods: During the period from 2008-2016, we have managed 33 patients with pituitary adenomas with GK radiosurgery at our center. There were 22 male (66.6%) and 11 female (33.4%) patients and the mean age was 42.5 years. Nineteen patients (57.5%) presented with non-functioning and 14 (42.5%) with functional adenomas. Twenty-nine (88%) patients were managed with residual or recurrent tumors after surgery and 4 patients (12%) were managed as a primary mode. Gamma knife was accomplished with Leksell gamma unit 4-C at our center. Radiological, ophthalmological and hormonal responses were evaluated.

Results: The mean follow-up period was 39.8 months (range 3-87 months). None of the patients experienced decline in visual acuity or field of vision related to the procedure. Tumor control was achieved in 91% patients. One patient had increase in size and underwent surgery. Hormonal evaluation showed no new endocrinopathy. Of the 8 patients with prolactinomas, 7 (77.7%) had normalization of hormone level; one patient had experienced increase in prolactin level. Five patients with acromegaly responded well. One patient with Cushing’s disease relapsed and underwent second session of gamma knife after 3 years. Of the one patient who presented with cranial nerve dysfunction, showed complete recovery within 12 months of therapy.

Conclusion: Gamma knife radiosurgery is an effective and safe mode of treatment for residual or recurrent pituitary adenomas.

Poster Display - Begnin tumors /Skull Base
P012 : Dosimetric comparison between TMR10( tissue maximum ratio10) and convolution algorithms for acoustic schwannoma plans in Gamma Knife radiosurgery

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Keywords: Dosimetry, comparison, TMR10, convolution, acoustic schwannoma, Gamma Knife radiosurgery
Introduction: The treatment planning for Gamma Knife (GK) stereotactic radiosurgery (SRS) that performs dose calculations based on tissue maximum ratio (TMR) algorithm has disadvantages in predicting dose in tissue heterogeneity. The latest version of the planning software is equipped with a convolution dose algorithm as an optional extra and the new algorithm is able to compensate for head inhomogeneity. However, the effect of this improved calculation method requires detailed validation in clinical cases. In this study, we compared absolute and relative dose distributions of treatment plans for acoustic schwannoma between TMR10 and the convolution calculation.

Methods: Twenty-nine clinically used plans created by TMR10 algorithm were recalculated convolution method. Differences between TMR and convolution were evaluated in terms of absolute dose (beam-on time), dosimetric parameters including target coverage, selectivity, gradient index.

Results: The discrepancy in estimated absolute dose to the target ranged from 1 to 7 % between TMR and convolution. In addition, dosimetric parameters of the two methods achieved statistical significance. However, it was difficult to see the change of relative dose distribution by visual assessment on a monitor.

Conclusions: Convolution algorithm are necessary to reduce the dosimetric uncertainty of each case in GK SRS.

Poster Display - Benign tumors /Skull Base

P013 : Efficacy and safety of Linac-based stereotactic radiosurgery (SRS) and hypofractionated stereotactic radiotherapy (HFSRT) for acromegaly. A long-term follow-up study.

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Keywords: stereotactic radiosurgery, stereotactic radiotherapy, acromegaly, pituitary adenoma

Aim: The goal of our investigation was to evaluate efficacy and safety of SRS and HFSRT in patients suffering from growth hormone producing pituitary adenomas, treated with the use of linear accelerator at our institution between 2001 and 2011.

Material and methods: A group of 96 patients treated with radiosurgery was reviewed to include 49 patients (26 women, 23 men) with acromegaly. The mean and the median age at the time of radiosurgery was 46 and 44 years, respectively (range 24 - 74). Almost all patients were treated surgically before SRS (94%). Anterior pituitary insufficiency was diagnosed in 17 cases. Diabetes insipidus occurred in 6 cases. The mean and the median total doses were 13.7 and 15 Gy, respectively (range 6 - 25Gy). The treatment was applied in 1 - 3 fractions. Serum IGF-1 and GH levels were obtained before radiotherapy and during the follow-up at 1 to 2-year intervals.

Results: After the treatment, complete hormonal evaluation was performed in 30 (60%) cases. The median follow-up was 77 months (range: 9-166). Hormonal response was defined as a normalization (complete response) or more than 50% reduction (partial response) in serum IGF-1 levels. Normalization was noticed in 56% cases. However, progression after initial complete response was seen in 13% in the median time of 55 (24-120) months after the treatment. More than 50% reduction in IGF-1 levels was confirmed in another 17% patients. In 27% cases there was no hormonal response seen after irradiation and another course of radiotherapy was conducted in 7 cases. There were 8 cases of new hormonal deficits found in the current series. Radiological stabilization of the adenoma was seen in 32/34 patients (94%). In one case progression and in another one progression was diagnosed. Two-, five-, and ten-year local control was 96%. There were no new visual deficits after SRS observed in our investigation.

Conclusions: Stereotactic radiosurgery provides satisfactory radiological and hormonal control in patients suffering from acromegaly. Long term follow-up is essential in detecting new pituitary insufficiencies or disease progression.

Poster Display - Benign tumors /Skull Base

P014 : Integrating surgery and radiosurgery: Our first experiences with adaptive hybrid surgery analysis software in benign skull base tumors

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Keywords: benign skull base tumors, Adaptive Hybrid surgery, radiosurgery, software
**Abstracts**

**Background:** The treatment of benign skull base tumors remains challenging. These tumors are often located in close relationship to critical structures and can be quite large when finally diagnosed. Thus a radical resection can be virtually impossible or would be associated with high morbidity. Therefore multimodal treatment concepts with partial tumor resection followed by radiosurgery are optimal. Adaptive Hybrid Surgery Analysis (AHSA) is a software developed by BrainLab that provides an automatic virtual real-time treatment plan during surgery for the feasibility of stereotactic radiosurgery.

**Methods:** The AHSA software was applied in four patients who underwent partial resection of a benign skull base tumor. Tumor volumetry was obtained on preoperative and postoperative MR scans. Organs at risk were automatically delineated with the Atlas Mapping feature of the Elements software by BrainLab and adapted if needed.

**Results:** Three patients underwent a suboccipital craniotomy for a partial resection of a tumor within the posterior fossa (vestibular schwannoma, ependymoma, petroclival meningioma) and in one patient a temporal approach for resection of a medial sphenoid wing meningioma was performed. The preoperative tumor volumes ranged between 8.52 and 25.2 cm³. The intraoperative volume of the residual tumor measured with the AHSA software was between 2.13-12.17 cm³ (25-47% of the preoperative tumor volume) differing between 8-20% from the real residual tumor volume measured on the postoperative MR scan. The preoperative estimated residual tumor volume differed only between 3-5% from the real residual volume measured on the postoperative MR. The intraoperative automatic AHSA plans of the remaining tumor volume suggested in all four patients that a safe radiosurgery would be feasible.

**Conclusion:** The AHSA software is a smart tool that enables the neurosurgeon to preoperatively plan and estimate a multi-modal approach for complex skull base tumors and thus minimizing the morbidity risks for surgery as well as radiosurgery. Further the software provides a continuous intraoperative feedback of residual tumor volume and the resulting radiosurgery plan, which appraises if the remaining tumor could be feasibly and safely treated with radiosurgery. The accuracy of the intraoperative surface scanning of the residual tumor depends on the angle, location and depth of the remaining tumor together with the relation of the pointer and camera visibility respectively and therefore can differ quite a bit from the real residual tumor volume.

**Poster Display - Benign tumors /Skull Base**

**P015 : Evaluation and comparison of dosimetric parameters for CyberKnife and Novalis stereotactic radiotherapy of brain tumours**

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**Keywords:** Stereotactic radiotherapy, hypofractionation, CyberKnife, Novalis, conformity index, gradient index

**Objective:** A comparison of dosimetric parameters of CyberKnife (CK) and Novalis plans for hypofractionated treatment of different intracranial pathologies.

**Materials and Methods:** 15 patients with single intracranial tumors (tumors have different histology, volume, and localization) previously treated on the CyberKnife were selected for comparison of dose distribution. Targets and critical structures were contoured by MultiPlan and transferred in iPlan with CT scan of the patient for recalculation. Mean doses in targets for each patient were equal in both planning systems. Homogeneity index (HI), coverage (CO), conformity indexes (CI_{RTOG}, nCI), gradient indexes (GI_{50}, GI_{25}), the dose in normal tissues (V_{10}, V_{12}) and critical structures (optic nerves, chiasm, brain stem) were obtained from DVH. To automate processing of DVH a software was developed in Borland C++ Builder 6.0.

**Results:** The most informative indicators for comparing plans were the GI_{50} gradient index, the conformity indexes CI_{RTOG} and nCI, as well as indicators of radiation doses on the brain V_{10} and critical structures. While Novalis provided more homogeneous dose distributions within the target, CK irradiated less exposed volume in normal tissues. Doses in critical structures, located far from the target, are lower for Novalis. If the tumor is adjacent to critical organs, CK allows to reduce the dose in them more effectively, due to the high dose gradient outside the target.
Poster Display - Begin tumors /Skull Base

P016 : Jaw immobilization for Gamma Knife surgery in patients with mandibular lesions: A newly innovative approach

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Keywords: Radiosurgery, Mandibular immobilization, Extracranial lesions, Arteriovenous malformation, Schwannoma, Gamma Knife surgery

Background: The purpose of our report is to describe an innovative system used for mandibular immobilization during Gamma Knife surgery (GKS) procedures. It is based on an approach originally developed in Marseille in extracranial lesions, close to or involving the mandible, which may imply a certain degree of movement during the therapeutic image acquisitions and/or GKS treatment.

Methods: The maxillofacial surgeon applied bone titanium self-tapping monocortical screws (4; 2 mm diameter, 10 mm length) between roots of the teeth in the fixed gingiva (upper and lower maxillae) the day before GKS (local anesthesia, 2 minutes time). Two rubber bands were sufficient for the desired tension required to undergo GKS. We further proceeded with application of the Leksell stereotactic G frame and carried out the usual GKS procedure.

Results: The mean follow-up period was 2.3 years (range 0.6–3). Three patients have been treated with this approach: 2 cases with extracranial trigeminal schwannomas involving the mandibular branch, with decrease in tumor size on MR follow-up; 1 case with residual paraccondylian mandibular arteriovenous malformation following partial embolization, completely obliterated at 7 months (digital subtraction angiography programmed 1 year after treatment).

Conclusions: Jaw immobilization appears to be a quick, minimally invasive, safe and accurate adjunctive technique to enhance GKS targeting precision. Additionally, with the help of this procedure and/or the use of the new GKS Icon Model (Elekta Instruments AB, Sweden), we can expand the therapeutic radiosurgical management that can be offered to patients with lesions located at this level, by increasing targeting accuracy, which is particularly necessary within this location, due to possible jaw movement.

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Poster Display - Begin tumors /Skull Base

P017 : Long term local control in malignant meningiomas treated with gamma knife radiosurgery followed by systemic diffusion: report of two cases

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Keywords: Gamma Knife, anaplastic meningioma, metastasis.

Treatment of aggressive meningiomas may require a combination of surgery, radiotherapy and radiosurgery to achieve long term local control (LC). We report two patients with histologically defined malignant meningiomas infiltrating dural sinuses, which underwent several Gamma Knife treatment achieving long term radiosurgical LC. These patients after several years had systemic diffusion with thoracic and abdominal metastasis.

Case 1: A frontal parasagittal meningioma was partially resected in a 48 yo woman (Simpson not 0 for sinus involving). The histological diagnosis was meningioma (G1 WHO). Two years later she was reoperated for a removal of LR. The second histological diagnosis was anaplastic meningioma (G3 WHO). Two years later she was reoperated for a removal of LR. The second histological diagnosis was anaplastic meningioma (G3 WHO) with high cellularity, frequent mitosis (16x10 HPF), high nuclear pleomorphism, necrosis areas and vimentin expression. During the following 9 years the patient underwent 5 GKRS procedures and a new surgery for LR (G3 WHO). In every occasion a dose of 15 Gy (50% isodose) was delivered to the growing tumor. At 62 yo she presented with 3 lesions al level of L5, of the right adrenal gland and of right lung and underwent to a right lobectomy.
and mediastinum lymphadenectomy. The lung lesion was characterized as an anaplastic meningioma metastasis (G3 WHO). No LR brain lesion at last follow-up, KPS 100.

**Case 2:** In a 47 yo woman an anaplastic atypical meningioma (G2 WHO) involving the torcular was resected with Simpson not 0 for sinus involvement. 3 years later she had SRT (32 Gy) and Tamoxifene for LR. During the following 5 years she underwent routinely brain MRI scans as follow up. During the following 5 years she underwent 5 GKRS for local recurrences in contiguous fields (dose range 15-16 Gy, 50% isodose) important to note that the recurrence was not in field of previous radiosurgical treatment. Octeotride was administered with no clear benefit. At 61 yo multiple lesions in the lungs, liver and kidney were found. A liver biopsy showed an anaplastic meningioma (G3 WHO). No LR brain lesions at last follow-up, KPS 100. Extracranial metastases of meningioma often reach the lungs (60%), abdomen and liver (34%). We present two long survival intracranial malignant meningiomas cases treated with multimodality treatment, also with several GKRS treatments, that gave metastatic systemic diffusion. In our opinion the possibility to control the local recurrence of this small percentage of malignant meningiomas allows the opportunity for these lesions to metastasize so we suggest radiological systemic control in those particular cases.

**Poster Display - Benign tumors /Skull Base**

**P018: Pre-treatment tumor growth does not affect radiosurgery control rates for sporadic vestibular schwannomas**

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**Keywords:** vestibular schwannoma, Gamma Knife, stereotactic radiosurgery

**Background:** The natural history of many small-to-moderate sized vestibular schwannomas is to remain stable over time, without any treatment. Numerous large studies have reported excellent control rates (>95%) with SRS, but have not accounted for whether or not the treated tumors were growing before SRS. The goal of this study was to determine the control rate of growing vestibular schwannomas to SRS.

**Methods:** This retrospective single-institution study included all sporadic vestibular schwannomas treated primarily with Gamma Knife radiosurgery between 2002 - 2014. Patients with a history of NF2, prior surgical treatment, or less than 2 years of imaging follow-up were excluded. Clinical data including reason for treatment, dose prescription, and need for salvage treatment, were collected. Volumetric tumor analysis was performed on the initial, treatment planning, and latest follow-up MR T1 post contrast imaging, from which the pre-treatment and post-treatment percent volume change was calculated. Tumors were then classified as ‘growing’ or ‘stable’ based on the presence of a volume change exceeding published volumetric measurement errors (Snell 2006) based on tumor volume and MR slice thickness. Radiographic and clinical control rates were calculated for these two groups and compared using a x² test.

**Results:** 184 sporadic vestibular schwannomas were primarily treated with Gamma Knife SRS between 2002 and 2014. 97 cases were excluded due to insufficient follow-up information. The remaining 87 patients included 50 women, had a median age of 60.9 years, a median tumor volume of 0.78 cm³, and a median follow-up time of 4.25 years. Median dose prescription was 12 Gy to the 50% isodose line. Five patients required salvage treatment (4 surgical, 1 repeat Gamma Knife). The overall clinical (no salvage treatment required) and radiographic (no significant volume increase) control rates were 96% and 76%, respectively. Prior to SRS treatment, 34 patients had significant tumor growth (median increase 60% per year, median treatment volume 0.9 cm³), 36 did not have significant growth (15% per year, 0.6 cm³), and 17 did not have available interval pre-treatment imaging. The clinical control rate was 97% for both growing and stable tumors (at median follow-up of 3.3 and 4.5 years, respectively). Radiographic control rates were 68% and 81%, respectively. There was no significant difference between the control rates (clinical and radiographic) between growing and stable tumors.

**Conclusion:** In this small series, we did not see a significant difference in the clinical or radiographic control rates after SRS for growing versus stable vestibular schwannomas.
Poster Display - Beginn tumors /Skull Base  

P019 : Linac-based stereotactic radiosurgery for benign brain tumors: efficacy and safety after long-term follow up of neuroma and meningioma patients

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Keywords: radiosurgery, neuroma, meningioma, efficacy, toxicity, follow up

Therapeutic options for benign intracranial tumors have expanded beyond surgery to include fractionated and single fraction radiation therapy. Stereotactic radiosurgery delivers a highly conformal dose to the intracranial target in a single or few fraction. Multicenter studies and single institutional analyses report high control rates and low toxicity after radiosurgery for intracranial neuromas and meningiomas, making it an appealing alternative to surgical intervention. Radiosurgery has been traditionally performed as Gamma Knife surgery but linac-based modalities have gained popularity and are now also widespread.

We present the results of linac-based stereotactic radiosurgery for 34 consecutive neuroma and meningioma patients after long follow up. All patients were given primary or adjunct radiosurgical treatment for a single intracranial tumor with a median volume of 5.95 cm³ and a maximum diameter of 35 mm. Prior intracranial radiotherapy was an exclusion criterion. Stereotactic radiosurgery was performed using the 6 MV beam of a non-dedicated Elekta SL-18 linear accelerator converted for radiosurgery with the attachment of an isocentric subsystem (Phillips SRS200XK). Non-coplanar arc irradiation was delivered with circular collimators ranging in diameter from 10-30 mm. A stereotactic head-ring fixation was used. A treatment plan was achieved using 1-8 isocenters. Neuroma patients were treated with 11-12 Gy, while larger doses of 12-15 Gy were given to meningioma patients. Dose refers to the prescription isodose which covered 95-100% of the tumor. Combining a different number, span and weight of non-coplanar arcs, as well as weight and collimator size of each isocenter used, high conformity of the treatment dose to the borders of the tumor was established at the expense of planning time.

An extended follow-up is required after radiosurgery for benign intracranial tumors to assess not only tumor control but also the safety of the method. Our follow-up protocol consisted of imaging studies and clinical examination with cranial nerve function assessment at 6-months intervals for the first year and yearly thereafter. Clinical follow up was obtained from the patients or their referral doctors.

After a follow-up time ranging from 50 to 171 months (median 86), 56% of tumors decreased in size. Shrinkage of the tumor was observed in 58% and 61.5% of neuroma and meningioma patients, respectively. No patient developed new permanent facial or trigeminal neuropathy.

Overall, our study confirms the efficacy and safety of linac-radiosurgery after long follow up for neuroma and meningioma patients.

Poster Display - Body

P020 : Efficacy of cyber knife radiosurgery in treating patients with localized prostate cancer

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Keywords: Radiosurgery, Prostate, PSA, Toxicity

Background: Radiosurgery is an increasingly preferred treatment option for localized prostate cancer, and stereotactic body radiation therapy (SBRT) a relatively established modality of therapeutic irradiation. The present study analyzes the toxicity and biochemical efficacy of SBRT in 6 consecutive prostate cancer patients treated with CyberKnife Robotic Radiosurgery System.

Methods: Six patients were treated with SBRT at Cyber Knife SRS Department Jinnah Postgraduate Medical Center, Karachi, Pakistan. All patients included in this IRB-approved protocol-driven prospective study had biopsy proven prostate cancer. None of the patients developed low, intermediate or high risk post Cyber knife
toxicities. The patients were treated with CyberKnife-SBRT (CK-SBRT), the prescription dose was 35 Gy in five fractions, corresponding to 92 Gy in 2-Gy fractions (α/β=1.5 Gy).

**Results:** The follow up PSA was repeated after every 3 months of radiosurgery. The mean PSA value for patients treated with Cyber Knife was 10.5ng/ml with a minimum value of 8ng/ml and maximum of 14 ng/ml. First follow up revealed a mean PSA value of 4.75 ng/ml with 6.2 ng/ml and 3.4 ng/ml maximum and minimum PSA values respectively. For next two follow up PSA evaluation the mean PSA values were, 3.31 ng/ml and 1.59 ng/ml respectively. None of the patients developed genitourinary and gastrointestinal toxicities.

**Conclusions:** In this study CK-SBRT has provided promising outcomes in localized prostate cancer with good PSA response, minimal toxicity and patient inconvenience.

**Poster Display - Body**

**P021 : Stereotactic body radiation therapy for metastatic lung tumors**

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**Keywords:** SBRT, lung, oligometastases

**Purpose:** To evaluate clinical outcomes of stereotactic body radiation therapy (SBRT) for lung oligometastases.

**Methods:** Between June 2009 and October 2016, 27 patients (16 males and 11 females) with 32 lung oligometastatic lesions were treated with SBRT at our institution. The median age was 73 (range, 48-85) years. The primary sites were the lungs (n = 17), colorectum (n = 3), uterus (n = 2), stomach (n = 2), liver (n = 1), thymus (n = 1), and buccal mucosa (n = 1). The histological types included adenocarcinoma (n = 16), squamous carcinoma (n = 8), large cell neuroendocrine carcinoma (n = 1), leiomyosarcoma (n = 1), and hepatocellular carcinoma (n = 1). The primary cancer sites were treated with surgery (n = 19), chemo-radiotherapy (n = 6) and SBRT (n = 2). The median interval between initial therapy and SBRT was 32 (range, 6–94) months. The median tumor diameter was 15 (range, 8–29) mm. The prescribed dose was defined at the isocenter. The total doses and fraction numbers were 48 Gy in 4 fractions for 27 lesions, 50 Gy in 5 fractions for 5 lesions, respectively. Over all survival (OS), cause specific survival (CSS), local control rate (LCR), and relapse free survival (RFS) were calculated using Kaplan-Meier curves. Univariate and Multivariate analysis for RFS were performed using log-rank test and a Cox- proportional hazards model, respectively. Statistical significance was set at p<0.05.

**Results:** The median follow-up period was 26 months (range, 4 - 88 months), for all patients, and 37 months (range, 4 - 88 months) for survivors. During follow-up, 14 patients had recurrence (in-field failure, 2, primary site, 2, the other lung metastases, 6, and other distant metastases, 4). Of the 27 patients, 9 died of the primary disease, 3 died of other causes, and 15 survived. Of the 15 survivors, 8 are alive without recurrence and the other 7 are alive with cancer-bearing state. Of the 6 patients who presented with new lung metastases, 3 with oligometastasis underwent SBRT for the second time, of which one underwent SBRT for the third time. The 3-year OS, CSS, LCR, and RFS were 61.0%, 68.5%, 91.5%, and 37.4%, respectively. Univariate and multivariate analysis revealed that no factor significantly affected RFS. No adverse event of grade 3 or greater occurred.

**Conclusion:** SBRT is an effective and safe treatment option for lung oligometastases.

**Poster Display - Body**

**P022 : Development of thermoplastic mask set up monitoring system using force sensing resistor (FSR) sensor**

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**Keywords:** thermoplastic mask, force sensing resistor sensor

**Purpose:** To improve the setup accuracy of thermoplastic mask, we developed a new monitoring method based on force sensing technology and evaluated its feasibility.

**Methods:** The thermoplastic mask set up monitoring system consists of a force sensing resistor sensor unit, a signal transport device, a control PC and an in-house software. The system is designed to monitor...
pressure variation between the mask and patient in real time. It also provides a warning to the user when there is a possibility of movement. A preliminary study was performed to evaluate the reliability of the sensor unit and developed monitoring system with a head phantom. Then, a simulation study with volunteers was conducted to evaluate the feasibility of the monitoring system. Note that the sensor unit can have multiple end-sensors and every end-sensor was confirmed to be within 2% reliability in pressure reading through a screening test.

**Results:** To evaluate the reproducibility of the proposed monitoring system in practice, we simulated a mask setup with the head phantom. FRS sensors were attached on the face of the head phantom and pressure was monitored. For 3 repeated mask setups on the phantom, the variation of the pressure was less than 3% (only 1% larger than 2% potential uncertainty confirmed in the screening test). In the volunteer study, we intended to verify that the system could detect patient movements within the mask. Thus, volunteers were asked to turn their head or lift their chin. The system was able to detect movements effectively, confirming the clinical feasibility of the monitoring system developed.

**Conclusion:** Through the proposed setup monitoring method, it is possible to monitor patient motion inside a mask in real time, which has never been possible with most commonly used systems using non-radiographic technology such as infrared camera system and surface imaging system.

**Poster Display - Body**

**P023 : Development of real time abdominal compression force (ACF) monitoring and visual biofeedback system**

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**Keywords:** abdominal compression radiation therapy, gas pressure sensor, abdominal compression force, visual biofeedback

**Purpose:** Hard-plate based abdominal compression is known to be effective, but no explicit method exists to quantify abdominal compression force (ACF) and maintain the proper ACF through the whole procedure. In addition, even with compression, it is necessary to do 4D CT to manage residual motion but, 4D CT is often not possible due to reduced surrogating sensitivity. In this study, we developed and evaluated a system that both monitors ACF in real time and provides surrogating signal even under compression. The system can also provide visual-biofeedback.

**Methods:** The system developed consists of a compression plate, an ACF monitoring unit and a visual-biofeedback device. The ACF monitoring unit contains a thin air balloon in the size of compression plate and a gas pressure sensor. The unit is attached to the bottom of the plate thus, placed between the plate and the patient when compression is applied, and detects compression pressure. For reliability test, 3 volunteers were directed to take several different breathing patterns and the ACF variation was compared with the respiratory flow and external respiratory signal to assure that the system provides corresponding behavior. In addition, guiding waveform were generated based on free breathing, and then applied for evaluating the effectiveness of visual-biofeedback.

**Results:** We could monitor ACF variation in real time and confirmed that the data was correlated with both respiratory flow data and external respiratory signal. Even under abdominal compression, in addition, it was possible to make the subjects successfully follow the guide patterns using the visual biofeedback system.

**Conclusion:** The developed real time ACF monitoring system was found to be functional as intended and consistent. With the capability of both providing real time surrogating signal under compression and enabling visual-biofeedback, it is considered that the system would improve the quality of respiratory motion management in radiation therapy.

**Poster Display - Body**

**P024 : Re-irradiation with CyberKnife radiosurgery or stereotactic radiotherapy as a salvage treatment for in-field neck lymph node recurrences after radiotherapy**

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**Conclusion:** The developed real time ACF monitoring system was found to be functional as intended and consistent. With the capability of both providing real time surrogating signal under compression and enabling visual-biofeedback, it is considered that the system would improve the quality of respiratory motion management in radiation therapy.
Keywords: re-irradiation, neck lymph node, recurrence, CyberKnife

Purpose/Objective: Neck lymph node recurrences in irradiated field occur in 5 to 10%, which are important mode of failure for cancer patients. In spite of this, few studies have reported about salvage re-irradiation for lymph node recurrences. We retrospectively investigated the safety and efficacy of CyberKnife (CK) treatment for neck lymph node recurrences after radiotherapy.

Material/methods: Between 2008 and 2014, 16 patients with neck lymph node recurrences after radiotherapy were treated with CK at our institution. All of the recurrences were inoperable due to medical reasons. The treatment doses and fractions were decided depending on tumor- and surrounding critical structures’ volume. The dose to the 10 cm³ of skin and mucosa was limited to be < 14 Gy given as stereotactic radiosurgery (SRS) to avoid adverse effects. Local control (LC) and overall survival (OS) were calculated using SPSS software.

Results: The follow up period after CK ranged from 2 to 53 months (median, 11 months). The previous radiation dose ranged from 50 to 70 Gy (median, 65 Gy). Neck dissection had been performed for 6 patients (38%) as primary treatment. The target volume ranged 0.05 to 91 cm³ (median, 1.2 cm³). The prescribed isodoses ranged from 52 to 89% (median, 64%) for the target. The prescribed marginal dose was ranged 18 to 40 Gy in 1 to 8 fractions. Assuming SRS, the marginal dose ranged from 17 to 22 Gy (median, 20 Gy). SRS, the 3-fraction, 5-fraction, 6-fraction and 8-fraction radiotherapy was administered to 40, 5, 2, 1, and 1 lesions, respectively. The local recurrence was observed as 9 lesions in 6 patients. The 1-year LC rate was 81%. The 1-year OS was 84%. Fatal bleeding was observed in one patient who had huge (91 cm³) and widespread tumor invasion to carotid artery before CK. The other patients did not develop Grade 3 toxicities. The 1-year LC with the target volume ≤ 1.3 cm³ was significantly higher than with the target volume >1.3 cm³ (p = 0.007). There was no significant difference in the 1-year LC due to the marginal dose for SRS (< 20 Gy versus ≥ 20 Gy).

Conclusion: CyberKnife for neck lymph node recurrences were performed safely and efficiently in most cases. CK may be a candidate as a salvage treatment. We have to pay much attention to large and widely invasive tumor before CK.

Poster Display - Body

P025 : Efficacy and safety of Linac-based stereotactic body radiation therapy (SBRT) with volumetric modulated arcs for the treatment of localized prostate cancer: results from a phase II trial

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Keywords: prostate, SBRT, radiotherapy

Purpose: Aim of the present study was to evaluate the efficacy and toxicity of Stereotactic body radiotherapy (SBRT) in patients with low or intermediate risk prostate cancer.

Materials and methods: Patients with the following characteristics were enrolled: initial PSA ≤ 20 ng/ml, Gleason Score ≤ 7, IPSS ≤ 7. The treatment schedule was 35 Gy in five fractions, delivered with Volumetric Modulated Arcs (VMAT) and flattening filter free beams (FFFs). Toxicity was recorded according to CTCAE criteria v4.0. Biochemical failure was calculated according to the Phoenix definition. The EPIC questionnaire was used to evaluate quality of life (QoL).

Results: Between March 2012 and April 2015, 100 patients were enrolled (58 low risk, 42 intermediate risk). The median age was 72 years (range 48 - 82). Acute toxicity was mild. Rectal grade 1 toxicity was found in 15 patients, whereas grade 2 toxicity in 6 patients. Thirty patients presented grade 1 urinary toxicity and 31 patients presented grade 2, mainly represented by urgency, dysuria and stranguria. Regarding late toxicity, grade 1 proctitis was recorded in 14 patients and grade 1 urinary in 44 patients; only 2 events of grade 2 urinary toxicity were observed. At a median follow-up of 33 months, three intermediate risk patients and one low risk patient experienced a biochemical failure. Health-related QoL revealed a slight worsening in all the domains during treatment, with a return to baseline 3 months after treatment.

Conclusions: Stereotactic body radiotherapy proved to be safe and effective in localized prostate cancer patients.
Poster Display - Body

P026: Linac-based stereotactic radiotherapy for jugulotympanic paragangliomas

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Keywords: Parangangioma, Head and Neck, stereotactic radiotherapy

Objectives: Jugulotympanic parangangiomas can cause significant morbidity, despite the majority behaving in a non-malignant fashion. Radiotherapy is useful both in the salvage setting where surgery fails, and in the primary setting it provides a good alternative to surgery. We report on the outcomes of 27 cases of jugulotympanic parangangioma treated with Linac-based stereotactic radiotherapy at a single institution.

Methods and materials: Between 1999-2015, a total of 27 patients were treated with Linac-based stereotactic radiotherapy. Small tumours were treated in a single fraction with a median dose of 16Gy prescribed to the 80% isodose. Intermediate sized tumours received 28Gy in 7 fractions (prescribed to the 80%) and large tumours or those in broad-contact with the brainstem received 50.4Gy in 28 fractions (prescribed to 90%).

Results: Median follow-up was 53 months (range 8-138). Eight out of 27 patients had surgery prior to radiotherapy and the median time to progression (after surgery) was 5 years.

Fifteen (56%) tumours were treated in a single fraction. Mean percentage volume coverage 98.8% and the mean conformity index was 1.55, defined as the ratio between the prescription isodose volume and the target volume.

Of the 27 patients, 26 (96%) achieved radiological control with 5 tumours reducing in size, 3 patients documented to have a temporary enlargement of the tumour before subsequently reducing and the remaining 18 cases did not change in size throughout the follow up period. Clinical control (defined as stability or improvement in symptoms) was achieved in 25 (93%) patients. The total number of cranial neuropathies present prior to radiotherapy was 58 and after radiotherapy this reduced to 49. There were 3 cases of new onset hearing impairment attributable to radiotherapy.

Conclusion: Linac-based stereotactic radiotherapy represents a safe and effective treatment for Jugulotympanic parangangiomas, both as a primary and secondary treatment modality.

Poster Display - Body

P027: Reirradiation with SBRT in patients with local recurrence of the head and neck carcinoma - own experience.

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Keywords: head and neck, recurrence, reirradiation, hypofractionation

Purpose/Objectives: Locoregional recurrence is a major cause of death in patients with squamous cell carcinoma of the head and neck (HNSCC). At the moment, there are no clear recommendations and standards regarding the timing, total doses and dose tolerance of normal tissues to re-exposure. Based on limited studies on the re-irradiation with high total doses, we evaluated the tolerability of high-dose re-irradiation with SBRT.

Materials/Methods: 6 patients with histologically confirmed locoregional recurrence of HNSCC, received reirradiation in 2015-2016. Median time after primary radiotherapy course was 36 months (9-108). The treatment volumes and total doses were formed as follows: GTV (local recurrent tumor or nodal recurrence delineated on CT, MRI and 18F-FDG PET-CT) + CTV (0.3-0.5 cm, excluding unaffected bones and OARs) + PTV (0.2 cm or 1 mm near OARs) was treated to the total dose of 35-39 Gy (equivalent to 66-70 Gy of conventional fractionation, \(\alpha/\beta=3\)). Single doses to these volumes were 7-13 Gy. Radiation treatment course consisted of 3-5 fractions. Varian Eclipse v.10 (VMAT) and Accuray MultiPlan 4.6 were used for treatment planning; patients were treated on Varian TrueBeam STx and Accuray CyberKnife 4G. According to the literature, in a year after primary irradiation almost complete recovery of normal tissue tolerances is observed. Tolerances of the eye, lens, optic nerves and chiasm, brain stem, spinal cord, parotid gland, blood vessels, intact mucosa of the mouth and pharynx were not exceeded. Patient positioning accuracy was
controlled by kV-imaging and cone beam CT on linac and kV-imaging system on CyberKnife.

**Results:** All 6 patients received full course of radiation therapy. Radiation toxicity manifested with grade 2 oral and pharyngeal mucositis (depends on tumor localization) and grade 2 radiation epidermitis in 2-3 weeks after irradiation. After one month, almost complete relief of radiation mucositis and dermatitis was observed. In 5 patients partial response and stabilization of irradiated lesion were achieved according to MRI at one, three and six months after irradiation. Three patients performed 18F-FDG PET-CT with full metabolic response. At present time 4 patients are alive. One patient died in 4 months after RT due to comorbidities. Cause of death of another patient was fatal bleeding from irradiated tumor, located in hypopharynx, in 6 days after RT completion.

**Conclusion:** Using SBRT for curative reirradiation of recurrent HNSCC is available with maintaining satisfactory tolerability. Local control is quite promising, but accurate patient selection needed according to comorbidities and fatal complications risk.

**Poster Display - Body**

**P028 :** SBRT Treatment of the lung cancer with VMAT techniques: the ASST Papa Giovanni XXIII experience

Luca Berta (1), Fabio Piccoli (2), Marco Fortunato (1), Claudia Bianchi (1), Gaia Moretti (3), Silvia Takanen (2), Roberta Muni (2), Eva Iannacone (2), Francesco Romeo Filippone (2), Laura Maffioletti (2), Stefano Andreoli (1), Luigi Franco Cazzaniga (2)

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**Keywords:** lung sbrt, VMAT, follow-up, toxicity, dosimetry, quality assurance

From March 2013 to December 2016, 39 patients with lung tumors received SBRT at our institution. The aim of this study was to analyze clinical and dosimetric data, including pretreatment quality assurance (QA) measurements, for patients treated with volumetric modulated arc therapy technique (VMAT) and with a follow-up greater than 3 months.

Nineteen patients were evaluated (14 male, 5 female) with median age of 76 (59-83) and median performance status, according to Karnofski scale, of 80 (70-90). Eighteen were primary lung tumors (cT1a-cT2a, 3 histologically proven) and 1 was a metastasis. Five lesions were centrally located and 14 were peripherally located. The prescribed dose ranged from 40 to 60 Gy in 3-8 fractions. The BED$_{10}$ ranged from 80$_{(10)}$ to 112.5$_{(10)}$ Gy.

The target volumes (PTV) were delineated on the average CT series of a 4D-CT acquisition as 5mm isotropic expansion of the ITV. The median PTV volume was 17.9 cm$^3$ (9.1-66.3 cm$^3$). All plans were elaborated with TPS eclipse v.10.0 using 2-5 coplanar and non-coplanar arcs and delivered with a Varian Trilogy.

The median dose received by 99%, 95%, 50% and 2% of PTV was respectively 102.7%, 105.8%, 114.9% and 121.3% of the prescribed dose. Dose constraints for critical structures, according to the AAPM-TG101 report, were respected in all plans.

QA measurements were analyzed with EPIQA v2.2.3 comparing planar dose distributions at the isoplane calculated in water phantom and acquired with the EPID during the delivery of each arc. Dose distributions were locally compared in terms of gamma analysis with 3mm and 3% (Gamma$_{3\text{mm}, 3\%}$) as distance-to-agreement and dose difference. The Gamma Index Passing Rate was calculated for all arcs (A-GIPR, n=58) and then averaged for all arcs in the 19 plans (P-GIPR). Average A-GIPR and P-GIPR were respectively 96.4% (89.2%-99.4%) and 96.4% (91.2%-98.6%). With more restrictive criteria, (Gamma$_{2\text{mm}, 2\%}$, Gamma$_{1\text{mm}, 1\%}$) the average P-GIPR decreased to 87.9% and 54.8% indicating the need of different criteria for acceptance.

With a median follow-up of 13.6 months (3.3-30.8), no patients experienced G3 lung toxicities (according to RTOG score). Two acute G2 and 4 late G2 lung toxicities were observed. Complete response or stable disease were obtained respectively in 10 and 3 patients. Three patients experienced locoregional outfield disease progression and 1 died. Three patients experienced distant disease progression and 2 died.

SBRT with VMAT technique offers a safe and effective approach for treatment of T1-2a lung tumors or small metastatic lesions.

**Poster Display - Body**

**P029 :** Extreme stereotactic body hypofractionation radiotherapy for prostate cancer.

Giancarlo Beltramo (1), Isa Bossi Zanetti (2), Achille Bergantin (1), Anna Stefania Martinotti (1), Irene Redaelli (1), Paolo Bonfanti (1), Andrea Bresolin (1), Livia Corinna Bianchi (1)
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**Keywords:** prostate, hypofractionation

**Objectives:** Stereotactic body radiotherapy (SBRT) for organ-confined prostate cancer has increased in acceptance over the past few years, as multiple studies continue to emerge demonstrating excellent biochemical control and low toxicity. We examined clinical outcomes of extreme SBRT using Cyberknife.

**Methods and Materials:** From July 2007 to December 2016 a retrospective analysis was carried out on 218 consecutive patients with a median age of 74 years (range 52 – 86) years, mean prostate volume of 75.6 cc (range 37.03 -163.16) and clinically localized prostate cancer. Pre-treatment PSA ranged from 1.75 to 51.13 ng/ml (median 7.19 ng/ml). Cyberknife was used to deliver fiducials based image guided hypofractionated Stereotactic Radiotherapy. According to D’Amico risk classification the majority of patients 116 (53%) were low risk, 58 pts (27%) were intermediate risk and 44 pts (20%) were high risk. Among the entire study cohort 19 of 44 high risk patients received androgen deprivation therapy (ADT), ADT was not administered to any low – intermediate risk patients. A prescribed dose of 38 Gy in four fraction was delivered to the PTV, which was defined as the prostate (plus seminal vesicles in high risk patients). Real-time intrafractional motion tracking was used.

**Results:** Acute urinary symptoms (frequency, dysuria, urgency, hesitancy and nocturia) were common in 44 % of patients experiencing grade I-II RTOG acute urinary toxicity. No patients experienced RTOG grade 3 acute urinary toxicity while 7 patients (3%) experienced RTOG grade 3 late urinary toxicity, in 3 of them as consequences of repeated urological instrumentation, including cistoscopy and urethral dilatation. No RTOG grade 3 acute and late rectal toxicity was observed. The actuarial median follow up is 58 months (range 12 – 114 months). The five years actuarial psa relapse free survival rate according to D’Amico risk classification is 94.3% (CI: 92.5%-96.1%) with 99.1% for low risk, 94.6% for intermediate-risk and 83.7.% for high risk respectively. Overall 11 (5%) of 218 patients failed biochemical failure, occurring in 1 low-risk patient, 4 intermediate-risk patients and 6 high-risk patients. 23 patients (10%) died during follow up for unrelated causes, only one patient (0.4%) died for prostate cancer (bone metastases).

**Conclusions:** Cyberknife SBRT produces excellent biochemical control rates with mild toxicity and minimal impact on quality of life. Median PSA levels compare favourably with other radiation modalities and strongly suggest durability of our results.

**Poster Display - Body**

**P030 : The evolving gleason grading system and stereotactic hypofractionated radiation therapy in prostate cancer**

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**Keywords:** prostate, hypofractionation

**Objectives:** Recently The International Society of Urological Pathology (ISUP) proposed a new «Grade Group» system to better reflect prostate cancer biological behavior. In patients with clinically localized prostate cancer treated with Cyberknife Stereotactic Body Radiotherapy (SBRT) we compared the D’Amico Risk classification with the New «Grade Group» System in attempt to better strafity patients.

**Methods and Materials:** From July 2007 through December 2016 a retrospective analysis was carried out on 218 consecutive patients with clinically localized prostate cancer. Pre-treatment PSA ranged from 1.75 to 51.13 ng/ml (median 7.19 ng/ml). According to the D’Amico risk classification 116 patients (53%) were low risk, 58 patients (27%) were intermediate risk and 44 patients (20%) were high risk. Following the new grading System patients were classify: Group 1 (GS 3+3) 145 pts (67%) , Group 2 (GS 3+4) 29 pts 12%, Group 3 (GS 4+3) 17 pts (8%), Group 4 (GS 4+4) 19 pts (9%), Group 5 (GS 9-10) 8 pts (4%). Cyberknife was used to deliver fiducials based image guided Hypofractionated Stereotactic Radiotherapy, all patients were treated with 38 Gy in four fractions given daily.

**Results:** With a median follow up of 58 months (range 12 – 114 months) the five years actuarial psa relapse free survival rate according to D’Amico risk classification is 94.3% (CI: 92.5%-96.1%) with 99.1% for low risk, 94.6% for intermediate risk and 83.7.% for high risk. Overall 11 (5%) of 218 patients failed biochemical failure, occurring in 1 low-risk patient, 4 intermediate-risk patients and 6 high-risk patients. 23 patients (10%) died during follow up for unrelated causes, only one patient (0.4%) for prostate
cancer. Kaplan-Meyer five years actuarial PSA relapse free survival rate according to the new « Grade Group» System observed are: group 1: 98.6%, group 2: 89.1%, group 3: 84.7%, group 4: 84.8%, group 5: 87.5%.

Conclusions: The comparison on our patients cohorts shows that a slightly higher number of patients (67% vs 53%) can be classified in a low risk group class with similar five years PSA relapse free survival, a restricted number (13% vs 20%) belongs to high risk class with no difference on PSA relapse free survival, while a significant difference on PSA relapse free survival was registered in intermediate group (85-89 % - vs 95%). The new « Grade Group» System classification differs significantly from the D’Amico risk classification and seems to better stratify patients in predicting prostate cancer recurrence.

Poster Display - Body

P031 : Toxicity and quality of life report of extreme stereotactic body radiotherapy as a monotherapy for localized prostate cancer.

Giancarlo Beltramo (1), Isa Bossi Zanetti (2), Achille Bergantin (1), Anna Stefania Martinotti (1), Irene Redaelli (1), Paolo Bonfanti (1), Andrea Bresolin (1), Livia Corinna Bianchi (1)

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Keywords: prostate, hypofractionation

Objectives: Clinical radiobiological data indicates that delivery of larger daily doses of radiation may improve the therapeutic ratio for prostate cancer. Treatment, however, often impact the quality of life due to side-effects and treatment-related toxicities. We report prospectively collected toxicity data from a cohort of localized prostate cancer patients treated with Cyberknife Stereotactic Body Radiation Therapy (SBRT).

Methods and Materials: Between July 2007 to December 2016 a retrospective analysis was carried out on 115 consecutive patients with a median age of 75 years (range 60 – 86), mean prostate volume of 67.7 cc (range 37.03 -163.16),and clinically localized prostate cancer treated with Cyberknife Stereotactic radiosurgery. The majority of patients 58 (50%) were low risk, 35 pts (30%) were intermediate risk and 20 pts (20%) were high risk using the NCCN criteria. Pre-treatment PSAs ranged from 1.75 to 51 ng/ml (median 7.6 ng/ml). 42% of patients had moderate to severe lower urinary tract symptom prior to treatment (baseline AUA > 8). The course of radiotherapy consisted of 38 Gy over four fraction given daily to the GTV, which was defined as the prostate (plus seminal vesicles in high risk patients). Real-time intrafractional motion tracking was used. RTOG toxicity grades were assigned for genitourinary (GU) and gastrointestinal (GI)

Results: In total 13 patients died during follow up for unrelated causes. Data to assess GI and GU Toxicity were available for 102 patients with a median follow up of 80 months (range 61 -114). Acute urinary symptoms (frequency, dysuria, urgency, hesitancy and nicturia) were common with 54 % of patients experiencing grade I-II RTOG acute urinary toxicity. No patients experienced RTOG grade 3 acute urinary toxicity, in 6 patients (5%) we recorded RTOG grade 3 late urinary toxicity, in two of them urethral dilatation was required for bulbar urethral stricture. In one patient a bladder fistula was observed. No RTOG grade 3 acute and late rectal toxicity was observed. The median time from CK radiotherapy completion to the occurrence of late grade 3 GU toxicity was 42 months (range 18-76)

Conclusions: Significant long term toxicities are minimal when Cyberknife stereotactic Hypofractionated radiotherapy is performed as monotherapy: this probably reflects the ability for current technology to minimize adverse effects of therapy. Continued accrual and follow up will be necessary to confirm long-term results.

Poster Display - Body

P032 : Frameless stereotactic body radiotherapy for stage ia-ib non small cell lung cancer

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Keywords: lung, stereotactic

Purpose: Although surgical resection remains the standard of care for patients with early stage non-small cell lung cancer
(NSCLC), Stereotactic body radiation therapy (SBRT) utilizing high doses per fraction is being increasingly employed in the setting of early stage non small cell lung cancer (NSCLC). We report prospectively collected data from a cohort of early NSCLC patients treated with Cyberknife (CK) Stereotactic Body Radiation Therapy (SBRT).

Materials and methods: Between February 2005 to October 2013, a total of 90 consecutive patients with a median age of 76 years (range 42 - 90) and pathologically proven NSCLC (squamous cell carcinoma, adenocarcinoma, large-cell carcinoma, bronchoalveolar cell carcinoma, or NSCLC not otherwise specified) diagnosed as 41 stage IA and 56 stage IB were referred to our Radiotherapy Department for Cyberknife stereotactic radiotherapy treatment (SBRT). In all patients selected tracking modalities depending on tumor size, location and extent of respiratory movement were performed. 27 pts with lower lobe lesions were treated with fiducial markers (1-3), in the others 70 fiducial less X sight option was used. The median tumor volume was 30 cc (range, 4-143). Depending on tumor size and location different curative dose regimens were used, but in all pts a high BED (> 100 Gy) was delivered to the tumor bed. The prescribed dose was 25-60 Gy in 1-5 fractions. Median follow-up was 30 months (range, 6 - 102).

Results: The Kaplan-Meier LC rate at 1,2,3 and 5 years was respectively 98%, 92%, 88.5% and 81%. Reported acute side effects have generally been mild including esophagitis, fatigue, chest wall tenderness and cough. For the evaluation of toxicity we used the RTOG/EORTC scale. We detected a late radiation-induced local fibrosis using CT imaging in most pts, in 3 we observed grade 3 pneumonitis, in 1 patient chest wall pain and rib fracture and in another one G3 radiation induced mielopathy at an interval of 30 months following CK/SRS treatment.

Conclusions: CK/SBRT for limited-stage primary lung cancer has been shown to be a promising treatment with high LC rates and very low toxicity. Prospective studies should be performed to determine whether this therapy may be an alternative option for surgery.

Poster Display - Body
P033 : Planning and delivery of small-field radiosurgery with a high definition MLC

Ivan Brezovich (1), Xingen Wu (1), Richard Popple (1), Rex Cardan (1), Elizabeth Covington (1), John Fiveash (2), Barton Guthrie (3), Markus Bredel (2), Winfield Fisher (3)

We investigated geometric and dosimetric accuracy of SRS treatments planned on a standard external beam treatment planning system (TPS, Eclipse, Varian Medical Systems) and delivered with an MLC-equipped accelerator (Edge, Varian Medical Systems). Nine field sizes from 1.6x5 to 30x30 mm were planned for delivery to a plastic block phantom using 10 MV flattening filter free (FFF) rotating beams. The fields were shaped by an MLC with 2.5 mm wide leaves. For each field size, the dose distribution generated by a 360° gantry arc was computed and compared to film measurements. The phantom had markings for precise positioning at kV isocenter. After exposure, films were scanned and evaluated using in-house software. Averaged over all field sizes and 10 deliveries per field, planned peak doses agreed with measurements within 2.4±2.0%. Planned and measured beam profiles along the x- and y- directions agreed better than 0.2 mm. The centers of delivered doses missed target center on average by no more than 0.18 ± 0.07 mm, with maximum error 0.33 mm. For multiple-arc SRS at various couch angles, the effect of table excursions was investigated by tracking the position of a pointer, originally positioned at CBCT isocenter, as the couch was rotated. Deviations up to 0.5 mm from its setup position were noted. These were entered into the TPS as isocenter shifts in a plan consisting of 9 arcs of 160° gantry sweeps delivered at 6 different couch angles with 2.4x5 mm fields. The plan showed that couch excursions shifted the dose cloud by only 0.13 mm and had negligible effect on the shape of dose profiles. For end-to-end tests, a cylindrical phantom was constructed having a 3 mm long, 3.15 mm diameter air-filled cavity for simulation of a small brain target. Following CT simulation (head protocol, 1 mm slices) the 9-arc regimen was planned and delivered under CBCT guidance. Based on film in the coronal and sagittal planes, the average targeting error was 0.33±0.06 mm with 0.41 mm maximum. The measured dose agreed with the TPS within 1.6±2.0%. Accelerator and imaging system proved stable and reliable throughout the 6 month time span of the tests. In conclusion, even for the small field sizes used in SRS, the Eclipse TPS and Edge accelerator with MLC can provide a high degree of dosimetric and spatial accuracy.

Keywords: Radiosurgery, MLC, Small Field, Linac

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P034 : How to manage the dosimetric shift in clinical practice when moving from dose-to-water reporting mode to dose-to-medium?

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Keywords: Dose-to-medium, Acuros XB, TCP and NTCP

Objectives: Modern dose calculation algorithms (DCA), solving the linear Boltzmann equation (which is statistically solved with Monte Carlo (MC) methods), such as Acuros XB, are presently being introduced into routine practice. When using MC calculation model, the absorbed dose is calculated to the medium (Dmed) divided in voxels, instead to water (Dw) as with most previous generation algorithms. The purpose is to attract attention to the required dosimetric parameters, radiobiological criteria and dose tolerance values for target and organs at risks (OARs) to safely implement the Dmed mode into routine treatment planning.

Methods: Ten lung cancer patient cases were used. The doses were calculated using Dw algorithms as reference, and recalculated with Dmed either using the same number of monitor units (MUs) obtained with Dw, or the same prescription dose (Dpr), keeping the same beam arrangements. The dosimetric parameters were compared. The 2D gamma (γ) was used to calculate γ-average, γ-passing rates (γrates), and γ-maps. The equivalent uniform dose (EUD) model was used for TCP and NTCP calculations. The bootstrap simulation method with no parametric tests was used to estimate the significant difference, with p < 0.05.

Results and Discussion: To precisely calculate Dmed, taking into account the secondary electron transport in lungs, requires significantly more MUs, compared to Dw models, inducing an over irradiation of the patient. The dosimetric differences, sometimes exceeding 5%, between Dw and Dmed depend on the selected and final DCA. This dosimetric shift should be taken into consideration regarding Dpr, if the 2%/2 mm criteria, at least, would not be satisfied with γrates. However, caution should also be paid, when comparing dose distribution from a reference ‘true’ MC simulation with any DCA using γ-value and γrates due to the statistical noise of the dose distributions calculated by MC. The radiobiological analysis showed that EUD(Dmed) < EUD(Dw) for target, using same MUs, leads to an overestimated TCP with Dw; but comparable EUD are produced for OARs. When using the same Dpr, EUD(Dmed) > EUD(Dw) leading to more TCP/NTCP.

Conclusion: Although it would be justifiable to suggest an adjustment of Dpr, when changing DCA from Dw to Dmed, most departments would certainly prefer to keep on with the same Dpr, thus taking advantage of the small increase of TCP. Then a reasonable goal would be to increase the constraints for OARs to limit the NTCP shift.

P035 : Stereotactic body radiotherapy and radiosurgery (SBRT and SBRS) with flattening filter free (FFF) technique in the treatment of lung cancer: clinical results and comparative analysys with flattening filter (FF) technique

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Keywords: Radiotherapy, SBRT, SBRS, lung cancer, flattening filter free, comparative analysys, clinical results

Objectives: To compare Flattening Filter (FF) and Flattening Filter Free (FFF) photon beams SBRT treatments for lung cancer; and determine potential benefits and drawbacks of using unflattened beams.

Methods: Since July 2016, 11 patients were treated by Elekta VERSA HD 6-10MV FFF photons beams: 10 peripheral and 3 central lesions (max diameters 1-3 cm). Treatment plans were developed both for FFF and FF by Monaco TPS with Montecarlo. The prescription dose at 95% of PTV (GTV+0.5cm all directions) was 26 Gy/1Fx (peripheral lesions) and 60Gy/8Fx (central lesions).
Results: Median follow-up was 3.5 months: no thoracic/mediastinal disorders; minimal pulmonary toxicity G1 at imaging; 8 no-captating PET and 5 TC lesions reduction at follow-up.

Isodoses/DVH for both techniques were compared: a lower Sigma index for FFF indicates an improved dose homogeneity at PTV; conformity index is comparable for both techniques; peripheral doses are smaller and at organs at risk mean doses are 2-4% lower in FFF modality, mostly using 10 MV energy.

FFF plans (higher dose rate 2200MU/min) displayed a higher MonitorUnit average number, but a reduction in treatment delivery/immobilization time, with clinical benefits in intrafraction organ motion management, patient comfort and dose delivery accuracy.

FFF reduces scatter, leakage, off-axis variations in beam energy and photon fluence per monitor unit produced by the high energies, in comparison to FF.

Conclusion: FFF photon beams modality seems currently advantageous and shows no drawbacks to deliver clinically acceptable SBRT/SBRS treatments for lung cancer.

By using FFF modality with small field sizes, high dose rate and high dose fraction, as well as in SBRT/SBRS, some recommendations would have to be considered.

Beam data acquisition, scanning techniques and beam modeling are vitally important. Because of the proximity to critical organs of PTV, the penumbra determination of small fields is clinically important. The dosimetry of FFF beams is made more complex by the P-ion determination: corrections to beam percentage depth doses and profiles need.

The FFF X-rays have a lower “effective energy” compared to FF X-rays. Therefore, it is important to evaluate the skin (entrance) doses for internal organs. For VERSA HD, FFF skin doses are marginally higher than FF skin doses, but likely not clinically significant.

Moreover, several scientific articles address radiobiological concerns using FFF photons beams, regarding to high dose rate use and high dose per fraction delivery.

Scientific protocols and a longer follow-up are claimed to evaluate these topics and potential benefits on the treatments outcome.

Poster Display - Body
P036 : Clinical Experience with MLC based Brain and Spine SRS on CyberKnife M6™ System

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Keywords: MLC, SRS, CyberKnife

Purpose: To report our clinical experience on brain and spine stereotactic radiosurgery (SRS) using InCise™2 Multileaf Collimator (MLC) on CyberKnife M6™ System.

Method: The InCise™2 MLC has been successfully implemented in routine clinical use in our institute for more than a year. To assess the benefits of using the MLC over cone based collimator, we performed plan comparison on 14 selected patients (7 brain cases and 7 spine cases) who were treated with MLC, and two potential MLC candidates (1 brain and 1 spine) who were ultimately treated with Iris. For these selected cases, the planning treatment volume (PTV) ranged from 20 cc to 258 cc (average 75 cc). Treatment doses ranged from 20 Gy to 40 Gy in 1 to 5 fractions. All the treatments were planned using the same constraints and objectives with both MLC and Iris collimator. Target coverage, critical structure sparing, prescription isodose line, conformity index (CI), monitor units (MU), treatment time, as well as the dose gradient (defined by the ratio of V50% to PTV) were compared between the two methods.

Results: MLC plans were found to be clinically equivalent or better compared to Iris plans in the fourteen patients treated with MLC. MLC plans were prescribed to (79.9±2.8)% with (94.7±3.9)% target coverage, and CI of 1.28±0.1. The Iris plans were prescribed to (80.6±2.8)% with (95.7±2.9)% target coverage, and CI of 1.27±0.1. All of the 14 plans met constraints on the critical structure sparing. Less MUs and treatment time were required for all the MLC plans. The average reduction in MUs and treatment time were 36% (9% - 66%) and 35% (21% - 53%) respectively. All the MLC plans had slight smaller dose gradient compared to that of Iris plans (3.03 for MLC plans versus 3.46 for the Iris plans), which means better dose drop off around the target for MLC plans. For the two patients with superior Iris plans,
their MLC plans were not able to meet the critical structure constraints with the same PTV coverage. Both patients were in the setting of repeat irradiation with PTVs in contact with critical structures and with stricter dose constraints.

**Conclusion:** The Incise™2 MLC is beneficial for treatment with larger PTVs (>20 cc). Compared to Iris collimator, MLC allows an average reduction of 35% in MUs and treatment time, with an improved dose gradient.

**Poster Display - Body**

**P037 : Long term results of stereotactic body radiotherapy (SBRT) for stage I non-small cell lung cancer (NSCLC)**

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**Keywords:** Stereotactic Body Radiotherapy Stage I Non-small Cell Lung Cancer

SBRT is becoming a standard treatment for patients with stage I NSCLC who are inoperable or refuse surgery. We started SBRT in July 2006 using a linac system equipped with micro-multi-leaf collimators and an accurate patient setup system. We used a plastic shell with confirmation of the same spine position by X-rays but without an invasive marker or a respiratory tracking system.

Enrolled were 207 patients with NSCLC (156 men and 51 women) with a median age of 79 years (range, 55-89) treated by March 2013. All patients had stage IA or IB cancer. 169 lesions were histologically confirmed; 98 adenocarcinoma (AD), 60 squamous cell carcinoma (SCC), 11 NSCLC. The CTV was delineated using CT images taken at 3 phases (expiratory, inspiratory and free breathing). The PTV margin was 3-7 mm. Three coplanar and 4 non-coplanar beams were used. Median PTV volume was 47 cc (range, 14-122). The SBRT dose was 48-52 Gy in 4 fractions over 2 weeks (n = 178), 56-64 Gy in 8 fractions in 3 weeks (n = 27), or other (n = 2).

The median follow-up period was 51 months (range, 5-94) for living patients. The 5-year overall survival rate was 72% and 54%, respectively (p=0.02). 56 were long-term survivors over 5 years (27%). We assessed the 5-year survival, cause-specific survival, local control, progression-free, and radiation pneumonitis (RP) rates. The 5-year survival rates of female patients, patients with high PS, and AD were higher than those of other patients (p=0.0001, 0.008, and 0.02, respectively). The 5-year local control rate was significantly higher in AD than SCC patients (89% vs 72%, p=0.003), while the progression-free survival did not differ. Grade 2 or higher RP occurred in 13%. Local recurrence was observed in 24 patients and re-irradiation was performed in 10; 8 achieved local control again.

Our relatively simple SBRT method without an invasive marker was safe and efficient for stage I NSCLC. Local control of IB patients did not differ from that of IA, although metastases were more frequent. Higher doses may be necessary for SCC, while AD may require adjuvant chemotherapy in light of the high rate of distant metastasis. Re-irradiation for local failure could achieve local tumor control.

**Poster Display - Body**

**P038 : Definitive radiation therapy for early stage breast cancer: dosimetric feasibility of stereotactic body radiation therapy (SBRT) for intact breast tumors**

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**Keywords:** SBRT, breast cancer, inoperable, treatment planning, dosimetry

**Purpose:** Few definitive treatment options exist for elderly, medically inoperable patients diagnosed with early stage breast cancer. Historical data suggests very poor local control with hormone therapy alone. In this study, we examine the dosimetric feasibility of definitive robotic stereotactic body radiation therapy (SBRT) for the treatment of early stage breast cancer.

**Methods and materials:** Patients with biopsy-proven early stage breast cancer were identified who underwent pre-operative CT scans. Using these scans, a GTV was identified and contoured to include all visible tumor. A CTV was generated by applying a 5 mm expansion,
appreciating anatomic boundaries of spread. The PTV was a 2 mm expansion from CTV for robotic SBRT plans, and standard RTOG expansions were utilized to generate comparison PTVs for 3D-CRT plans. The appropriate PTV was treated to a total dose of 50 Gy in five fractions utilizing both robotic SBRT and 3D-CRT for dosimetric comparison. Five-fraction dose volume criteria were specified as per NSABP B-39/RTOG 0413 and TG-101.

Results: The mean GTV and CTV volume were 4.92 cc and 16.84 cc, respectively. The mean PTV for SBRT and EBRT plans were 24.35 cc and 65.18 cc, respectively (p < 0.01). GTV and PTV coverage was excellent for robotic SBRT plans, with mean V50Gy values of 99.93% and 98.41% respectively. Although GTV coverage was equivalent in 3D-CRT plans, PTV coverage was notably worse (V50Gy = 91.73%, p = 0.02). The mean ipsilateral breast V40Gy was significantly lower in SBRT plans than 3D-CRT plans (5.34% vs. 13.14%, p < 0.01). The mean maximum dose to the chest wall was 44.08 Gy in SBRT plans, compared to 50.17 Gy in 3D-CRT plans (p = 0.02). The mean maximum dose to skin was 36.39 Gy in SBRT plans, compared to 41.66 Gy in 3D-CRT plans (p = 0.05). No significant differences were noted in ipsilateral lung, contralateral lung, heart, or thyroid dosimetry. Cardiac sparing with robotic SBRT was excellent, with a mean heart V2Gy for patients with left sided tumors of 5.12 cc.

Conclusions: Based on this preliminary data, definitive robotic SBRT appears to be a dosimetrically feasible treatment for early stage breast cancer. Significant normal tissue sparing, even with the high doses necessary for ablation, seem to be achievable. Prospective clinical trials will be crucial to explore the safety and efficacy of definitive SBRT in this patient population.

Poster Display - Functional

P039 : Role of CyberKnife radiosurgery in pituitary mass and improvement in growth hormone levels

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Keywords: Cyberknife Radiosurgery, Pituitary adenoma, Growth hormone

Objective: Role of CyberKnife Radiosurgery in pituitary mass and improvement in Growth hormone levels.

Study Design: A prospective study.

Place and Duration of Study: This study was conducted in the Department of Radiology and Cyber Knife Stereotactic Radiosurgery, JPMC Karachi from January 2013 to August 2015.

Methodology: A prospective study was conducted during the year of January 2013 to August 2015 in the department of CyberKnife, JPMC, Karachi in patients with pituitary adenoma diagnosed through MRI having clinical symptoms of amenorrhea, visual disturbances and headaches. Tumor size and Growth hormone levels were assessed before going through surgery and after Cyberknife treatment, reduction in tumor. A total of 50 patients with pituitary adenoma underwent Cyberknife radiosurgery procedure. The patient group comprised of 50 diagnosed cases of pituitary adenoma of men (56%) and women (44%). Included patients were either those with surgically inaccessible or post-surgical residual lesions. The median tumor volume was 10.14cm³ with a mean volume of 24.70 cm³. Maxim prescription dose was 25 Gy with prescription isodose line ranging from 60 to 84. The mean and median folllow-up periods were 3 months and 6 months respectively.

Results: Out of the 50 patients, 21(42%) patients with pituitary adenoma showed Reduction in size of tumor and marked decrease in growth hormone levels 38(76%) after Cyberknife robotic radiosurgery. 29(58%) patients showed stable size radiologically with reduced hormone level but 12(24%) patients showed same hormone level on follow ups. A pre and post cyber knife Radiosurgery visual acuity test was performed for each individual. No visual complication was observed on post cyber knife Radiosurgery.

Conclusion: Cyberknife is a cutting edge technology in the field of radiation oncology. After cyberknife Radiosurgery, the normal functioning of pituitary gland was found less affected with maximum dose delivery to the tumor. Our results proved cyber knife Radiosurgery as the safest treatment for those patients with post operative residual pituitary adenomas and those with inoperable tumors without any post radiosurgical complication.
Keywords: functional, radiosurgery

Introduction: To our knowledge this is the first report of functional radiosurgery with a fully automated Rotating Gamma Ray Unit (Infini®) by Masep (Shenzhen, China) in the Americas. One of the singularities of this machine is that uses 30 cobalt sources that rotate around the isocenter at one revolution per minute, the treatment requires an invasive frame in a similar fashion that its better known predecessor, the Gammaknife®.

Material and methods: From April 2014 to October 2016, 37 patients of functional disorders. We used the Infiniti, gamma ray with the treatment planning system SuperPlan®, using image data sets acquired by Magnetic Resonance Imaging on T1 or T2 sequences as needed. We report four thalamotomies, three for tremor and one for intractable pain, two hipofisectomies for pain in terminal cancer patients, two bilateral capsulotomies for psychological disorders, one case of epilepsy and 28 cases for trigeminal neuralgia. In general single 4mm isocenters were chosen and on occasion tandem 4mm. Doses ranged from 78 Gy to 96 Gy in trigeminal neuralgia and 124Gy to 150Gy to the 100% isodose line for the rest of the disorders.

Results: Using the Dorsal Root Entry Zone (DREZ) as target for the first half of the trigeminal patients we achieved an 86% of excellent to good results according to Barrow Scale. In the cases of pain in terminal cancer patients the pain relief varied from 80 to 90% in both cases and results were seen according to Visual Analog Scale starting at 48 to 72 hours post treatment. In tremor from diverse pathologies the Fahn-Tolosa Marin-tremor rating scale improved in 60 and 70%, one is pending as well as the medial thalamotomy for pain as treatments are recent. Finally, in one case of Obsessive Compulsive Disorder an 80% improvement is noticed two years after treatment and on and aggressive and autism patient that is the case remaining, minimal to no improvement has been noticed one year out after treatment.

Conclusions: We report our initial experience in functional radiosurgery using Infiniti® and the clinical results are in accordance of what has been published with similar technology.

We foresee a wider application of radiosurgical treatments in countries like ours were other technologies used in surgery are economically less feasible.

Poster Display - Functional

P041 : Early stereotactic radiosurgery for medically refractory trigeminal neuralgia

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Keywords: Gamma Knife, radiosurgery, trigeminal neuralgia, early, pain

Objective: To evaluate the outcomes of high-dose gamma knife radiosurgery (GKRS) for the treatment of medically refractory trigeminal neuralgia (TN), and to clarify the effectiveness of early GKRS in the treatment of medically refractory TN.

Material and Methods: This retrospective review covers 108 consecutive patients presenting with medically refractory, idiopathic TN between 2006 and 2014. The median follow-up period was 43 months. All patients underwent GKRS treatment targeting the root entry zone with median maximum dose of 90 Gy and isodose line of 20%. Telephone questionnaires were used for the collection of pre-operative and post-operative data. Outcomes pertaining to pain and facial numbness were scored using the Barrow Neurological Institute (BNI) pain and facial numbness scales, respectively. BNI pain scores of I to IIb were defined as pain relief.

Results: Following a median latency period of four weeks, we observed complete or adequate pain relief (BNI scores of I to IIb) in 86 of the 108 patients (90%). Twenty-two patients (26%) experienced pain recurrence at a median period of 17 months. Fifty-nine patients (55%) reported new onset facial numbness. The treatment failure rates were highest among patients with a longer history of pain. Compared to patients with pain history of ≤5 years, those with pain history of >5 years experienced longer latency prior to pain relief (p=0.027, Kaplan-Meier). We did not observe a significant difference in the pain relief maintenance rate between patients with pain histories of ≤5 and >5 years (p=0.776). Univariate and multivariate analyses demonstrated that pain history of ≤5 years was a significant predictor of pain relief (p=0.049 and p=0.045, respectively).

Conclusions: GKRS achieves a high rate of pain relief among patients with medically refractory, idiopathic TN. Pain history of ≤5 years is a reliable predictor of pain relief and appears to be associated with shorter latency to pain relief following GKRS. This means that early GKRS treatment for patients with medically refractory, idiopathic TN is recommended.
P042: Frameless stereotactic radiosurgery for the treatment of multiple sclerosis-related trigeminal neuralgia

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Keywords: trigeminal neuralgia, multiple sclerosis, facial numbness, stereotactic radiosurgery, frameless radiosurgery, Cyberknife

Background: Trigeminal neuralgia (TN) affects 7% of patients with multiple sclerosis (MS). In such patients, TN is difficult to manage either pharmacologically and surgically. Radiosurgical rhizotomy is an effective treatment option. The non-isocentric geometry of radiation beams of CyberKnife introduces new concepts in the treatment of TN. Its efficacy for MS-related TN has not yet been demonstrated.

Methods: Twenty-seven patients with refractory TN and MS were treated. A non-isocentric beams distribution was chosen; the maximal target dose was 72.5 Gy with a 4-6 mm of the trigeminal nerve included in the 80% isodose line (58 Gy). The maximal dose to the brainstem was

Results: Median follow-up was 37 (18-72) months. Significant pain relief was achieved in 23/27 (85%) patients within 45 days. Prescription isodose line (80%) accounting for a dose of 58 Gy incorporated an average of 4.85 mm (4-6 mm) of the nerve and mean nerve volume of 26.4 mm3 (range 20-38 mm3). No complication was observed. The rate of pain control decreased progressively after the first year and only 44% of patient retained pain control 4 years later.

Conclusions: Frameless radiosurgery provides a fully non-invasive technique for retroGasserian rhizotomy. Pain relief was satisfactory and, with our dose/volume constraints, no sensory complications were recorded. Nonetheless, long-term pain control was possible in less than half of the patients. This is a limitation that Cyberknife radiosurgery shares with other techniques in MS patients.

P043: Glossopharyngeal neuralgia treated by Gamma-Knife radiosurgery: Safety and efficacy through a long-term follow-up.

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Keywords: Vago-Glossopharyngeal neuralgia, Glossopharyngeal neuralgia, Radiosurgery, Gamma-knife

Introduction: Glossopharyngeal neuralgia (GPN) is a rare and disabling condition. In the manner of trigeminal neuralgia, Gamma Knife radiosurgery (GKRS) is more and more described as a therapeutic option. We propose to assess long-term safety and efficacy of GKRS in this indication.

Methods: From 2007 to 2015, 9 patients (4 males, 5 females) underwent a total of 10 GKRS procedures. All the patients presented GPN that were refractory to all medical treatment with a long-lasting pain story. One patient had previously undergone a surgical micro-vascular decompression. 5 patients presented a MRI-identified neurovascular conflict. Concerning GKRS procedure, the IXth nerve was localized on MRI and CT under stereotactic conditions. The target was located at the glossopharyngeal meatus of the jugular foramen. The dose administered to the nerve was 80 Gy in 3 patients and then 90 Gy for the others. Patients were followed at 6 and 12 months of the procedure and then repeatedly.

Results: 8 patients presented an improvement within a median onset of 7 weeks after GKRS (range 2-12 months). At the first follow-up, 6 patients were pain-free (Class 1-3) including 4 patients medication-free (Class 1). 2 patients were partially improved (Class 4) and one remained unchanged. The mean follow-up time was 46 months (range 10-90 months). At the last follow-up 6 patients remained pain-free (Class 1-3) including 4 patients medication-free (Class 1). No side effect was observed.

Conclusion: Because of its safety and efficacy, GKRS appears as a useful tool to treat essential glossopharyngeal neuralgia, including as a first-line treatment.
Poster Display - Functional

**P044 : Stereotactic radiosurgery using CyberKnife system in Parkinson's disease**

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**Keywords:** CybertKnife, radiosurgery, PD, Parkinson’s Disease

**Background/Purpose:** The Parkinson’s Disease is the second most common neurodegenerative disease. Most frequent and essential clinical symptom is tremor. For treatment of this symptom alternative method to pharmacotherapy and radiofrequency ablation is radiosurgery.

The aim of this pilot study is to show the method and results of the stereotactic radiosurgery planning using CyberKnife System in patients with Parkinson’s Disease.

**Materials & Methods:** Heads of 9 patients had immobilised using thermoplastic masks. Precise symmetrical positioning of the head with the sagittal axis and the orbital line perpendicular to the table was a key point of the treatment planning. Target and organs at risk was defined using MR (T1-weighted with contrast medium and fractional anisothropy) and CT (with and without contrast medium) fusion. Complex irradiated area included thalamic nucleus (Ventralis oralis Anterior and Ventralis oralis Posterior) on the opposite side to the limb suffering the tremor. The direct location of the target area was determined based on the guidelines defined in the stereotactic atlas (usually 12 millimeters to the side of the midcommissural point).

Radiosurgery treatment planning was performed using MultiPlan CyberKnife System. To collect base set of the images for dose calculation, CT without contrast medium was used. Treatment plans were performed according to approved protocol of the clinical trial.

**Results:** Three of 9 patients received total dose of 70 Gy as a maximal dose in the center part of the target. Total dose gradually increased by 5 Gy for the following next two groups, each of three patients. Therefore, total doses of 70 Gy, 75 Gy and 80 Gy were delivered.

Maximum dose to brainstem was 7.8 Gy ± 0.6 Gy, optic chiasm 1.9 Gy ± 0.8 Gy, lenses 0.2 Gy ± 0.1 Gy, optic nerves 1.1 Gy ± 0.9 Gy and internal capsule 22.2 Gy ± 7.9 Gy.

The 50% isodose had less than 8mm in the horizontal plane. Irradiation takes 47 ± 5 minutes and the number of radiation beams was 127 ± 11.

**Conclusions:** At the first glance, there is no reasonable arguments to ignore Stereotactic Radiosurgery using CyberKnife System as a treatment alternative to traditional treatment modalities of the Parkinson’s Disease.

**Poster Display - Functional**

**P045 : Trigeminal neuralgia secondary to intracranial lesions: a prospective series of 20 consecutive cases**

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**Keywords:** trigeminal neuralgia, secondary, radiosurgery, gamma knife surgery

**Objective:** Trigeminal neuralgia (TN) is usually idiopathic. However, there are rare cases (aprox 10%), in which TN is due to intracranial lesions. The most frequent are cavernous sinus menigiomas and trigeminal schwannomas. The purpose of the study was to assess the role of Gamma Knife surgery (GKS) in secondary TN caused by space-occupying lesions.

**Methods:** From July 2010 till November 2016, 20 patients had GKS for secondary TN. Eleven cases (55%) were menigiomas, 6 (30%) trigeminal schwannomas, 2 (10%) brain metastases and 1 (5%) arterio-venous malformation (AVM). The primary outcome was tumor control. The secondary outcomes were the alleviation of pain and the eventual secondary effects. Covariates were the age, duration of symptoms, duration till alleviation etc. The tumor was the primary target in all cases, with the exception of one, in which both the tumor and the nerve were targeted, with a free pain interval between treatments. The former was excluded from the present analysis

**Results:** The mean age in this series was 61.9 years (range 39-79). The mean follow-up period was...
2.6 years (range 1.3-5). The mean duration of TN was 11.8 months (range 0.5-160). Follow-up was available for 19 patients (95%). Pain alleviation appeared after a mean time of 4.2 months (1-11) in 17 patients (89.5%). Six (31.6%) patients completely stopped medication in a mean time of 7.2 months (range 1-12) and three (15.8%) decreased it at half of the initial doses. No patient developed new hypoesthesia or other cranial nerve complication. One patient presented at 6 months with a worsening of the symptomatology; after a corticotherapy, which lasted for one week, the patient regained the previous state. The marginal doses for meningiomas and trigeminal schwannomas were 12 Gy (12-14), for metastasis 20 (20-20) and for AVM 24 Gy. The mean maximal diameter was 20.17 (range 9-36). The mean target volume was 1.94 cc (range 0.12-8.10). The mean prescription isodose volume was 2.77 cc (0.19-11.90). The mean number of isocenters was 14.7 (4-27). At last follow-up, tumor decreased in 13 (65%) patients, was stable in 6 (30%) and increased in one (5%), the latest at 6 months.

Conclusions: Gamma Knife surgery is safe and effective in treating intracranial lesions presenting with secondary TN secondary to intracranial lesions. The initial pain freedom response (BNI I-IIIA) was close to 90%, while having no secondary effect. Pain alleviation is achieved even in the absence of a volume variation of the lesions.

Poster Display - Functional

P046 : Gamma Knife radiosurgery for symptomatic trigeminal neuralgia — How should we decide the treatment strategy

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Keywords: Gamma knife radiosurgery, symptomatic trigeminal neuralgia

Introduction: For the treatment of essential trigeminal neuralgia(TN), Gamma Knife radiosurgery(GKRS) is widely adopted now. But there are few reports about GKRS for symptomatic TN caused by a tumor, arteriovenous malformation, etc. Generally, pain of symptomatic TN is controlled by GKRS of targeting the lesion earlier than that of essential TN. We also have experienced some cases of symptomatic TN. Here, we summarize the results of our cases and reviewed the strategy of GKRS for symptomatic TN.

Methods: From January 2006 to December 2015, 24 patients suffering from symptomatic TN were treated by GKRS at our institution. Of them, 20 patients that could be followed up for a minimum of 6 months were retrospectively examined.

Results: In 15 of the 20 cases, pain could be controlled by GKRS targeting only the lesion. But in some cases, pain could not be controlled in spite of the lesion control by GKRS. In these cases, the pain could be controlled by an additional GKRS directly targeting the fifth cranial nerve, using for treating essential TN. And, in cases of emergency or in cases where GKRS was not suitable for treatment of the lesion, from the first, adding or using the same GKRS for treating essential TN was effective.

Conclusions: We reviewed the strategy of performing GKRS for symptomatic TN from our experienced cases. In some symptomatic TN cases, pain could not be controlled only through lesion control by GKRS. Although GKRS for symptomatic TN should be directed to the lesion rather than the trigeminal root originally, in such cases, it was indicated that adding or using the same GKRS for treating essential TN was effective and safe for the treatment of symptomatic TN. Thus, we recommend that GKRS should be directed to the trigeminal root in the following cases: 1. when GKRS targeted at the lesion has not been effective. 2. if there is an emergency. 3. if the lesion is deemed not amenable to GKRS.

Poster Display - Functional

P047 : DTI tractography integration for the radiosurgery planning of functional disorders.

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Keywords: diffusion tensor imaging, tractography, radiosurgery, cyberknife, functional radiosurgery
Functional disorders of the brain, such as movement disorders, dystonia and neuropathic pain, may respond poorly to medical therapy. A noninvasive alternative to deep brain stimulation (DBS) is radiosurgical ablation with high radiation doses. Although considerable positive experience has been recently reported, nowadays functional radiosurgery suffers from some limitations: MRI anatomical targeting is difficult and debatable and one therefore must rely mainly on stereotactic coordinates. Furthermore, lesion sizes may vary, and shielding adjacent radiosensitive neural structures may be difficult. The target volumes are delineated by a skilled multidisciplinary team of expert radiotherapists and neurosurgeons, hopefully with the support of semi-automatic atlas-based methods that limits the identification errors. Despite the usefulness to assess the axonal organization of the white matter tracts for the saving of the main neural pathways, the MR diffusion tensor imaging (DTI) in functional radiosurgery has not been proven and its use has not been reported yet.

In this methodological and feasibility study we used the envelope of DTI tractography fiber bundles in the treatment planning of essential tremor with Cyberknife in four patients. For this purpose, after a standard DTI preprocessing we reconstructed the corticospinal tracts (CST) using a two regions of interests (ROI) approach, based on anatomic knowledge about fiber bundles with one ROI in the anterior mid pons and the other in the white matter close to the sensorimotor cortex. Then the CST, coregistered and fused on a 3D T1 MRI sequence, where exported in DICOM format and loaded into the treatment planning system (TPS), contoured and considered as organs at risk.

The dose distributions obtained with and without considering the CST as organ at risk during the inverse planning optimization procedure showed strong differences in the dose to the white matter tracts (up to 100%), while target coverage, average dose to the brain, and treatment delivery time remained unchanged. Such dose differences depend on the subjects anatomical variability and on the relative position between target and CST.

In conclusion we implemented a method that go beyond the visual inspection of fibers before planning, integrating them into a Cyberknife environment. This may be useful for the evaluation and control of radiation dose to the white matter tracts, particularly for the functional radiosurgery where high doses are involved (around 100 Gy) and to improve the knowledge about the pyramidal tract dose tolerance.

**Poster Display - Functional**

**P048 : Single shot gamma ventral capsulotomy for intractable obsessive-compulsive disorder**

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**Keywords:** Radiosurgery, obsessive-compulsive disorder, neurosurgery

**Objectives:** Psychiatric surgery evolved from a highly controversial field to a sophisticated approach to treat severe, disabling and otherwise intractable mental disorders. In this context, Gamma ventral capsulotomy (GVC), is a promising treatment option for refractory obsessive-compulsive disorder (OCD). Most studies suggest that double shot GVC is efficacious, despite a few complications (e.g., brain cysts). Recently, single shot GVC has been proposed as a less deleterious technique, showing good efficacy and favorable adverse events profile. The aim of this study was to replicate these findings on a cohort of five refractory OCD patients.

**Methods:** Five patients with intractable OCD were selected by OCD-experienced psychiatrists and received single shot GVC. Radiosurgery was performed using Gamma Knife Perfexion from 2014 to 2016. Targets were located at the most ventral borders of the anterior limb of the internal capsule, using a maximum dose of 150 Gy and 4 mm collimators. Patients were assessed for symptom severity (Yale-Brown Obsessive-Compulsive Scale – Y-BOCS), global functioning (Clinical Global Impressions Improvement scale - CGI), anxiety (Beck Anxiety Inventory and Hamilton Anxiety Rating Scale), depressive symptoms (Beck Depression Inventory and Hamilton Depression Rating Scale), and neuropsychological and personality changes, at baseline. Follow-up evaluations were done by psychiatrists periodically, checking for adverse events and treatment response during the follow-up. Response criteria was defined as a minimum of 35% reduction in Y-BOCS scores and an “improved” or “much improved” score on the CGI.

**Results:** No severe adverse events were reported after the procedure. Four patients (A, B, C, D) have already completed 12 months of follow up and one patient (E) has been followed up for 3 months. Among the five patients that
have been submitted to the single shot GVC, none fulfilled our response criteria: the median decrease in Y-BOCS score was 4.48% for the first 4 patients with >12 months of follow-up. No patients presented “improved” or “much improved” scores on the CGI after the surgery. There were no significant changes on depression or anxiety symptoms.

**Conclusions:** Although a previous study suggested positive findings with single shot GVC, our results do not indicate so far a good efficacy profile of such small volume lesions. Future studies should address the relationships between target location, white matter fiber tracking along the internal capsule and clinical response. The effects of an additional dorsal shot lesion should also be investigated.

*Poster Display - Functional*

**P049 : Gamma Knife thalamotomy based on the strategy of stereotactic thermocoagulation.**

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**Keywords:** thalamotomy, Gamma Knife, essential tremor

**Objective:** To evaluate the safety and efficacy of unilateral Gamma Knife (GK) thalamotomy for treatment of severe tremor with a retrospective assessment in our Institute.

**Methods:** From October 2014 till September 2016, 24 patients (mean age, 78 years; 13 men; mean duration of symptoms, 25.8 years) with severe drug-resistant tremor (21 essential, 1 dystonian, 1 post-thalamic hemorrhage, 1 parkinsonian) were treated with unilateral GK (all on left side) targeting the ventral intermediate nucleus (VIM) with single shot through a 4-mm collimator. Beam blocking technique was used in 4 patients. Neurosurgeon initially selected the target in the same way as with usual thermo-coagulation, then discussed the modification to the final target with GK surgeon. The maximum dose was 130 Gy. Neurologic and neuropsychological assessments were performed by an independent neurosurgeon before treatment and at 12 months thereafter. MRI follow-up was achieved at 1, 3, 6, and 12 months. Upper limb severity of the tremor in 14 patients with less than 12 month follow-up was statistically analyzed by the modified TETRAS (the essential tremor rating assessment scale).

**Results:** The upper limb every tremor sub-score, writing sub-score and circle drawing sub-score (0-4) was significantly improved (p=0.001, 0.001 and 0005 respectively according to Wilcoxon test). Tremor score was improved by 1 to 12 months (mean period, 5.5 months) after GK, while 2 patients had no effect after GK. The only side effect was a hemiparesis associated with excessive edema around the thalamotomy in one patient.

**Conclusion:** The well-discussed target decision with the strategy for GKT is a safe and efficient treatment for severe medically refractory tremor.

*Poster Display - Malignancy*

**P050 : Radiosurgical decompression for benign perioptic tumors causing compressive cranial neuropathies: a feasible alternative to microsurgery?**

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**Keywords:** stereotactic radiosurgery, hypofractionation, cranial neuropathy, radiation-induced optic neuropathy, visual outcome

Several studies have reported the efficacy and safety of hypofractionated stereotactic radiosurgery (hSRS) in the treatment of benign periorbital tumors. This study went further and evaluated the feasibility of hSRS in the treatment of those causing compressive cranial neuropathies (CCNs) among periorbital tumors with special consideration of functional improvement. Twenty-six patients with CCNs (CN II=19; CN III/IV/VI=9; CN V=3) caused by periorbital tumors underwent hSRS between 2011 and 2015. hSRS was delivered in 5 fractions with a median marginal dose of 27.8 Gy (=14 Gy in a single fraction, assuming an α/β of 3) to a tumor volume of 8.2±3.3 cm3. All tumors except 1 shrank after treatment, with a mean volume decrease of 35% (range, 4%-84%) during the mean follow-up period of 20 months. In 19 patients (38 eyes) with compressive optic neuropathy, vision improved in 55.3% of eyes (n = 21), was unchanged in 36.8% (n = 14), and worsened in 7.9% (n = 3) (2.6% after excluding 2 eyes deteriorated due
Abstracts

Poster Display - Malignancy

**P051 :** Optimal dosimetric planning in stereotactic radiosurgery for perioptic tumors: a comparative study between CK versus GK

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**Keywords:** Stereotactic radiosurgery, Brain metastases, Cyberknife, Gamma Knife, perioptic tumor

**Purpose:** We investigated the dosimetric differences between robotic-arm based Cyberknife (CK) and frame based Gamma Knife (GK) in treatment planning of hypofractionated stereotactic radiosurgery (hSRS) for perioptic tumors.

**Methods:** We selected 18 perioptic tumors previously treated using CK between 2011 and 2015. The CK plan was generated using 4 or 5 dose-limiting auto-shells, one at prescription dose (PD) level, another at intermediate dose level (50% of PD) for steeper dose fall-off, and the others at low-dose levels, with an optimized shell-dilation size based on our experience. The GK plan was also produced using the original contour set. Thus, both data set of dosimetric parameters was generated and compared. hSRS was delivered in five fractions with a median marginal dose of 27.8 Gy (≈14 Gy in a single fraction, assuming an $\alpha/\beta$ of 3) to a median tumor volume of 3.1 cm$^3$. All treatment planning goals was maximizing the minimum dose to perioptic tumor, while satisfying the dose-volume constraints criteria ($D_{max} < 25$ Gy and $V_{20Gy} < 0.2$ cc) of the optic apparatus as closely as possible.

**Results:** There were no differences between CK and GK plans in the D99.9% of tumor (mean 24.05 and 23.44, respectively; $P=0.054$) and conformity index (mean 1.24 and 1.27, respectively; $P=0.825$). However, CK plans produced significantly higher values of tumor coverage than those produced by GK plans ($P<0.001$). The OA doses were well within the tolerated dose-volume limits in all plans.

**Conclusions:** These results indicate that CK and GK have provided similar dosimetric quality, except for tumor coverage, maintained dose-volume limit of the OA.

Poster Display - Malignancy

**P052 :** Hypofractionated stereotactic radiotherapy (3 x 7.7 Gy) to the postoperative resection cavity for brain metastases: a single-center report.

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**Keywords:** Resection cavity; stereotactic radiotherapy; brain metastasis.

**Purpose:** To analyze the outcomes of patients treated with the LINAC frameless stereotactic system for the resection cavity of brain metastasis (BM).

**Methods and Materials:** We retrospectively reviewed patients with no prior whole brain radiotherapy (WBRT) who underwent hypofractionated stereotactic radiotherapy (HFSRT) to the surgical bed of brain metastases at a dose of 23.1Gy (3 x 7.7Gy) prescribed to the 70% isodose line. The planning target volume was the resection cavity with the addition of a 2-mm margin.

**Results:** Between February 2012 and February 2015, 86 patients with 92 cavities were treated with post-operative HFSRT. The lung had the most primary tumors (51.2%), and 58 patients (63%) had a single metastasis. The median follow-up time was 12.9 months. The actuarial local control rates at the resection cavity were 94% at 6 months, 90% at 1 year and 88% at 2 years. On multivariate analysis, a higher PTV was predictive of local failure (LF) (HR=1.04, $p=0.031$), and patients with PTV $>$22mL had 3.94 times higher risk of developing local recurrence than patients with PTV $\leq$22 mL (HR=3.94, $p=0.026$). Distant brain failure (DBF) occurred in 57% of cases, and leptomeningeal
disease (LMD) developed in 13% of cases. Subtotal resection of BM was significantly predictive of developing LMD (HR=7.4, p=0.0006). The median overall survival (OS) was 14.5 months. On multivariate analysis for OS, KPS>70 % (HR=0.53, p=0.044), a radiological suspicious of radionecrosis (HR=0.088, p<0.001), the time interval between the primary tumor diagnosis and manifestation of BM (HR=0.99, p=0.04), the presence of a single metastasis at treatment (HR=0.057, p=0.008) and a decreasing time between planning MRI and HFSRT (HR=0.92, p=0.0002) were favorable prognostic factors for OS. Salvage therapies included WBRT (28%), stereotactic radiotherapy for LF (n=4) or DBF (n=27), and surgery (n=5 for LF; n=2 for DBF). Fifteen patients (16%) developed brain radionecrosis at a median time of 14.4 months.

Conclusion: HFSRT to the tumor bed without WBRT is an effective treatment for resected metastases. A PTV>22 mL was associated with a higher risk of local failure and subtotal resection of BM with an increasing risk of developing LMD. Although most patients develop distant intracranial failure, the stereotactic radiotherapy approach allowed the avoidance or delay of WBRT in most cases.

Poster Display - Malignancy
P053 : Outcomes of adjuvant whole-brain radiotherapy versus hypofractionated stereotactic radiotherapy after surgical resection of brain metastases: a propensity score-matched analysis

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Keywords: whole brain radiation therapy, stereotactic radiotherapy, surgical bed, brain metastases, propensity score.

Purpose: To assess the risks of local and distant failure and overall survival time in patients treated with hypofractionated stereotactic radiotherapy (HFSRT) to the postoperative cavity for brain metastases compared with patients treated with adjuvant whole-brain radiation therapy (WBRT).

Methods and Materials: Between July 2005 and February 2015, 196 non-randomized patients with 202 resected brain metastases were treated with post-operative WBRT or HFSRT at a single institution. The propensity score was included as a covariate to compare the interval to local failure, distant brain failure and overall survival time. The matching covariates consisted of the age, Karnofsky performance status, primary disease, number of brain metastases, extracranial disease status and presence or absence of extracranial metastases.

Results: In total, 110 patients (54.5 %) received adjuvant WBRT, and 92 HFSRT procedures (45.5 %) were delivered after surgery. A Cox model adjusted on the propensity score showed that the brain distant failure was significantly associated with treatment modality. Compared with WBRT, the patients who received HFSRT had a significantly greater risk of developing brain recurrence (HR = 3.37 [2.13-5.33], p < 0.001). No difference was observed in local failure (HR = 1.16, p = 0.77) between the groups. In the propensity-matched cohort, the effect of treatment on survival was not significant (p = 0.14), but it depended on the time. Within the first 20 months, the patients treated with WBRT had a 2 times higher risk of death than did patients treated with HFSRT (HR = 2.17 [1.42-3.32], p = 0.0003).

Conclusion: Compared with the standard WBRT after the resection of brain metastases, stereotactic radiotherapy to the surgical bed produced a comparable local control rate to that of WBRT with a survival advantage in the first 20 months.

Poster Display - Malignancy
P054 : A case of bilateral optic nerve sheath meningioma treated by fractionated stereotactic radiotherapy

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Keywords: optic nerve sheath meningioma, fractionated stereotactic radiotherapy

Background: Optic nerve sheath meningioma (ONSM) is a rare benign tumor. Despite of the histologically benign tumor, it can cause visual disturbance and lead to blindness. The management of ONSM remains controversial especially in patients with bilateral lesion. We report a case of 27 years old woman with bilateral ONSM who was underwent fractionated stereotactic radiotherapy.

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Case Presentation: A 27-year-old woman felt blurred vision of right eye. Her symptom gradually deteriorated and then she was referred to neurosurgical department. She underwent MRI and it demonstrated abnormal mass involving bilateral optic nerves. The lesion showed iso intensity on T2 weighted image and homogeneously enhanced with gadolinium. The tumor progressed and her visual function worsened in a couple of months. She had an operation and bilateral unroofing of optic canal and biopsy of the tumor were performed. Despite of the operation, visual acuity did not improve and gradually deteriorated in both side instead. So she was introduced to our hospital for radiation therapy. When she was referred to our hospital, her visual acuity was deteriorated to hand motion on the right side and 24/40 vision on the left side. She underwent fractionated stereotactic radiotherapy of 50.4Gy in 28 fractions. After radiation treatment, ophthalmologic examination showed improvement in visual acuity of the left eye and MRI demonstrated slight reduction of tumor volume.

Discussion: Although ONSM is benign tumor, this slow growing tumor can lead to visual loss. Bilateral ONSM can cause total blindness. The treatment for patients with ONSM remains controversial because of the variability of the natural course of this disease. A small fraction of patients might have a stable course and/or present a slight improvement of the symptom during a follow-up period.

Historically, surgery was recommended to confirm the diagnosis and to decompress the optic nerve. However, surgery may deteriorate visual acuity instead. Recently, it has been reported that radiation therapy can control the growth of this tumor and maintain or improve visual function. The optimal timing of radiotherapy is uncertain. Some group reported that a longer time from the onset to radiotherapy might relate to poor outcome in visual acuity after treatment and so it is important to start radiotherapy immediately after appropriate diagnosis in order to avoid visual loss especially in patients with bilateral ONSM.

Conclusion: We experienced a case of bilateral ONSM. Fractionated stereotactic radiotherapy immediately after diagnosis could control the growth of tumor and improve visual function.

Keywords: SEGA, TSC

Subependymal giant cell astrocytomas (SEGA) are benign gliomas that occur in patients with the tuberous sclerosis complex (TSC). Surgical removal is the preferred treatment and expert opinion is strongly against the use of radiotherapy, insomuch that it is not even mentioned as a treatment option in reviews or guidelines. Recently, success has been reported with the mTOR inhibitor everolimus in reducing tumor volume, but regrowth has been observed after cessation of the drug. We report about a case with inoperable bilateral SEGA that was successfully treated with fractionated stereotactic radiotherapy (30 X 2Gy) with a follow-up of over 7 years before being treated with everolimus for renal involvement of TSC and currently a follow-up of 10 y. Successive volumetries on MR demonstrated a, 80% volume reduction after radiotherapy only, further enhanced by everolimus until only minimal residue is visible. Review of the literature shows there is no evidence for contraindicating fractionated stereotactic radiotherapy in SEGA and that real-life surgery is still associated with recurrence, mobidity and mortality. We believe that stereotactic radiotherapy alone or sequentially combined with everolimus deserves to be studied as an alternative to removal in difficult surgical cases that do not require immediate volume reduction.

Poster Display - Malignancy

P056: Optimal dosimetric planning in stereotactic radiosurgery for perioptic tumors: a comparative study between CK versus GK

KyoungJun Yoon (1), Byungchul Cho (2), JungWon Kwak (2), Doheui Lee (1), Do Hoon Kwon (3), SeungDo Ahn (2), Sang-Wook Lee (2), Chang Jin Kim (3), Sung Woo Roh (3), Young Hyun Cho (3)

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Keywords: Stereotactic radiosurgery, Brain metastases, Cyberknife, Gamma Knife, perioptic tumor

Purpose: Stereotactic radiosurgery (SRS) for skull base perioptic tumors is challenging with concerns about the risk of radiation-induced optic neuropathy. For these cases, hypofractionation of SRS with an optimal
dosimetric planning in terms of dose-volume constraints to the optic apparatus (OA) as well as higher dose to tumor may potentially reduce the risk of radiation toxicity with acceptable tumor control. Here we investigated dosimetric outcomes of the Cyberknife (CK) and the Gamma Knife (GK) for perioptic tumors.

**Methods:** We selected 18 perioptic tumors previously treated using CK between 2011 and 2015. All tumors harbored no margin from OA with 10 of them compressing or 8 abutting onto it on MRI. Tumor type included 11 meningiomas, 4 hemangiomas, 2 pituitary adenomas, and 1 craniopharyngioma. For dosimetric planning, thin-sliced CT and MR images were obtained and fused for delineation and contouring of both tumor and OA. Identical contour set was used to produce both CK and GK plans for each case. For 5 fraction treatment, the goal of dosimetric planning was to limit dose to OA with dose-volume constraints of Dmax < 25 Gy and V20Gy < 0.2 cc, while maintaining tumor coverage as high as possible with median prescription dose of 27.8 Gy. A paired data set of dosimetric parameters based on each modality was obtained and analyzed.

**Results:** Although all plans of both CK and GK complied with the dose-volume constraints to OA, tumor coverage (mean 94.4% in CK vs 88.5% in GK; P<0.001) and minimum dose to tumor (mean 22.9 Gy vs 19.1 Gy; P<0.001) were significantly higher in CK than in GK. There were no differences in the conformity index (mean 1.24 vs 1.27; P=0.825). The gradient index (mean 3.39 vs 2.89; P=0.004) was significantly lower in GK than in CK.

**Conclusions:** These results suggest that CK inverse planning system appears to be more suitable for an optimal dosimetric planning for perioptic tumors than GK planning system.

**Keywords:** Gamma Knife, Hypofractionation, Optic

**OBJECTIVE:** Stereotactic radiosurgery (SRS) in single session (SSR) has proved its efficacy in treating anterior cranial base lesions inferior to 15-20 mL. However SSR seems potentially hazardous in cases of anterior optic pathways (AOP) close-fitting or larger (>20 mL) lesions, especially for risks of radiotoxicity. Following this, many Centers have adopted hypo-fractionation protocols. Objective of this study is to compare SSR versus Hypofractionated Stereotactic Radiosurgery (HSR) performed with Gamma Knife (GK) or Cyber Knife (CK).

**Method:** HSR group consists of 100 patients (40 GK; 60 CK – minimum follow-up 24 months). Twenty-six males; 74 females. Mean age 56.05 yrs (range 35-85). Mean follow-up was 52.3 months (range 25.3-71.34). Mean planning target volume (PTV) was 5.69 mL (range 0.71 -19.17 mL).

GK-HSR was performed in 3 fractions (Mean PD/fx. 6.4 Gy; mean PI 50.5%) and CK-HSR respectively in 2 (26%), 3(60%), 5(10%) and 4 (4%) fractions (21 pts treated with PD of 18 Gy; 14 with a PD

**RESULTS:** HSR group: Seventy-four (74%) patients were stable (if no deficit pre-GK reported) or improved; 10 (10%) were unchanged while 16 (16%) worsened. In 48/100 we radiologically observed lesion a shrinkage; 38/100 were unchanged, 11/100 showed a “delayed control” (initial pseudo-progression than stable) and 3/100 increased. SSR group: 48 (42.4%) patients were stable or improved; 45 (39.8%) were unchanged, 20 (17.8%) worsened (7/20 for tumor progression, 13/20 for ARE). Seventy-eight cases (69.1%) showed a volume shrinkage at neuroradiological follow-up, 23 (20.3%) unchanged and 10/113 (8.8%) progressed. In 2 (1.8%) cases, tumor was no longer recognizable at MRI.

**Conclusion:** Hypofractionated stereotactic radiosurgery appears to be a safe and effective even in patients with AOP close-fitting meningiomas. Pre-operative visual conservation seems to be associated with a more favourable clinical course.

**Keywords:** Gamma Knife, Hypofractionation, Optic

**OBJECTIVE:** Stereotactic radiosurgery (SRS) in single session (SSR) has proved its efficacy in treating anterior cranial base lesions inferior to 15-20 mL. However SSR seems potentially hazardous in cases of anterior optic pathways (AOP) close-fitting or larger (>20 mL) lesions, especially for risks of radiotoxicity. Following this, many Centers have adopted hypo-fractionation protocols. Objective of this study is to compare SSR versus Hypofractionated Stereotactic Radiosurgery (HSR) performed with Gamma Knife (GK) or Cyber Knife (CK).

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**Conclusion:** Hypofractionated stereotactic radiosurgery appears to be a safe and effective even in patients with AOP close-fitting meningiomas. Pre-operative visual conservation seems to be associated with a more favourable clinical course.
Poster Display - Malignancy

P058 : Gamma Knife radiosurgery for brainstem glioma

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Keywords: Glioma, Brainstem, Radiosurgery, Gamma Knife

Objective: To analyze role of Sterotactic Radiosurgery for Brainstem Gliomas

Method: Sixty nine patients with Glial tumors were treated consecutively between 2008 and 2016 with Leksell Gamma knife Model B and Perfexion. Out of these 16 tumors were involving brainstems. They were selected using clinical criteria without histopathology, with MR Spectroscopy. Functional imaging FDG PET / Radionucleide Spectroscopy was used for diagnosis and planning where ever possible. Dose prescription was limited by extent involvement of brainstem and volume. There were 3 females and only one was operated before treatment. Age of patient was from 8 to 67 years [mean 39.9yrs]. Five patients had disabling neurological defects and were bed ridden at time of treatment. Two patients were treated twice. Tumor volume ranged from 1.2 to 22.3cc [Mean 11.8cc]. Prescription dose was 8-25Gy [mean 13.9 Gy]. Patients were followed with contrast MRI scan every 3 months

Results: Patients survived from 1-13 years [mean 4.5 years] after Radiosurgery. Five patients developed side effect with significant neurological deficit with in 6 months. Longest surviving patient treated second time after 10 years died of coronary disease. Eight patient showed initial improvement in their clinical status as compared to pre SRS with in 6 months. Various Clinical details and comparison with various published series will be compared.

Conclusion: Gamma Knife Radiosurgery has role in controlling inoperable brainstem glial lesions.

Poster Display - Malignancy

P059 : Draining vein shielding in intracranial AVM's during Gamma-Knife: A new way of preventing post Gamma-Knife edema and hemorrhage

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Keywords: gamma knife (GK) therapy, intracranial AVM's

Introduction: Following gamma knife (GK) therapy for intracranial AVM's, obliteration of the nidus occurs over several years. During this period there is a risk of edema and hemorrhage. We hypothesized that decreasing radiation dose to the draining vein(s) may prevent early draining vein obliteration leading to a decrease in edema and hemorrhage rates in the post GK period.

Materials and methods: This retro-prospective study over 5 years (Jan 2009 to Feb 2014) included patients with intracranial AVM who underwent gamma knife therapy (Leksell Perfexion®, Elekta, Stockholm) at our center. Approval from the institute's ethics committee was taken. All patients who underwent draining vein shielding (DVS) by senior author (DA) were included in the test group and patients who did not undergo DVA were put in the control group. Patients with less than 6 months of follow up were excluded. All patients were followed up 6 monthly clinically as well as radiologically with CT head/MRI brain to see for edema. DSA was done at 2 years for all patients and repeated at 5 years for those with incomplete obliteration of nidus.

Results: 185 patients were included in this study of which 96 were in the control group and 89 in the test group. The mean age, sex distribution, co-morbidities and adjuvant treatment were comparable in both groups. The lobar distribution of the AVM, angio-architecture and radiation dose were comparable between the two groups. Due to shielding, the test group patients received significantly less radiation to the draining vein (0.0001). On follow up, significantly less number of patients in the test group had new neurological deficits (p = 0.001).

Importantly, significantly more number of patients in the control group had post-radiosurgery intracranial hemorrhage (p = 0.03) and brain edema (p = 0.002). Both the group had comparable AVM obliteration rates following radiosurgery.

Conclusion: Shielding of draining vein is a potent new strategy in minimizing edema and hemorrhage as well as clinical deterioration following gamma knife therapy for intracranial AVM's.

Poster Display - Metastases

P060 : Survival patterns of patients with solitary, 2-4, 5-10, and >10 brain mestastases following stereotactic radiosurgery (SRS)
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Keywords: Brain metastasis, stereotactic radiosurgery

Background: A recent prospective observational study revealed that the survival pattern of SRS treated patients with 2-4 BMs are comparable to those with 5-10 BMs. The survival pattern of patients with >10 BM remain poorly characterized.

Methods: A retrospective analysis of data from 5976 patients with brain metastasis treated with SRS were analyzed. Multivariate Cox proportional hazard modeling was performed, and overall survival was estimated by the Kaplan-Meier method.

Results: The primary cancer types of the study cohort were: breast (n=763), gastrointestinal (n=699), lung (n=3840), melanoma (n=341), and renal cell carcinoma (n=333). We recapitulated the findings of the previous prospective observational study. Median overall survival for patients with solitary BM (7.1 months) was superior to those with 2-4 BMs (6.4 mo) and 5-10 BMs (6.3 mo). The median survival of patients with 2-4 BMs did not significantly differ from those with 5-10 BMs (6.3 mo). The median survival of patients with >10 BMs (5.5 months), however, were lower than those with either 2-4 or 5-10 BMs (p<.001). The difference in survival between these two patient populations remained significant in a multi-variate model that accounted for age, Karnofsky Performance Score, systemic disease status, tumor histology, and cumulative intracranial tumor volume. Cox-proportional hazard analysis revealed that the hazard of death after SRS was increased by 15.8% in patients with >10 BMs relative to those with 2-10 BMs.

Conclusions: The survival profile of patients with >10 BMs were less favorable relative to those with<10 BMs.

Poster Display - Metastases

P061 : Plan quality comparison between Gamma Knife Perfexion and volumetric modulated arc therapy planned using a non-radiosurgery linear accelerator for brain metastasis

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Keywords: Gamma Knife Perfexion, volumetric modulated arc therapy, radiosurgery, brain metastasis

Objectives: To compare the plan quality for brain metastatic lesions treated on Gamma Knife Perfexion (GK) with Volumetric Modulated Arc Therapy (VMAT) planned on a non-radiosurgery linear accelerator.

Methods: 5 patients with a single and multiple brain metastatic lesions planned and treated on GK, these cases were re-planned on Eclipse with a single isocenter, 5 to 6 non-coplaner partial arcs using VMAT technique on 2100CD Varian linear accelerator which equipped with Millennium Multi Leaves Collimator 120 (MLC), and maximum doserate of 600MU/min. The MLC is 5 mm width over the 20 cm central region and 10 mm width over the two 10 cm peripheral regions. The size of the target ranges from 0.1 cc to 5.9 cc, and the prescribed dose ranges from 18 to 22Gy according to the target volume. Plans were normalized so that 99% - 100% of the target volume receive 100% of the prescribed dose.

Dosimetric parameters used to analyze the plans were: conformity index (CI) (100% isodose volume/Target volume), gradient index (GI) (50% isodose volume/100% isodose volume),12, 9 and 3 Gy isodose volume (V12, V9 and V3), dose to the nearby organs at risk and the beam on time.

Results: The VMAT plans showed a lower CI than the GK (1.28 ± 0.16 vs 1.43 ± 0.25), but it has a higher GI (4.94 ± 1.8 vs 2.75 ±0.25). The V12 and V9 were comparable between the two modalities, for the low dose region, GK showed a smaller volume (V3=105 cc vs 179 cc), it has been noticed that the low dose region depends on the position and numbers of the treated lesions. For the nearby organs at risk (brain stem and optic nerve) the results were comparable. The mean beam on time for VMAT was 14 min while for GK at the time of treatment was 115 min.
Conclusion: For the range of target volumes used in this comparison, VMAT technique for multiple brain metastasis planned on a non-radiosurgery linear accelerator showed an equivalent plan quality to GK, with better CI, shorter beam on time and comparable V12 and V9 and nearby organ at risk, so it could be an optional treatment modality, bearing in mind the quality of the linear accelerator in terms of accuracy and precision that has to meet the recommended tolerances for radiosurgery treatment delivery.

Disclosure: No significant relationship

Poster Display - Metastases

P062: Dosimetric comparison between single isocenter Volumetric Modulated Arc Therapy (VMAT) and multi-isocenter Dynamic Conformal Arc Therapy (DCAT) for multiple brain metastases (≥4).

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Keywords: multiple brain-metastases, stereotactic radiotherapy, VMAT, DCAT, dosimetric comparison

In this study, we evaluated the dosimetric plan quality of single isocenter VMAT (Volumetric Modulated Arc Therapy) versus multi-isocenter DCAT (Dynamic Conformal Arc Therapy) for treatment of multiple brain metastases (≥4). Twenty patients treated with DCAT technique were replanned with VMAT technique. Plan quality has been evaluated by target conformity, quality of coverage, healthy brain tissue dose, dose gradient index, dose to organs at risk and delivery treatment time. The results showed that no significant difference was found for the conformity index (CI) and quality of coverage index. However, the healthy brain volume exposed to 12 Gy and 21 Gy was respectively 64% and 36% lower with DCAT and the dose gradient R_{12Gy/21Gy} went from 1.74 cm with DCAT to 2.19 cm with VMAT. Moreover, organs at risk near PTVs (< 5 mm) are better spared by VMAT than DCAT. Finally, single isocenter VMAT required a 25 minutes treatment time regardless the number of metastases against 25 minutes for each lesion with DCAT technique. DCAT and VMAT are both efficient techniques to treat multiple cranial metastases and the choice of treatment technique should be done with respect to target coverage and OARs (Organs At Risk) protection as well as patient age and health condition.

Poster Display - Metastases

P063: Long term results of Gamma Knife radiosurgery for recurrent brain metastasis of SCLC patients who already treated WBRT

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Keywords: SCLC, Gamma Knife, WBRT

Purpose: The previous treatment of brain metastasis from small cell lung cancer(SCLC) was Whole Brain Radiotherapy(WBRT). WBRT could be performed only once, so this method could not be used twice when metastatic brain tumors recurred after WBRT. Gamma Knife Radiosurgery(GKRS) is a new treatment method in recurred metastasis after WBRT. The effect of GKRS after WBRT for brain metastasis from SCLC was analyzed retrospectively.

Material and method: Thirty onepatients of brain metastasis from SCLC were analyzed in our study. When brain metastasis recurred after WBRT, GKRS was performed in all cases. The survival rate of GKRS plus WBRT was analyzed.

The tumor control rates, local recurrence rates and distant new recurrence rates were analyzed after GKRS with WBRT.

We also analyzed the cause of death - brain lesion or systemic disease.

Results: Thirty one patients could be follow-up except one patient. Median survival rate was 26(6-65) months. All patients were dead during follow-up periods. Kaplan Meier’s survival curve reveals that 1 year survival rate was 93.3%, 2 year was 66.7%, 3 year was 6.7%. Radiologic follow-up was possible in 23 patients. Mean follow-up
period was 27(12-63) months. Only one patient had local recurrence after GKRS, whereas 5 patients had new metastasis. Both local recurrence and new metastasis had occurred in 1 patient. When local or new metastasis occurred, reGKRS could be performed. The cause of death from brain lesion was in 7 patients, from systemic disease was in 18 patients and both reasons were in 5 patients.

**Conclusions:** Patients who underwent GKRS after WBRT had significantly improved survival rates compared to the patients who had WBRT alone. The cause of death after WBRT plus GKRS was mainly due to the systemic disease.

**Poster Display - Metastases**

**P064 : Optimization of Cyberknife dosimetric planning using a dose-limiting auto-shell method for brain metastases**

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**Keywords:** Stereotactic radiosurgery, Brain metastases, Cyberknife, Gamma Knife, Auto-shell

**Purpose:** We investigated the impact of optimization in dose-limiting auto-shell function on the dosimetric quality of Cyberknife (CK) plans in treating brain metastases (BMs).

**Methods:** We selected 19 BMs previously treated using CK between 2014 and 2015. The original CK plans (CK_{original}) had been produced using one to 3 dose-limiting auto-shells, one at the prescription dose (PD) level for dose conformity and others at low-dose levels (10–30% of PD) for dose spillage. In each case, a modified CK plan (CK_{modified}) was generated using 5 dose-limiting auto-shells, one at PD level, another at intermediate dose level (50% of PD) for steeper dose fall-off, and the others at low-dose levels, with an optimized shell-dilation size based on our experience. A Gamma Knife (GK) plan was also produced using the original contour set. Thus, a triplet data set of dosimetric parameters was generated and compared.

**Results:** There were no differences among CK_{original}, CK_{modified}, and GK plans in the conformity index (mean 1.22, 1.18, and 1.24, respectively; \(P=0.079\)) and tumor coverage (mean 99.5%, 99.5%, and 99.4%, respectively; \(P=0.177\)), whereas CK_{modified} plans produced significantly smaller normal tissue volumes receiving 50% of PD than those produced by CK_{original} plans \( (P<0.001, \) with no statistical differences in those volumes compared with GK plans \( P=0.345 \)

**Conclusions:** These results indicate that significantly steeper dose fall-off can be further achieved in the CK system by optimizing the auto-shell function, while maintaining high conformity of dose to tumor.

**Poster Display - Metastases**

**P065 : Tumor-control effect of gamma knife surgery on metastatic brain tumors of lung cancer**

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**Keywords:** Gamma Knife Surgery, lung cancer, metastasis, brain

**Purpose:** The purpose of this study was to evaluate control rate and reducing volume of gamma knife surgery of single or multiple metastases in each pathology of lung cancer.

**Material & Methods:** Between November 2012 and July 2016, 144 patients (681 lesions) with lung cancer metastases were treated with gamma knife surgery. Among them, We studied 93 patients (431 lesions) who were able to follow up MRI for more than 3 months.

**Results:** The male to female ratio in the SCLC and NSCLC was 8 to 1, 2 to 1 and the mean age of the patients was 64.11, 63.24 years. The average follow-up time after gamma knife surgery was 8.40 months (range 3-42 months). The mean volume reduction rate of tumor in SCLC and NSCLC was 76% and 48.5%. The tumor control rate in SCLC (89 tumors) & NSCLC (342 tumors) was 95.5% and 95.6%. 26 patients had single metastasis. The rest of the patients had multiple brain metastases : every 38 patient had 2~5 lesions (110 tumors) and 29 patients had more than 5 lesions (295 tumors).

**Conclusion:** Gamma knife surgery was effective for tumor control and reducing volume of metastases in SCLC and NSCLC.
Poster Display - Metastases

P066 : Breast cancer brain metastasis managed by stereotactic radiosurgery; Prognosis related to subtypes

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**Keywords:** Breast cancer, Brain metastasis, Gamma knife radiosurgery, Stereotactic radiosurgery, Subtype

**Objective:** Breast cancer is well known as one of the common primary tumors of brain metastasis. Although the incidence of brain metastases in breast cancer patients has increased, the management of brain metastasis is still a challenge in clinical practice. Breast cancer is classified by presence of some hormone and gene receptors (e.g., estrogen, progesterone, HER-2). Subtype classification is useful for prognosis prediction and treatment planning. We investigated the prognosis of the patients with in breast cancer brain metastasis managed by stereotactic radiosurgery (SRS) according to breast cancer subtypes.

**Patients and Methods:** From 2004 to 2015, total 42 breast cancer brain metastasis patients were managed by gamma knife radiosurgery (GKRS) in our hospital. The median age of the patients was 51.02 (range, 25-83) at the time of initial diagnosis of brain metastasis. The prognosis was analyzed according to their breast cancer subtypes; Luminal A, Luminal B, HER-2 and triple negative (TN) groups.

The total number of metastatic lesions was 136, and the indications for GKRS were the number of metastasis below 10 and maximal diameter 3.0 cm. According to breast cancer subtypes, the number of Luminal-A type was 17, and Luminal-B 53, HER-2 44, and TN 22.

**Result:** The tumor control was achieved in 87 out of 136 tumors, and the control rate was 64.0% with the median progression free survival (PFS) of 370 days (range, 53-1901). Luminal-A, HER-2 and TN subtype groups’ median OS were 295 days (range, 151-807). Luminal-B, HER-2 and TN subtype groups’ median OS were 573 days (range, 161-2302) and 338 days (range, 91-990), respectively.

**Conclusion:** Breast cancer TN subtype group showed most poor prognosis in overall survival, and their brain metastases showed shortest PFS after SRS compared with other subtype groups. Therefore, the patient confirmed pathologically TN subtype breast cancer should be followed up more closely after SRS.

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Poster Display - Metastases

P067 : Synergic effect of stereotactic radiosurgery and systemic pembrolizumab (Keytruda®) treatment for metastatic brain tumors from advanced gastric cancer: A case report

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**Keywords:** Brain metastasis, Gamma knife radiosurgery, Gastric cancer, Pembrolizumab, Stereotactic Radiosurgery

Gastric cancer brain metastasis is rare and it is known to be relatively radio-resistant. We report a gastric cancer patient with brain metastases who underwent stereotactic radiosurgery (SRS) and systemic pembrolizumab (Keytruda®) treatment, and showed dramatic tumor control.

A 39-year-old man underwent 2nd SRS for a locally recurred brain metastasis and newly developed several metastases. One year ago, he had undergone SRS for a single metastasis in another gamma knife center, and the target tumor volume was 5.4 cc. At the 2nd SRS, the locally recurred tumor volume was 14.6 cc and a margin dose of 14 Gy was prescribed to the 50% isodose line at the tumor border. The tumor volumes of the five new metastases were 0.3, 1.4, 1.5, 10.8, and 4.0 cc and the prescribed marginal dose was 22, 22, 20, 16, and 20 Gy, respectively. After that, for the locally recurred advanced gastric cancer, the patient underwent intravenous pembrolizumab (Keytruda®) treatment at the department of oncology. The dose was 100mg, and 5 times injections were performed with two-week interval.
Three months after the 2nd SRS, those new metastases were controlled dramatically in the follow-up MRI. Three small tumors disappeared, and the other two larger tumors were regressed dramatically, and their volume were 1.1 and 0.2 cc, respectively. Although the volume of repeated treated tumor was similar, the methionine positron emission tomography (PET) showed only small hot spots.

Considering both local progression of the previously treated with only SRS and dramatic control of the tumors managed by both SRS and consecutive systemic pembrolizumab (Keytruda®) treatment, SRS and systemic pembrolizumab (Keytruda®) might have a synergic effect in the treatment for metastatic brain tumors from gastric cancer.

Poster Display - Metastases

P068 : Implementation of frameless brain SRT at Waikato Hospital

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Keywords: Frameless, SRT, brain metastasis

Purpose: The project objective was to safely introduce frameless fractionated stereotactic radiotherapy (SRT) into our clinic using existing equipment.

Background: We have traditionally treated brain metastasis with whole brain radiotherapy (WBRT) in our clinic. Recently published American Society for Radiation Oncology evidence-based guidelines on the management of newly diagnosed brain metastases state that patients presenting with multiple brain metastases (all less than 3–4 cm) have various treatment options, including stereotactic radiosurgery (SRS) alone, WBRT with SRS boost, or WBRT alone, with no mention of SRT(1). However, the use of SRT has spread considerably in the past 10 years. SRT has been shown to be more effective than WBRT in the management of low volume brain metastases specifically in patients with tumours arising from the gastro-intestinal tract (2).

SRS and SRT treatments have largely occurred in departments with dedicated SRS systems. New Zealand has only one centre with dedicated SRS equipment. This often requires patients to travel long distances for treatment.

Our department has decided to take advantage of the advances in imaging technology (on board imaging), patient support assembly systems (tighter couch top rotation, 6 Degrees of Freedom couch (6DoF)) and enhanced beam delivery systems (Flattening Filter Free (FFF)) to introduce SRT. The introduction of SRT offers more options to our patients and potentially more convenience as they do not have to travel long distances for treatment.

Methods: Firstly, we validated our existing beam model for small field dosimetry. We evaluated our immobilisation system to determine margins. Planning technique studies were retrospectively done to decide the best technique between RapidArc, Conformal arc and static fields (for both co-planar and non-co-planar configurations). Winston Lutz tests were done to confirm coincidence of imaging and radiation isocentres. End to end testing was done with a Rando head phantom. Extensive testing was done using pin point chamber and GaF chromic film measurements. Pre-treatment QA procedures were established using a CIRS head phantom.

Results: The beam model was accurate down to a 1x1cm². The margins were determined to be 2mm, with a margin review task for instances where there was rotation exceeding 2% in patient set up.

Conclusion: Our experience has shown it is possible to implement an SRT brain technique with existing resources without huge capital expenditure in dedicated SRT/SRS systems. The next focus will be to explore doing single fraction treatments when the 6DoF feature has been commissioned and fully functional.

Poster Display - Metastases

P069 : Adaptive hypofractionated gamma-knife radiosurgery in the acute / subacute management of critically located brain metastases.

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Keywords: fractionated gamma knife radiosurgery, cerebral metastases, adverse radiation effects.

Objectives: Cerebral metastases located close to eloquent brain are one of the biggest challenges in neuro-oncology. The use of adaptive hypofractionated gamma knife...
radiosurgery might prove beneficial to patients that are not suitable candidates for both surgical intervention and single fraction radiosurgery. By dynamically adapting peripheral prescription doses and tumor bed dose distributions to ongoing tumor volume changes over the course of the treatment, this technique applied in next-to emergency settings aims to achieve rapid results in terms of tumor volume reduction whilst minimizing the risk of radiation induced side effects. The aim of our study is to report the short term results (at 1 and 4 weeks after treatment completion) in patients treated at our institution, with focus on tumor ablation, salvage of organs at risk and toxicity.

**Methods:** 23 patients with 26 critically located brain metastases, treated over 7 days by means of three (3) separate Gamma Knife radiosurgeries (GKRS) between November 2013 and November 2016, were retrospectively analyzed in terms of tumor volume decrement at 1 week (between GKRS 1 and 3) and at 4 weeks after GKRS 3 (first follow up MRI). Karnofsky score, RPA, perilesional edema, cortisone treatment and salvage of organs at risk were taken into consideration.

**Results:** Mean peripheral doses at GKRS 1, 2 and 3 were 7.8 Gy, 8Gy and 8.5Gy (range 6-9 Gy) respectively. Mean tumor volume depletion at one week was 11%. Five patients died prior to first follow-up. In the surviving group (18) mean tumor volume reduction was 61% at 5 weeks. No treatment related side-effects were observed.

**Conclusion:** In this study, adaptive hypofractionated gamma-knife radiosurgery proved effective in achieving rapid tumor volume reduction in critically located cerebral metastasis with limited toxicity.

**Objective:** To evaluate hippocampal doses and target volume coverage with and without hippocampal-sparing when treating multiple brain metastases using various stereotactic radiosurgery (SRS) platforms.

**Materials and Methods:** We selected 10 consecutive patients with a total of 14 separate treatments who had been treated in our department for 3-10 brain metastases and added hippocampal avoidance contours. All 14 treatments were planned with GammaPlan® for Gamma Knife®, Eclipse™ for single isocenter volumetric modulated arc therapy (VMAT), TomoTherapy® Treatment Planning SystemTM for TomoTherapy®, and MultiPlan® for CyberKnife®. Initial planning was performed with the goal of PTV coverage of V100>95% without hippocampal avoidance. If the maximum hippocampal point dose (Dmax) was <6.6 Gy in a single fraction and <40% of the hippocampi received ≤4.5 Gy, no second plan was performed. If either constraint wasn’t met, replanning was performed with these constraints.

**Results:** There was a median of 6 metastases per plan, with an average total tumor volume of 7.32 mL per plan. The median hippocampal Dmax (in Gy) without sparing averaged 1.65, 9.81, 4.38, and 5.46, respectively (p<0.0001). Of 14 plans, three Gamma Knife and CyberKnife plans required replanning, while 13 VMAT and eight TomoTherapy plans required replanning. The hippocampal constraints were not achievable in one plan on any platform when the tumor was bordering the hippocampus. The mean volume of brain receiving 12 Gy (in mL), which has been associated with symptomatic radionecrosis, was 23.57 with Gamma Knife, 76.77 with VMAT, 40.86 with CyberKnife, and 104.06 with TomoTherapy (p = 0.01). The overall average conformity indices for all plans ranged from 0.36 to 0.52.

**Conclusions:** Even with SRS, the hippocampi can receive a considerable dose; however, if the hippocampi are outlined as organs of risk, sparing of these structures is feasible in nearly all situations with all four platforms, without detriment to target coverage, and should be considered in all patients undergoing SRS for multiple brain metastases.

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**Conclusions:** Even with SRS, the hippocampi can receive a considerable dose; however, if the hippocampi are outlined as organs of risk, sparing of these structures is feasible in nearly all situations with all four platforms, without detriment to target coverage, and should be considered in all patients undergoing SRS for multiple brain metastases.
Keywords: Novalis, large brain metastasis, stereotactic radiotherapy, fractionated radiotherapy

Background: To assess clinical outcome using linac-based fractionated stereotactic radiotherapy (FSRT) for the large brain metastasis (LBM) unsuitable for surgical resection.

Material and methods: Between January 2009 and October 2016, we have treated 26 patients who had a LBM by using linac-based FSRT. LBM was defined as larger than 25mm with maximum diameter of axial, coronal or sagittal image of gadolinium enhanced magnetic resonance images. This study included the patients who were unsuitable for general anesthesia and did not want to have an operation. The median age of these patients was 72.8 years (range 47-87 years). Fifteen patients were male, eleven patients were male. LBM originated from the lung (n=21, 80.7%), the ovary (n=2, 7.7%), the gastrointestinal tract (n=2, 7.7%), and the breast (n=1, 3.8%). Pretreatment KPS was 61.1 (range 50-90). No patient was in RPA class 1, ten patients (38.5%) were in class 2, and sixteen patients (61.5%) were in class 3.

Results: The median follow-up was 9 months (range 1-52 months). Tumor volume ranged from 6.23 to 26.5cm$^3$ (median 13.7cm$^3$). All patients were treated with FSRT using linear accelerator with micro-multileaf collimator having a high spatial resolution of 3mm (Novalis, BrainLAB, Germany). 35 Gy in five fractions was basically prescribed in twenty patients, 40 Gy in ten fractions in two patients, 42 Gy in six fractions in one, 36 Gy in ten fractions in one, and 30 Gy in three fractions in one. The median survival time was 7.0 months (95% confidence interval: 2.660-11.340). Fifteen patients died of systemic disease and two patients died of intracranial brain metastasis. Grade 2 radiation necrosis was observed in two patients (7.7%), Grade 3 in three patients (11.5%) according to the Common Terminology Criteria for Adverse Events version 4.0. Among them, three patients underwent the administration of bevacizumab for radiation necrosis. One patient underwent the additional surgical removal for local progression.

Conclusion: Linac-based FSRT was effective and safe non-invasive treatment for large brain metastasis unsuitable for surgical resection with limited toxicity.

Poster Display - Metastases

P072 : Repeat stereotactic radiosurgery for new brain metastases after initial treatment allows avoidance of whole-brain radiation therapy

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Keywords: Radiosurgery, brain metastases

Purpose: Stereotactic radiosurgery (SRS) is the preferred primary treatment option for patients with a limited number of asymptomatic brain metastases. In case of a central nervous system (CNS) oligo-progression after initial SRS the optimal salvage treatment is not well defined.

The aim of our retrospective analysis was to investigate the feasibility and toxicity of repeated courses of SRS to defer or avoid Whole-Brain Radiation Therapy (WBRT).

Material and Methods: From 2014 until 2016, 23 patients with a total of 114 brain metastases have been treated with multiple courses of SRS at our institution. Treatment was delivered as single fraction (18 or 20Gy) or hypo-fractionated (6 fractions with 5Gy) radiosurgery prescribed to the 80%-isodose line. Regular follow-up included clinical examination and contrast-enhanced cMRI at 3-months intervals were performed.

Results: Median Diagnosis-specific Graded Prognostic Assessment (ds-GPA) at time of first SRS course and repeated SRS courses were 2.5 (range, 1-4) and 2 (range: 0-3.5) respectively. A median number of 1 lesion (range: 1-13) per course and a median of 2 courses (range: 2-4) per patient were administered. The median interval between SRS courses was 4.5 months (range: 0.8-18.5 months). WBRT as a salvage treatment was required in only 5 patients (21.7%) after median interval of 6.6 months (range: 5.5-10 months). Of the 18 patients who received repeated SRS only, 11 were still alive at time of last follow-up. 5 of the 10 deceased patients had died of neurological death, 3 of them had received WBRT previously. Median overall survival (OS) was 22 months (95%CI: 15-NA). No grade 4 or 5 acute
or late toxicity occurred. Acute and late toxicity grade 3 was observed in only 3, or 2 patients respectively.

**Conclusion:** In selected patients with a relapse of brain metastases amenable to SRS repeat courses of SRS can safely be administered with excellent local control and low toxicity. Despite high rates of distant cranial recurrence, the majority could be salvaged by repeat SRS. With an encouraging OS in our cohort, potentially neurotoxic WBRT could be avoided in significant proportion of patients.

**Poster Display - Metastases**

**P073 : Stereotactic radiotherapy in oligometastatic patients with renal cell carcinoma**

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**Keywords:** sbt, renal cell carcinoma, oligometastases

**Aim:** The aim of this study was to evaluate the performance of stereotactic radiotherapy (SRT) with either CyberKnife (Accuray, Sunnyvale, CA) or Vero™ (BrainLab Mitsubishi Feldkirchen, Germany) in term of toxicity and local control (LC) of cranial or extracranial metastasis in oligometastatic renal cell carcinoma (RCC) patients (pts).

**Materials and methods:** Between January 2012 and September 2015, 26 patients (overall 33 metastatic lesions) with metastases of RCC were treated. SRT was performed on a singular new site lesion or on residual disease during a systemic therapy. Disease control was evaluated with serial imaging. Toxicity was recorded according to the Common Toxicity Criteria version 4.0 and reported as early and late. The total radiotherapy doses ranged from 10 to 54 Gy, given in 1 to 3 fractions. The biological equivalent doses (BED) and 2Gy-per-fraction equivalent dose (EQD2) were calculated using the \( \alpha/\beta=10 \) for tumors. We stratified the patients into 3 groups (gr) according to the EQD2 delivered group 1 range 12-36 Gy; group 2 range 42-50 Gy; group 3 66-126 Gy.

**Results:** After a median follow-up of 14 months (range 1-36), we achieved the best result in gr 3 (CR and SD in 77.7% and 22.3 % of pts) versus 60 % and 40 % in Gr 2 and 50 and 50 % in Gr 1. Only out-field progression of disease was observed in 8 cases after a median 5.1 months from SRT. No toxicity was registered. Eleven pts had more than 12 months follow-up: 11/11 had complete response in the site of treatment and two of these had PD in other site (2 pts are of Gr 1). Clinical and radiological response was thus evaluated in all patients.

**Conclusion:** SRT is a feasible approach in oligometastatic RCC patients with an excellent LC and a favorable toxicity profile. SRT could play a role in the therapeutic strategy for these patients allowing them a delay in the start of a systemic therapy and its toxicity or a drug holiday after a long treatment period. Further studies are warranted to increase the quality of evidence of such composite approach.

**Poster Display - Metastases**

**P074 : Intracranial control after radiosurgery and hypofractionated stereotactic radiotherapy to the surgical cavity in patients with one to three brain metastases: Impact of regular MRI scan follow-up on outcome.**

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Results: A total of 75 Patients with 77 treated surgical cavities were enrolled. Median follow-up time was 15.8 months (range: 2-69 months). Single, 2 and 3 BM were seen in 65 (86%), 9 (12%) and 1 (2%) patient. Most frequent histologies were lung (37%) and melanoma (13%). Mean target volume was 13cc (range 1.8-45.5cc). Most patients (n = 60, 80%) were treated with a single fraction (fx). Five, 6 and 10fx were given in 3 (4%), 3 (4%) and 9 (12%) patients (mean = 2.4fx). Mean single and total dose (SD and TD) were 15Gy (range 4-20Gy) and 21Gy (range 15-40Gy). Median OS was 19.4 months (95% confidence interval (CI): 12-26 months). Actuarial LC, DBC and OS at 1 year were 72% (95% CI: 60%-83%), 60% (95% CI: 48%-72%), and 66% (95% CI: 53%-76%) respectively. Median number of follow up MRI scans at six months was n=1 (range 0-2). No median value was reached for local failure. Median distant brain failure occurred at 16.2 months (95% CI: 4.5-28 months). Salvage treatment was needed in 45 patients (WBRT n=15, surgery n=15, SRS n=15). The number of MRI follow-up scans at six months did not have an impact on OS (p = 0.56), but it had a significant association on DBC (p<0.035).

Conclusion: Patients with one to three BM treated with SRS and HFSRT alone to the surgical cavity and regular follow-up with MRI scans have an excellent outcome. The impact of regular MRI scan follow-up on DBC deserves further prospective evaluation with an additional focus on its financial impact on cost-effectiveness.
Abstracts

(nCl), homogeneity index (HI), treatment time per fraction - including setup time of 15min and 60sec. imaging interval - number of beams and monitor units (MUs) per fraction. Statistical analysis was performed with STAT/SE 14.1, using the t- test to compare plan quality metrics.

Results: MLC2 plans did not differ significantly in conformity (p= 0.87) and homogeneity (p=0.33) compared to VAC plans. Conformality index was 1.17 ± 0.06 and 1.17 ± 0.05 and HI was 1.43 ± 0.06 and 1.43 ± 0.00 for the MLC 2 and VAC plans respectively. No statistically significant difference in mean dose to the PTV was found (p= 0.9543). OAR dosimetric parameters (Dmin, Dmean, Dmax, D75, D50, D25, D10, D1cc) did not differ significantly between plans (p>0.50). Mean MUs per fraction for the MLC2 and VAC plans were 6830 and 7018, respectively (p= 0.86). There was a statistically significant difference for the minimum dose to PTV in MLC2 plans (p<0.01), number of beams (mean 55 beams MLC2 vs. VAC 161 beams, p<0.0001), and delivery time including setup time of 15min and 60sec. imaging interval (median time MLC2 43min vs. IRIS 59min, p<0.0001) regardless of single versus multiple lesions.

Conclusion: MLC2 produces treatment plans of similar quality as the VAC system with much faster treatment times and significant fewer beams for the clinical use of robotic liver SBRT.

Poster Display - Metastases

P076 : Radiosurgery followed with stereotactic fine needle biopsy as a salvage treatment for large central nervous system lymphomas

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Keywords: central nervous system lymphomas; radiosurgery; Gamma knife

Primary central nervous system lymphomas (PCNSL) may aggravate in very fast speed and cause serious neurological deficiency. There was at least one week between fine needle biopsy and chemotherapy without effect control of PCNSL. The role of radiosurgery in this specific period has not been established.

Inclusion criteria are 1) at least one lesion is larger than 15cc, 2) lesions are critically limited in central nervous system with confirmation of PET-CT, 3) performance status scale (PS) is 3 or 4,4)mini-mental state examination (MMSE) score is less than 24, 5) high intracranial pressure with middle line shift. A total number of 22 patients were enlisted in the study. All these patients were diagnosed by stereotactic fine needle biopsy and treated with Gamma Knife Perfexion at the same day without uninstall frames. The average prescription dose was 13.2Gy (10-14Gy), the average isodose was 42.5% (40%-50%). MRI was performed again 5 to 7 days later with blood tests. The PS and MMSE were evaluated again when a patient was discharged from the hospital.

All patients exhibited excellent tumor control and PS/MMSE improvement. No significant CNS toxicity was observed. The average volume of tumors was 16.12 cc at the treatment and was 2.56 cc 5-7 days later with a recovery of middle line shift. PS scores decreased at least 2 points in all patients. MMSE scores increased at least 5 points at all patients. MMSE scores larger than 24 were achieved in 18/22 patients. Interestingly, edema around lesions did not shrink synchronously with lesions. There were almost no differences of edema volumes before and after treatment (98.22cc vs. 92.82cc, p>0.05).

Radiosurgery may be very effective and safe in salvage treatments for large PCNSL lesions. This effectiveness is mostly due to dramatic shrinkage of lesions.

Poster Display - Metastases

P077 : Positive role of SBRT in the treatment of metastatic pancreatic cancer

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Keywords: pancreatic cancer, SBRT, metastatic, Cyberknife

Metastatic pancreatic cancer is characterized by poor prognosis. Only appearance of FOLFIRINOX increased the median survival of 11 months. However, high toxicity limits its use in elderly patients with severe comorbidities. Meanwhile, in patients with metastatic disease, local treatment didn’t show positive effect on life expectancy.
We present clinical case of 72 years old woman with metastatic pancreatic adenocarcinoma T3N0M1. CT revealed tumor in head of pancreas 40x61x47 mm and two lesions in the liver. 4 cycles of Gemcitabine+Erlotinib were performed, but due to progression second-line chemotherapy with CAPOX was started. Despite partial response after 4 cycles, chemotherapy was stopped because of toxicity. Due to high risk of progression, it was decided to perform consolidating radiosurgical treatment.

SBRT was performed with the use of Cyberknife. In order to monitor displacements of lesions during respiration, 1 radiopaque marker was implanted in the tumor of the pancreas and 4 in the liver 14 days before treatment. Two separate irradiation plans (one for pancreatic lesion and one for liver lesions) were prepared. Dose to pancreatic and liver lesions was 35Gy in 5 fractions. Pancreatic GTV was 26,3 cm³, 3 mm margin was added for PTV. Dose for all critical structures was acceptable in both plans. Nevertheless, during evaluation of the sum of two plans it was revealed, that dose to stomach and duodenum was outside possible tolerable dose. In order to avoid complications but to save the treatment dose and not to lose antitumor effect, it was decided to make a four week brake between two treatments.

During first follow-up 3 months after treatment shrinkage of all 3 lesions was described on MRI. After 9 months only one liver lesion and primary pancreatic tumor, stable in size were determined. At present time patient is alive and in good condition, disease is stable 45 months since diagnosis and 37 months after SBRT. No any other cancer treatment was performed after SBRT. No Grade II-IV adverse events were observed. Grade I diarrhea developed 3 months after irradiation and is controlled with loperamide.

Metastatic pancreatic cancer still has a poor prognosis, but combination of systemic and local treatment can potentially increase survival. SBRT provides a high level of local control, does not require interruption of drug therapy and is not accompanied with surgical trauma and high risk of postoperative complications. Further research is needed to determine the role of SBRT in the treatment of oligometastatic disease.

Poster Display - Metastases

P078 : The effect of Gamma Knife radiosurgery versus whole brain radiation therapy on cognitive functioning in patients with multiple brain metastases: an innovative protocol

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Keywords: Brain metastases, Gamma Knife radiosurgery, Stereotactic radiosurgery, Whole brain radiation therapy, Cognitive functioning, Hopkins Verbal Learning Test, Quality of life

Background: Treatment of multiple brain metastases (BM), without inducing cognitive side effects, is becoming more important, as more patients live longer due to better treatment options. Whole brain radiation therapy (WBRT) has long been the mainstay of treatment for patients with multiple BM. Meanwhile, Gamma Knife radiosurgery (GKRS) is increasingly applied in these patients and is expected to have less adverse effects on cognitive functioning than WBRT. Cognitive functioning is a collective term for cognitive skills such as memory, attention and concentration. There are no published randomized trials yet directly comparing GKRS to WBRT in patients with multiple BM, including objective neuropsychological testing.

Methods: CAR-Study B is a randomised trial comparing cognitive outcome after GKRS or WBRT in adult patients with 11-20 newly diagnosed BM (on a triple-dose contrast-enhanced MRI-scan), KPS ≥70 and life expectancy of at least 3 months. Before randomisation, patients complete a comprehensive neuropsychological test battery to assess cognitive functioning (HVTL-R, COWA, WAIS Digit Span and Digit Symbol, TMT A and B, Grooved Pegboard). In addition, patients fill-out 3 questionnaires concerning health related quality of life (FACT-BR), depression, anxiety (HADS), and fatigue (MVI). Randomisation is stratified by the cumulative tumour volume in the brain, systemic treatment, KPS, histology, baseline HVTL-R Total Recall score (a memory task) and age.
Follow-up for both groups is scheduled at 3, 6, 9, 12 and 15 months after treatment with cognitive testing, questionnaires and MRI-scans. The primary endpoint is the between-group difference in the percentage of patients with significant memory decline at 3 months. Significant decline is defined as a 5-point decrease from baseline in HVLT-R Total Recall score, based on the Reliable Change Index (RCI) with correction for practice effects. Secondary endpoints include cognitive functioning over time, health-related quality of life, depression and anxiety, fatigue, overall survival, local control and development of new brain metastases.

A power analysis based on Bayesian stopping rules suggest that the trial will be halted when 46 patients (23 in both groups) are enrolled. An independent statistician will perform monitoring of this trial using Bayesian statistical methods.

Discussion: This trial is currently recruiting. Results of this study are relevant in clinical decision-making and may be used to inform individual patients with BM more precisely about the cognitive effects they can expect from treatment. Knowledge gained from this trial may be used to change clinical practice (in the Netherlands).

Trial registration: Clinicaltrials.gov identifier: NCT02953717

Poster Display - Metastases

P079 : Stereotactic body radiotherapy for prostate cancer oligometastases

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Keywords: SBRT, prostate, radiosurgery, PET

Objectives: In the absence of trial data, SBRT is reported to safely prolong progression-free survival in patients with prostate cancer oligometastases. 18-F choline is sensitive and specific for prostate cancer oligometastases outside the pelvis and a CT or MRI correlate assists in target delineation for SBRT. We report the outcomes of two patients with challenging patient and tumour factors.

Methods: Patient 1: A choline PET/CT revealed a single painless oligometastasis in T2 in a 59 yr old patient with biochemical relapse (PSA 3.95 ug/l) 6 years after radical treatment of a Gleason 8 prostate cancer. Prior gastroplasty resulted in frequent hiccups. A head rest, wing board, mat and knee rest were used for immobilisation. 5 x 4 Gy with a 5 x 8 Gy integrated boost was prescribed analogous to the DOSIS study protocol and delivered with VMAT.

Patient 2: A 76 yr old patient with PSA 13.7ug/l 6 years after radical treatment of a Gleason 8 prostate cancer was found to have two 18F-PET positive lymph nodes (7.5 mm diam at L4 and 12.2 mm diam right common iliac) within 5 cm of each other. A head rest, wing board, mat, knee rest and chest/abdominal belt were used for immobilization. 3 x 15 Gy was delivered with VMAT within the NRG BR001 study due to unestablished normal tissue constraints in this situation. Androgen deprivation therapy had already been started in both patients.

Results: Patient 1: SBRT was delivered with a mean intrafraction motion vector of 0.55 mm (0.45-0.86 mm) despite hiccups during irradiation. 8 weeks after SBRT, the patient remained asymptomatic. A follow-up CT scan is planned 4 months after SBRT.

Patient 2: SBRT was delivered with a mean intrafraction motion vector of 0.53mm (0.01-0.99mm). Mean dose to the aorta was 6.2 Gy (min. 0.16-max. 49.3 Gy) and to the inferior vena cava was mean 11.5 Gy (min. 0.18 Gy – max. 47.6 Gy). Mean dose to the small bowel was 2 Gy (min. 0.07 Gy – max. 26.9 Gy). The patient remains on study follow-up.

Conclusions: SBRT for oligometastases is reproducible and is well tolerated but should be delivered in clinical trials where available. The high sensitivity and specificity of the new tracer Ga-68 PSMA may assist in the diagnosis of prostatic oligometastases. The recent decision to reimburse PSMA PETCT scans in Switzerland is likely to increase future referrals for SBRT for limited prostate cancer metastases.

Poster Display - Metastases

P080 : Gamma Knife Perfexion versus edge radiosurgery: a phase III randomized trial comparing two different modalities of radiosurgery for patients with limited brain metastases from different solid tumors

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Keywords: radiosurgery, gamma knife, linac-based, phase III trial

Objective: Radiosurgery is an emerging therapeutic approach for the treatment of brain metastases (BMs). Different technological modalities have been used. We draw this phase III trial with the aim to evaluate incidence of symptomatic radionecrosis using gammaknife versus linac-based (EDGE) radiosurgery. Local control and overall survival (OS) were assessed.

Materials and Methods: Patients with up to 4 BMs were enrolled. Inclusion criteria were: KPS ≥70, RPA class I-II, BMs maximum diameter ≤3 cm and/or with a total tumor volume <30 cm³. Prescribed dose was 24 Gy or 20 Gy depending on lesion dimension. Clinical outcome was evaluated by neurological examination and MRI.

Results: From October 2014 to December 2016, 101 patients of the expected 250, for 167 BMs were evaluated. Most common primary was NSCLC (55.4%). Symptomatic radionecrosis was observed in a total of 12 (11.9%) cases of the entire cohort evaluated. In the gammaknife ARM Grade II radionecrosis was recorded in 5 cases and Grade III in 2 cases. In the EDGE ARM only grade II radionecrosis occurred in 5 cases treated. No local progression in site of SRS occurred. At a median time of 11 months, 41.5% patients had new distant brain metastases, and 58% had extracranial progression at a median time of 8 months. The 6 months and 1 year OS were 81% and 70%, comparable in both arms.

Conclusion: Gamma-knife and LINAC based SRS for BMs were comparable in terms of LC. In this preliminary evaluation the risk of symptomatic radionecrosis was greater in the gammaknife arm.

Poster Display - Metastases

P081 : Stereotactic body radiation therapy (SBRT) for colorectal cancer liver metastases: An effective and safe ablative treatment

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Keywords: SBRT, colorectal cancer liver metastases

Purpose: To assess the safety and efficacy of Stereotactic Body Radiotherapy (SBRT) in patients with liver metastases from colorectal cancer (CRC) unsuitable for surgery and radiofrequency ablation (RFA).

Matherials and Methods: Patients with 1–3 inoperable CRC liver metastases and maximum tumor diameter

Results: From February 2010 to January 2016, 90 patients for a total of 129 CRC liver metastases were analyzed. Median follow-up was 14 months (range 5–80). One, two and three years LC rates for lesions were 90%, 81% and 75%, respectively. At univariate analysis, no correlation between LC and lesions size was detected. Median OS was 29 months. Actuarial OS rate at 1.2 and 3 years was 88%, 67% and 33%, respectively. Median PFS was 10 months, with a PFS rates of 81% at 1 year, 63% at 2 years and 40% at 3 years. No patients experienced radiation-induced liver disease or grade >3 toxicity.

Conclusions: SBRT is a non-invasive, safe and effective therapeutic option for patients with unresectable colorectal cancer liver metastases. Short treatment time, non-invasiveness, optimal tolerability of treatment joined to promising LC and OS rates represents the crucial advantages of this alternative ablative therapy for these selected oligometastatic patients.

Poster Display - Metastases

P082 : Efficacy of Gamma Knife radiosurgery in brain metastases of primary gynecological tumors

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Keywords: Gamma Knife Radiosurgery, Brain Metastases, Gynecological Tumors

Background: Cerebral metastasis of gynecological tumors are rare. Despite treatment, the majority of these patients do no survive >1 year due to extracranial disease. In case of brain metastases (BM) one can state that the survival is even less. Treatment options are operation, WBRT, stereotactic radiotherapy (SRT) or stereotactic radiosurgery (SRS). The use of SRS for these BM is not well known within the medical world.
Objective: The goal of this study is to evaluate the efficacy of Gamma Knife Radiosurgery (GKRS) for gynecological BM.

Material: Between 10-6-2002 and 19-5-2015, 3000 procedures were performed at our center for BM. A retrospective analysis of this data was performed. We included all patients who received GKRS for BM of gynecological tumors. Patients with multiple primary tumors were excluded. Pre- and post-GKRS clinical characteristics were reviewed. Outcome measures were local tumor control (TC), development of new BM and/or leptomeningeal disease after initial SRS, overall intracranial progression free survival (PFS).

Results: We included 41 patients (median age 64, median Karnofski-index 80). Primary tumors were endometrium (8), ovarian (29) and cervix carcinoma (4). A median dose of 22 Gy (range 18-25 Gy) was prescribed to the isodoseline covering 90-100% tumor volume. The mean tumor volume was 3.507 cm³ (range 0.0014-21.125 cm³). Sixteen patients (39%) had single BM and 25 (61%) had ≥2 lesions (median number per patient was 2, ranging 1-7). Eventually a total of 92 metastases (74 (80%) supratentorial and 18 (20%) infratentorial) were treated. Eleven (27%) patients had undergone intracranial treatment for the BM prior to SRS (7 resection followed by post-operative SRT, 2 biopsy and 2 WBRT). The median and mean FU time was 11 and 19 months, respectively. The TC was 100%, 92%, 88%, 76% and 67% at 2.5, 5, 7.5, 12.5 and 15 months, respectively. The PFS was 90%, 66%, 51%, 24% and 15% at 2.5, 5, 7.5, 12.5 and 15 months, respectively. During FU 18 (44%) patients had intracranial progression (4 local progression, 6 local progression with distant lesions, 6 only new BM and 2 had new BM with leptomeningeal disease). Thirty-one (76%) patients died due to extracranial tumor progression and only 2 (5%) patients died due to progressive intracranial disease.

Conclusion: GKRS is a good treatment option for controlling BM in patients with primary gynecological malignancies. As most patients die due to extracranial tumor progression, their survival might improve with better systemic treatment options in addition to GKRS.

Poster Display - Metastases

P083 : Additional radiotherapy to whole brain radiotherapy for multiple brain metastases

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Keywords: brain, metastasis, multiple, stereotactic radiosurgery, intensity modulated radiation therapy, volumetric arc modulated radiotherapy, dissemination, cerebellum

Multiple brain metastases are challenging to treat, especially if the number of tumors is large or if they accompanied with brain surface seeding. In addition to whole brain radiation therapy (WBRT), stereotactic radiosurgery (SRS) to some larger lesions and/or volumetric modulated arc radiotherapy (VMAT) boost on part of brain was performed in such cases. In four cases of multiple brain metastases, boost radiation to the cerebellum, where many tumors existed, by VMAT in addition to WBRT. In all seven cases, before or after WBRT, SRS was done to some larger lesions. Four cases were alive and three were dead with median follow-up period of 5 months (range, 1 to 18 months). Four cases developed advanced cerebrospinal fluid dissemination in their course.

Additional tumor boost by SRS and/or area boost by VMAT may prolong the control of multiple brain metastases in advanced situations for a certain period.

Poster Display - Metastases

P084 : The combined effects of dosimetric margin and prescription isodose selection on plan quality in single target dynamic conformal arc radiosurgery

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Keywords: radiosurgery, dynamic conformal arcs, conformity index

Objective: To examine the combined effects of prescription method and dosimetric margin on the quality of dynamic conformal arc plans for the treatment of single brain metastases.

Methods: This study consisted of two target sets: simulated targets and patient data. The simulated targets included spheres of varying size (0.5-3cm in diameter) and ellipses in varying orientations. Data from 11 patients (12 lesions)
were also included. Plans for the simulated targets were generated by using a standard 4 arc plan whereas for the patient data the beam arrangement used for treatment was also used in this study. For all plans, the dosimetric margins were varied in 1mm increments from -1mm to 3mm; the prescription isodose line (IDS) was varied independently of dosimetric margin from 50-98% isodose surface (where 100% is the maximum point dose) and 90-99.8% target coverage. Plans were evaluated by target coverage, minimum and maximum dose to target, heterogeneity, gradient index (GI), and conformity index (CI).

Results: Increased dosimetric margin increased the minimum IDS required to provide 100% target coverage of the prescribed dose. For fixed margins, minimum and maximum dose to the target were scaled directly by the IDS and a higher IDS resulted in lower maximum dose. Heterogeneity increased with decreasing margin size and was independent of IDS. The GI increased with dosimetric margin, however, for a given margin, the minimum GI occurred at the same IDS for each target. For patient data and simulation, the minimum CI for a given margin occurred at a higher IDS as the dosimetric margin increased. As the IDS increased the dosimetric margin that gave the lowest CI also increased. In the patient data when the target coverage was fixed to 99.8%, the 0mm margin had the lowest CI for 8 targets and the 1mm for 4 targets. When the maximum dose was also constrained to no more that 120%, the 1mm margin had the lowest CI for 9 targets. Under these constraints the targets larger than 2cm in diameter required a larger margin of 2mm or 3mm.

Conclusions: The dosimetric margin and prescription method both impact the dose distribution and associated quality metrics. Particularly, when it comes to finding an optimal conformity index, it cannot be assumed that fixing either the margin or prescription IDS to a predetermined value will result in the most desirable plan.

Poster Display - Metastases

P085 : Central lobe metastases. Radiosurgical treatment in single institution, 4 years experience.


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Keywords: central lobe metastases, radiosurgical treatment

Introduction: Current cancer treatments confront an increasing number of patients with metastatic brain metastases. We present the result of SRS in patients with metastases in the central lobes of the brain.

Material: All patients submitted to SRS (Varian-LINAC) for Brain Metastases between February 2013 and October 2016 were retrospectively studied. Seventeen patients with tumors in the Central Lobes were identified.

Method: Clinical symptoms; MRI pre and post - SRS of each patient; tumor volume; SRS dosimetry; MRI evidence of adverse radiation effects (ARE); Local Control and Outcome were investigated.

Results: Mean age (years) = 59.53; Median = 62.5. Most frequent primary tumor was Non SCLC = 12. No laterality predominance. Eight patients (47.5 %) had intracranial oligometastases condition (all tumors received SRS at the same day). Motor weakness, hypoesthesia and/or seizure were present in ten patients (58.82 %).

Prescription Doses: Mean = 18.33 Gy. PTV: Mean = 1.79 cc. Effective local control (LC) = 16/17 (88.23 %). Partial LC (>50%) in 5/17 patients (35.29%), coincident with larger PTV or shorter period of follow up. No patient was lost during the follow-up of the series. Salvage surgery of local relapse was performed in only one patient. ARE in the MRI follow up was present in six patients: four of them had brain edema in gyri contiguous to the metastases. Four patients developed epilepsy after SRS, in the absence of tumor growth, all presented gyral edema in MRI post SRS; three of them had PTV > 4 cc and V12 > 6.50 cc. One patient presented worsening of motor function after SRS, which improved with steroids medication. All the rest of patients with normal motor function preserve it after treatment.

Conclusions: Motor deficit prior to SRS and tumor’s presence within the Central Lobe did not correlate with worsened motor function following SRS. Prescription doses ≥ 18 Gy were used in the search of better tumor control; PTV and V12 values were also determinant at the
time of dose selection. Pre-SRS edema does not seem increase the risk of developing motor dysfunction. Regarding complications, epilepsy was more frequent than motor weakness. The occurrence of new lesions does not impact overall survival if salvage therapy is offered.

Poster Display - Metastases

P086 : Dosimetric characteristics of radiosurgical treatment of multiple brain metastases on Cyberknife and GammaKnife

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Keywords: CyberKnife, Gamma Knife, radiosurgery, dosimetric comparison, brain metastases, conformity index, homogeneity index

The aim of the study was to assess the quality of plans and comparison of the dosimetric parameters of dose distributions for the radiosurgery of multiple brain metastases (N≥4) on Cyberknife (CK) and Gamma Knife (GK).

Materials and methods: 13 patients with 68 brain metastases previously treated on the CK radiosurgery system were selected. Then contours of targets and critical structures according to CT and MRI data were transferred from MultiPlan to Leksell GammaPlan for reproducing treatment plan. The value of dose, covering 100% of target volume, was equal for both modality. Following characteristics were calculated from dose-volume histogram (DVH): homogeneity index (HI), coverage (CO), conformity indexes (CI\textsubscript{RTOG}, nCI), gradient indexes (GI\textsubscript{10}, GI\textsubscript{20}) and doses in normal tissues (V\textsubscript{10}, V\textsubscript{20}, V\textsubscript{10net}, V\textsubscript{12net}). The original software was developed for the automate DVH processing.

Results: Following results we achieved while comparing indicators calculated for two SRS system. Depending on the targets volume: for volume \text{[0,01;0,1)} cm\textsuperscript{3} statistically reliable difference for CI\textsubscript{RTOG} = 1,523 ± 0,094 (GK) vs 1,623 ± 0,166 (CK), p=0,35; for volume \text{[0,1;1]} cm\textsuperscript{3} GK dose distribution is more conformal (nCI: 1,262 ± 0,075 (GK) vs 1,313 ± 0,079 (CK), p<0,05). For all volumes of target CK gives more homogeneous dose distributions in target (HI: 62,43 (35,18 – 81,48) % (GK) vs 18,25 (13,82 – 24,30) % (CK), p <0,001); the GK dose heterogeneity in target is accompanied by high dose gradient out of the target and lower V\textsubscript{10} and V\textsubscript{10net} values. Independently on the number of lesions (N): nCI values are equal for CK and GK (1,211 ± 0,036 (GK) vs 1,332 ± 0,066 (CK), p=0,25), however CI\textsubscript{RTOG} conformity is better on GK (1,151 ± 0,023 (GK) vs 1,332 ± 0,066 (CK), p<0,05). For all N dose distribution in target is more homogeneous on CK (62,22 (18,02 - 78,04) % (GK) vs 21,93 (20,16 - 23,75) % (CK),p< 0,001), while dose gradients are higher on GK allowing more effective irradiation dose decreasing in brain.

Poster Display - Metastases

P087 : Physics considerations for single isocenter radiosurgery of multifocal disease: The Duke experience

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Keywords: VMAT, radiosurgery, multifocal, SRS

Our purpose is to address physics challenges of implementing a single isocenter radiosurgery approach for treating multifocal intracranial disease. The technique utilizes a radiosurgery specific thermoplastic mask for immobilization, and VMAT with HD-MLCs (2.5mm leaf-width at isocenter) for treatment planning. Physics aspects that we investigated during the implementation include: (1) quantifying and managing spatial uncertainty associated with image guidance and immobilization, (2) investigating VMAT treatment planning strategies such as ideal isocenter selection, number and geometry of VMAT arcs, and choice of optimization criteria, (3) determining whether plan quality is affected when targets are located distal from the isocenter, and whether a single isocenter is sufficient for spatially dispersed targets, and (4) revisiting tolerances for routine machine quality assurance based on the potential dosimetric effect. Our analysis showed that
after 6D correction of initial setup error, a 1mm margin was still needed to compensate for spatial uncertainty within the mask. Conformity and gradient indices improved with decreasing distance from isocenter, with this trend being more pronounced for targets < 1 mL. Alternative isocenters aimed at decreasing distance of small targets improved their gradient index, but resulted in poorer dose indices for large targets. Yet when targets were spatially dispersed, utilizing multiple isocenters resulted in only modest improvements in plan quality, thus indicating that a single isocenter is sufficient for most cases. Optimal treatment plan quality could be achieved when no constraint was placed on the maximum target dose; for cases with many targets at least 4 arcs were needed for optimal plan quality. Our investigation of routine machine QA tolerance found that in order to avoid potentially unacceptable dosimetric degradation to single isocenter multifocal VMAT plans, the gantry and collimator angular tolerance for routine (monthly) QA should be tightened to 0.5°.

**Poster Display - Metastases**

**P088 : Treatment of radiation necrosis with bevacizumab in melanoma patients who developed brain metastases**

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**Keywords:** radiation necrosis, brain metastasis, stereotactic radio surgery, melanoma, Bevacizumab, avastin

**Background:** Radiation necrosis (RN) is a potential late complication of radiotherapy for CNS malignancy, often associated with neurological morbidity. Traditionally, high dose corticosteroids or surgical resection have been the standard of care treatment, but protracted steroid course can lead to significant side effects and resection is not always feasible. While there is evidence that the anti-VEGF antibody bevacizumab (Bev) can be effective for RN in other cancer types, evidence supporting its use for RN in melanoma patients is lacking, due to known risk of spontaneous bleeding in melanoma brain metastasis (MBM) and increased bleeding risk with Bev.

**Methods:** We retrospectively identified 6 melanoma patients who received Bev for RN, and demographics, systemic and radiation treatment history were obtained.

Diagnosis of RN was established by MRI in all patients, and pathology confirmed RN in one patient.

**Results:** We present 6 melanoma patients who developed RN after CNS radiation and who were treated with 2-6 doses of Bev. Median age was 58 years-old (rang 52-71). Two patients received SRS (stereotactic radiosurgery) alone, 2 patients received WBRT (whole brain radiation therapy) alone, and 2 patients received SRS plus WBRT. Four patients received current or prior immunotherapy. Radiation necrosis was diagnosed 5 months after completion of radiation (range 4-7 months). None of these patients developed bleeding, and all patients experienced improvement in symptoms and quality of life, with concurrent improvement of imaging in 5 patients.

**Conclusions:** Our series suggests that in selected melanoma patients Bev may be a safe and effective treatment for RN for MBM and should be evaluated in a prospective setting.

**Poster Display - Metastases**

**P089 : Radiosurgery in the management of brain metastasis: A retrospective single-center study comparing Gamma Knife and LINAC treatment**

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**Keywords:** radiosurgery; Gamma Knife surgery; brain metastases; linear accelerator; oncology; stereotactic radiosurgery

**Objective:** The authors present a retrospective analysis of a single-center experience with treatment of brain metastases using Gamma Knife (GK) and linear accelerator (LINAC)–based radiosurgery and compare the results.

**Methods:** From July 2010 to July 2012, 63 patients with brain metastases were treated with radiosurgery. Among them, 28 (83 lesions) were treated with a GK unit and 35 (47 lesions) with a LINAC. The primary outcome was lo-
cal progression–free survival (LPFS), evaluated on a per-lesion basis. The secondary outcome was overall survival (OS), evaluated per patient. Statistical analysis included standard tests and Cox regression with shared frailty models to account for the within-patient correlation.

Results: The median number of lesions per patient was 2.5 (range 1–9) in the GK group and 1 (range 1–3) in the LINAC group (p < 0.01, 2-sample t-test). There were more radioresistant lesions (e.g., melanoma) and more lesions located in functional areas in the GK group. Additional technical reasons for choosing GK instead of LINAC were limitations of LINAC movements, especially if lesions were located in the lower posterior fossa or multiple lesions were close to highly functional areas (e.g., the brainstem), precluding optimal dosimetry with LINAC. The median marginal dose was 24 Gy with GK and 20 Gy with LINAC (p < 0.01, 2-sample t-test). For GK, the actuarial LPFS rate at 3, 6, 9, 12, and 17 months was 96.96%, 96.96%, 96.96%, 88.1%, and 81.5%, remaining stable until 32 months. For LINAC the rate at 3, 6, 12, 17, 24, and 33 months was 91.5%, 91.5%, 91.5%, 79.9%, 55.5%, and 17.1% (log-rank p = 0.03). In the Cox regression with shared frailty model the risk of local progression in the LINAC group was almost twice that of the GK group (HR 1.92, p > 0.05).

Conclusions: In this retrospective study comparing GK and LINAC-based radiosurgery for brain metastases, patients with more severe disease were treated by GK, including those harboring lesions of greater number, of radioresistant type, or in highly functional areas. The risk of local progression for the LINAC group was almost twice that in the GK group, although the difference was not statistically significant. Importantly, the OS rates were similar for the 2 groups, although GK was used in patients with more complex brain metastatic disease and with no other therapeutic alternative.

Poster Display - Metastases
P090 : Optimization of Cyberknife dosimetric planning using a dose-limiting auto-shell method for brain metastases

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Keywords: Stereotactic radiosurgery, Brain metastases, Cyberknife, Gamma Knife, Auto-shell

Purpose: We investigated the impact of optimization in dose-limiting auto-shell function on the dosimetric quality of Cyberknife (CK) plans in treating brain metastases (BM).

Methods: We selected 19 BMs previously treated using CK between 2014 and 2015. The original CK plans (CKoriginal) had been produced using one to 3 dose-limiting auto-shells, one at the prescription dose (PD) level for dose conformity and others at low-dose levels (10–30% of PD) for dose spillage. In each case, a modified CK plan (CKmodified) was generated using 5 dose-limiting auto-shells, one at PD level, another at intermediate dose level (50% of PD) for steeper dose fall-off, and the others at low-dose levels, with an optimized shell-dilation size based on our experience. A Gamma Knife (GK) plan was also produced using the original contour set. Thus, a triplet data set of dosimetric parameters was generated and compared.

Results: There were no differences among CKoriginal, CKmodified, and GK plans in the conformity index (mean 1.22, 1.18, and 1.24, respectively; P=0.079) and tumor coverage (mean 99.5%, 99.5%, and 99.4%, respectively; P=0.177), whereas CKmodified plans produced significantly smaller normal tissue volumes receiving 50% of PD than those produced by CKoriginal plans (P<0.001), with no statistical differences in those volumes compared with GK plans (P=0.345).

Conclusions: These results indicate that significantly steeper dose fall-off can be further achieved in the CK system by optimizing the auto-shell function, while maintaining high conformity of dose to tumor.

Poster Display - Metastases
P091 : Stereotactic body radiotherapy (SBRT) for oligometastatic urinary bladder transitional cell carcinoma: a retrospective analysis of 11 patients

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Keywords: Stereotactic body radiotherapy, Oligometastatic urinary bladder, Transitional cell carcinoma, Radiation therapy, Retrospective analysis

Purpose: To evaluate the clinical outcomes and radiation dosimetric details of SBRT for oligometastatic UBC.

Methods: We retrospectively reviewed 11 patients with oligometastatic UBC treated with SBRT between January 2014 and December 2016. All patients underwent SBRT for UBC metastases. The primary tumor was completely resected or had no evidence of disease. The treatment planning system was a Cyberknife. The median prescription dose was 28 Gy (range 20–30 Gy). The follow-up was completed in 10 of 11 patients at a median of 28 months.

Results: At the median follow-up of 28 months, no patient died of disease. Nine patients (82%) experienced disease control in the target. In 7 patients (64%), the disease control of the target and the local failure of the target were achieved. The median time to local failure was 12 months. The median time to control of the target was 6 months. No grade 4 or 5 toxicity was recorded.

Conclusions: SBRT for oligometastatic UBC is a feasible and effective treatment option with good control rate and low toxicity.
**Objectives:** The aim of our study was to retrospectively report on the image guided stereotactic body radiotherapy (SBRT) in the oligo-recurrent bladder cancer. Eleven patients treated in our department for urinary bladder transitional cell carcinoma with lymph node or bone recurrence were retrospectively reviewed. The endpoint was to evaluate the safety of SBRT, proposed as an alternative to systemic treatment, and in order to defer the start of a second line chemotherapy.

**Methods:** Inclusion criteria for our retrospective study were as follows: adult oligometastatic bladder transitional cell cancer (TCC) patients with lymph node or bone recurrence that underwent SBRT but not other local/systemic therapy. Previous radiotherapy, concomitant systemic therapy or surgery on the primary tumor were allowed. Previous systemic therapy or cystectomy was performed in all patients. The median treatment dose was 25 Gy (range, 20-30 Gy) given over a median of 5 fraction (range, 3-15 fraction). Toxicity and tumor response were evaluated using RTOG/EORTC and RECIST criteria.

**Results:** Eleven patients for a total of 19 lesions were treated with CyberKnife or Vero System- SBRT between 2012 and 2016 in our Division. Median age at SBRT was 65.3 years (range 45-80) and Karnofsky performance status (KPS) was 90 (range 70-90). Mean interval between TCC diagnosis and the first RT treatment was 3.1 years. Median follow-up was 20.3 months. Radiological response evaluated at the first imaging assessment was: complete response, partial response, local progression and not evaluable 11, 1, 6 and 1 lesions, respectively.

The radiological progression of disease was registered in 7 patients at the median of 8.2 months (range 2.3-18.5 months) from the end of SBRT; in 6 cases it was out-field and in-field progression, while in one patient an only out-field progression was observed.

At present (January 2017), 3 pts are alive with no evidence of disease (median of 20.1 months from the end of SBRT), 2 alive with evidence of disease, 4 dead of cancer related disease and 1 was lost at the follow-up. No severe acute (except for Grade 1 in 1 patient) and late toxicity were observed.

**Conclusions:** SBRT on lymph node or bone recurrence from TCC offers a good in-field tumor control with very low toxicity profile. In small proportion of patients the starting of another systemic therapy was deferred with a reasonable control of disease. Further study are needed to establish a role of SBRT in the oligometastatic recurrent bladder cancer.

**Keywords:** brain metastasis, radiosurgery, radiotherapy, neurocognitive status

**Purpose:** Although the possible impact of radiation therapy (RT) on neurocognitive functioning and quality of life (QoL) has become an important issue when choosing treatment for patients with brain metastases, related data are still scarce. The aim of this study is to evaluate neurocognitive and QoL outcome in patients treated with RT for brain metastases.

**Method:** Patients had neurocognitive evaluation and QoL testing before RT, 3 and 6 months after RT the first year, and then every 6 months. Mini mental state examination (MMSE), Trail Making Test (TMT A and B) and Clock Drawing Test (CDT) were used for neurocognitive assessment and EORTC QoL C30 and BN20 for QoL assessment. Differences in baseline points were analyzed with ANOVA test.

**Results:** 77 patients were enrolled (M/F=31/46) in the last two years, with median age 58y (range 28-77y). 64% of pts were RPA class 1 and 36% class 2, 39% had GPA score between 0.5-2 and 61% between 2.5-4. Primary tumor location was lung in 43%, breast in 30%, melanoma in 12% patients. 51% of pts had no neurological symptoms at diagnosis, 16% of symptomatic patients had headache. 55% of pts had 1 lesion, 13% and 16% respectively 2 and 3 lesions. 61% of pts had cortical and 38% subcortical localizations. At presentation, a surgical approach was chosen in 40% of...
cases. 62% of pts received whole brain irradiation (WB). 9 of them were also administered simultaneous integrated boost and 2 had stereotactic radiosurgery (SRS) after WB. 38% of pts had SRS without WB, and 19% received concomitant chemotherapy. 69% of pts received steroids and 26% had anti-epileptic drugs before RT. During treatment, 12% and 15% of pts reported respectively G1 and G2 headache. G1 and G2 fatigue was recorded respectively in 27% and 15% of the cases. The use of steroids increased during RT in 15 pts. Median overall survival for pts treated with WB vs SRS was 209 days (range 3-1096) and 257 days (range 68-1087) respectively. Baseline MMSE was between 24-30 (no neurological alteration) in 94% of pts. 4% had a score of 20-23 (suspected neurological alteration), none scored under 20. Baseline MMSE and CDT mean points did not differ in pts treated with WB vs SRS. Mean TMT A, B, A+B in WB and SRS groups were 65, 158, 92 and 44, 91, 46 respectively.

Conclusions: The mature data and the neurocognitive functioning after RT will be presented.

Poster Display - Metastases

P093 : Toxicity and efficacy of Gamma Knife radiosurgery for brain metastases in patients with immune therapy

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Keywords: brain metastases, immune therapy, Gamma Knife

The Gamma Knife Unit at the Department of Neurosurgery, Medical University Vienna looks back on 25 years of experience in radiosurgical treatment. In this timeframe several thousand patients with brain metastases (BMs) have been treated. Since the implementation of the Gamma Knife Perfexion® in 2012 the modern radiosurgical treatment era has commenced. Apart from developments in the radiosurgical treatment there has been significant progress in the oncological management of cancer patients since the introduction of immunotherapy and personalized targeted therapy. So far, even though concurrent treatment with radiosurgery and targeted drugs or immunotherapy is increasingly performed, available safety information is scarce. We have recently established a database of all patients with brain metastases treated in the modern radiosurgical and oncological era from 2012 onwards. So far the database includes 830 patients and 3079 radiosurgically treated BMs. In the modern radiosurgical era melanoma has presented itself as the second most frequent primary tumor of BMs (15%), at least in our series. Especially melanoma patients are increasingly treated with immune therapy. We provide radiological and clinical outcome data of patients with BMs treated in the modern radiosurgical and oncological era. We especially focus on complications after radiosurgery in patients with immune therapy or targeted therapy.

Poster Display - Metastases

P094 : Characterizing clinical survival patterns using machine learning: An analysis of brain metastasis patients treated with stereotactic radiosurgery (SRS)

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Keywords: Brain metastasis, prognosis, machine learning, stereotactic radiosurgery

Introduction: Increased sophistication in machine-learning algorithms and artificial intelligence has begun to reveal patterns that were otherwise unappreciated in clinical medicine. Here we applied one such algorithm, Factorial Analysis of Mixed Data, to better understand combinations of clinical variables that influence survival of brain metastasis (BM) patients treated with stereotactic radiosurgery (SRS).

Methods: A dataset of 6,326 BM patients were collated from four SRS centers (University of California, San Diego, Katsuta Hospital Mito GammaHouse, Tsukiji...
Neurological Clinic, and Melanoma Institute of Australia). We ran three models using Factorial Analysis of Mixed Data, each including one of the following in model construction: died before 3 months, survived for 1 year, or survived for 2 years. The other clinical variables included were age, Karnofsky Performance Status (KPS), cumulative intracranial tumor volume (CITV), total number of metastases, histology (breast, gastro-intestinal (GI) cancer, renal cell carcinoma (RCC), melanoma, and lung cancer), and systemic disease control.

Results: Our unsupervised machine-learning algorithm defined three groups of SRS-BM patients with different survival profiles. Dying within 3 months of SRS treatment was most significantly correlated with the group characterized by lower KPS, poor systemic disease control, higher CITV, higher number of metastases, and the diagnosis of GI cancers. Surviving beyond 24 months of SRS treatment strongly correlated with the category consisting of subsets of lung and breast cancer patients with higher KPS, controlled systemic disease, and lower CITV. A third category emerged from the analyses that consisted of young breast cancer patients with systemic disease control, but survival was not strongly correlated with this group. This group of patients was also defined independently of KPS, CITV, and the number of metastases.

Conclusion: Clinical survival after SRS for BM is defined by combination of known prognostic factors. A prognostic factor critical for survival prognosis in one sub-population of BM patients may bear little relevance in another.

Poster Display - Metastases
P095 : Technical issue of beam geometric optimization in multiple targets using single isocenter

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Keywords: beam geometry, multiple targets, single isocenter

Purpose: This work aims to raise and evaluate the issue of beam geometric optimization in multiple targets using single isocenter technique.

Method: OCTAVIUS 4D phantom (PTW, Freiburg, Germany) CT image set was utilized in this study. Seven targets of 2cm-diameter spheres located at central (C), right (R), left (L), anterior (A), posterior (P), superior (S) and inferior (I) and 5 cm apart from the central target. 2 mm margin was given to each target to create planning target volume (PTV) and prescribed 16 Gy to each PTV. Two single isocenter volumetric arc therapy (VMAT) plans with different collimator angles (20° and 70°) in Monaco v5.0 (Elekta AB, Stockholm, Sweden) were generated so that some of the targets were parallel to leaves direction during the trajectory. The plans were then delivered on Elekta Agility and measured by PTW OCTAVIUS 4D system and 1500 array detector. In order to obtain higher resolution, the plans were re-measured with 5 mm detector shifted. 3-dimenional (3D) dose distribution was reconstructed in Verisoft v7.0 and 3D gamma analysis (3D-γ) at 2%/2mm/ local-dose of 40x40x40 mm³ region of interest for each target were performed. The measurements were further reconstructed to provide the dose-volume-histogram information of each target. Independent t-test was used to compare the γ-index and percentage change in PTV coverage (%PTV) between two groups (MLC-direction and nonMLC-direction) with statistical significant at p<0.05.

Results: The average γ-indices of MLC-direction and nonMLC-direction were 91.2% and 96.3% respectively, while -13.3% and -5.2% were found for %PTV with both p<0.05.

Conclusion: The targets parallel to MLC have lower γ passing rates and more loss in PTV coverage. The loss in PTV coverage for all targets indicated that the complexity of the plans. Therefore, gantry and collimator angles should be carefully selected for this advance treatment technique.

Poster Display - Metastases
P096 : To compare treatment outcome of stereotactic body radiotherapy and metastasectomy for pulmonary metastases

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**Abstracts**

**Keywords:** stereotactic body radiotherapy, metastasectomy, pulmonary metastases

**Objective:** To assess the efficacy of stereotactic body radiotherapy (SBRT) and metastasectomy for treatment of pulmonary metastases

**Methods:** The study included 51 patients treated between January 2010 and June 2016. Among these patients, 21 patients received SBRT for 29 metastases and 30 patients received metastasectomy for 30 metastases. SBRT was performed using Cyberknife system and total radiation doses ranged from 48 to 60 Gy, as delivered in three to five equal fractions. In metastasectomy group, wedge resection was performed in most patients (93.3%). Local control rate (LCR), progression free survival (PFS), and overall survival (OS) were assessed.

**Results:** The median follow-up duration was 13.7 months and the median patients’ age was 65 years. The median tumor size was larger in SBRT group compared with metastasectomy group (2.5 cm vs 1.25 cm; p=0.015) and other synchronous metastases was prevalent in SBRT group (57.1% vs 20%; p=0.006). The LCR was similar between SBRT and metastasectomy groups (61.58% vs 69.86%; p=0.163) and 1-yr LCR was 83.5% for SBRT group and 91.5% for metastasectomy group. PFS was longer in patients receiving metastasectomy compared with those receiving SRS (10.9% vs 26.59%; p=0.02). 1-yr PFS rate was 47.6% in SBRT and 60% in metastasectomy group. OS did not show the difference between SBRT and metastasectomy group (52.75% vs 56.23%; p=0.534) and 1-yr OS rate was 79.5% in SBRT and 95% in metastasectomy.

**Conclusion** The present study shows the SBRT and metastasectomy for pulmonary metastases had similar LCR and OS result. The patients with other synchronous metastases were more included in the SBRT group, and that may result in inferior PFS in SBRT group.

**Poster Display - Metastases**

**P097 : Clinical outcomes of brain metastases treated with stereotactic radiosurgery and immune checkpoint blockade agents**

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**Keywords:** brain metastases, stereotactic radiosurgery, nivolumab

**Background:** Most recently, significant advances have been made in the field of in the immune check-point blockade. Nivolumab has been approved for use in patients with melanoma and non-small cell lung cancer (NSCLC). Little is known about the safety and outcomes in patients receiving immune checkpoint blockade agents and stereotactic radiosurgery (SRS) for the treatment of brain metastases (BM).

**Patients and methods:** We retrospectively reviewed medical charts of 18 patients with advanced NSCLC and 23 patients with melanoma, treated with nivolumab. There were 19 men and 22 women. The mean patient age was 66.

**Results:** SRS was administered before, during and after nivolumab in six, four, and two patients. One patient experienced seizure during the treatment with nivolumab, caused by perifocal edema 8 months after SRS. No other treatment-related neurologic toxicities were reported.

**Conclusions:** The relatively small number of patients and the heterogeneity of the population are limitations of this study. Nivolumab CNS activity warrants further evaluation.

**Poster Display - Metastases**

**P098 : Preoperative or postoperative radiosurgery for brain metastases?**

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**Keywords:** preoperative, postoperative, radiosurgery, brain, metastasis

**Objectives:** Preoperative radiosurgery facilitates target definition enabling a reduced planning margin. High local control rates with low toxicity are reported. Our aims were (1) to review the outcome of patients treated with postoperative hypofractionated stereotactic radiosurgery, (2) to compare matched preoperative GTV and PTV with postoperative CTV and PTV, (3) to explore dosimetry of preoperative radiosurgery, (4) to evaluate the patients in the context of the two current studies of preoperative radiosurgery.
Methods: We reviewed MRI follow-up imaging of 20 consecutive patients treated with postoperative radiosurgery (5 x 6 Gy to the 80% isodoses). Brain metastases were contoured retrospectively on the preoperative MRI to generate a theoretical preoperative GTV. A planning margin of 1 mm was added to the preoperative GTV and 2mm to the postoperative CTV. 12 Gy and 15 Gy plans were created (iPlan, Brainlab) for brain metastases > 3cm diameter. Patients were evaluated against the eligibility criteria for current Phase I and Phase II trials of preoperative radiosurgery (RAD001, NCT02514915).

Results: 5 patients declined MRI follow-up. MRIs showed 80% local control of the tumour bed [12 of 15 evaluable patients, median FU 15 mths, (range 3-55 mths)]. 3 patients (20%) had a local recurrence at the time of distant intracranial brain failure (median 8 mths), of whom one patient had leptomeningeal failure (6.6%). These outcomes are comparable to reports of preoperative radiosurgery (local control 85.6%, leptomeningeal relapse 4.5%). The postoperative CTV was larger than the preoperative GTV in 13/20 of our cases. Correspondingly, the postoperative PTV was larger than the preoperative PTV in 14/20 patients. The mean increase in PTV was 160% (18-530%), with increases >200% in the case of metastases <2 cm³. Where a decrease in volume was seen postoperatively, the mean preoperative GTV was 12.9 cm³ (11.3-76.2 cm³) and the average volume decrease was 37.6% (18-60.5%). 5 patients had synchronous brain metastases that were treated with radiosurgery. 13/20 patients would be eligible for current studies.

Conclusions: Preoperative radiosurgery is compelling due to more precise target definition, the potential for less normal brain toxicity due to a smaller irradiated volume and a dose reduction, a low incidence of leptomeningeal disease, enhanced patient convenience, reduced disruption of systemic therapy and radiosurgery of synchronous brain metastases. We propose a multidisciplinary registry study of preoperative radiosurgery for brain metastases indicated for resection with < 5mm midline shift.

Poster Display - Metastases

P099: Early tumour perfusion and diffusion evaluated in multi-modal imaging following radiosurgery for metastatic brain cancer

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Keywords: DCE, DWI, treatment response, brain metastases

Introduction: Early change in tumour perfusion and diffusion following stereotactic radiosurgery (SRS) is a potential biomarker of response. However, efforts for quantitative model-based measures of Dynamic Contrast Enhanced (DCE) and Diffusion Weighted Imaging (DWI) parameters have shown variable findings to-date that may reflect variability in the MR acquisition and/or analysis method. This work describes the use of a voxel-based, multi-modality GPU architecture to include various complimentary solute transport processes such as perfusion and diffusion into a common framework. This is anticipated to improve accuracy and robustness of the early imaging biomarker predictions.

Methods: Patients treated with SRS as part of REB-approved clinical trials underwent volumetric DCE-CT, DCE-MRI and DWI-MRI scans at baseline, then 7 and 20 days post-SRS. As DCE-CT is considered a good standard for tracer-kinetic validation given its signal linearity, we compared 3D pharmaco-kinetic parameter maps using a modified Tofts model (ktrans, Ve, Vp, AUC) from both modalities as well as the correlation between apparent diffusion coefficient (ADC) values from DWI-MRI and the extravascular, extracellular volume (Vc) from DCE imaging. A total of 14 tumours in 9 patients were evaluated. All imaging was co-registered to T1-Gad MR acquisition and/or analysis method. This work describes the use of a voxel-based, multi-modality GPU architecture to include various complimentary solute transport processes such as perfusion and diffusion into a common framework. This is anticipated to improve accuracy and robustness of the early imaging biomarker predictions.

Results: Voxel-wise analysis showed statistically significant correlations in K trans (P<0.001) between DCE-CT and DCE-MRI over all imaging time points as well as excellent agreement with very little bias. Statistically significant correlations were also present between ADC/Vc and peaked at Day 7 (R=0.85, p<0.001) but a large variation was present across tumors (R²: 0.15-0.8) and disappeared altogether when reviewing the mean ADC only hence disregarding tumor heterogeneity.

Conclusion: Utility of a common analysis platform has shown statistically higher correlations between pharmaco-kinetic parameters than has previously
been reported but is highlighting the need for a better understanding of the tumor microenvironment to improve biomarker sensitivity.

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**P100 : Clinical outcomes and toxicity of patients treated with stereotactic radiosurgery for brain metastases from lung cancer harboring an EGFR mutation**

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**Keywords:** Brain metastases, lung cancer, radiosurgery, EGFR mutation

**Background:** We have previously reported that patients with non-small cell lung cancer (NSCLC) harboring epidermal growth factor (EGFR) mutations have improved overall survival compared to patients with EGFR wild-type NSCLC. With the advent of second- and third-generation tyrosine kinase inhibitors patients are living longer, have better systemic control, and have a greater opportunity to develop subsequent brain metastases and toxicity. We present the clinical outcomes and toxicity of patients whose data were collected in a prospective registry.

**Methods:** Over a two year interval, 112 NSCLC patients had stereotactic gamma knife radiosurgery (GKRS) as their initial brain metastasis management. Fifty-six of these patients had EGFR mutations. Overall survival, intracranial progression-free survival, and time to intracranial failure were determined. Univariate and multivariate analysis were performed to determine factors affecting OS. Toxicity of care was evaluated.

**Results:** Median follow-up and overall survival were 15 months (range: 1-98 months) from initial GKRS. Twenty-one percent of patients lived longer than 2 years with 11% living longer than 3 years. Twenty-three patients had mutations in exon 19, 8 in exon 20, 21 in exon 21, and 4 patients were unknown. Twelve patients were symptomatic from intracranial disease at presentation. Twenty-one patients were on targeted therapy at the time of GKRS and nine were on concurrent chemotherapy. The median number of tumors treated at initial GKRS was 3.5 (range: 1-20) and median tumor volume was 0.88 cc (range: 0.03-7.05 cc). The intracranial failure free survival was 7 months (range: 1-50). Thirty-one patients developed distant brain failure, 2 failed locally, and 1 additional patient had local tumor progression and synchronous distant brain failure. Twenty-eight patients underwent salvage GKRS with a median number of GKRS treatments of 1 (range: 1-6). Two patients required salvage surgery and 14 had salvage whole brain radiotherapy. Twenty patients acquired biopsy confirmed T790M resistance mutations. Total tumor volume > 0.75 cc didn’t correlate with overall or failure free survival. Median survival was non-significantly higher in patients who underwent subsequent immunotherapy (24 vs. 16 months). No patients had toxicity from initial GKRS regardless of concurrent chemotherapy or targeted therapy. One patient developed seizures, required corticosteroids and anti-epileptic medication after a second GKRS.

**Conclusions:** With advances in targeted tyrosine kinase inhibitors and molecular testing patients are experiencing longer overall survival. The management of such patients with brain metastases should be based on the potential for longer term survival with an emphasis on maintenance of function.

**Poster Display - Metastases**

**P101 : Treatment of 27 brain metastases with single-isocenter VMAT radiosurgery: A case report**

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**Keywords:** stereotactic radiosurgery, brain metastases, linear accelerator, volumetric modulated arc therapy

**Purpose:** Level 1 evidence now supports stereotactic radiosurgery (SRS) as the sole treatment in patients with
up to four metastases. Prospective data on the use of SRS as an alternative to whole brain radiation therapy (WBRT) in patients with more than four metastases remains forthcoming. However, in order to avoid the deleterious effects of WBRT, it has been used in select patients with many more metastases. Gamma Knife (GK) SRS has been used to treat up to 43 targets in a single patient[i], and linear accelerator (linac) SRS has been used to treat up to 16.[ii] We present here the treatment of 27 individual targets in a single fraction with a single isocenter, to the authors' knowledge, the highest reported number for single-fraction linac based treatment to date.

**Methods:** A 63 year old Caucasian female with Stage IV (ER/PR+, HER2-) breast cancer, status post treatment with six rounds of traditional chemotherapy, CDK4/6 inhibition, and tamoxifen, presented to the emergency department with two-week history of new onset dizziness and falls, with associated headaches, weakness, and fatigue. MRI revealed numerous tiny new foci of enhancement since her previous scan 18 months before. After detailed discussion of the risks and benefits of SRS and WBRT, the patient chose focal therapy. Each lesion was prescribed 18 Gy, and a 4-non-coplanar RapidArc plan was generated in Eclipse for our Edge linear accelerator (Varian Medical Systems) according to our previously described template. The plan was normalized such that at least 99% of total target volume (TV) received the prescription dose. Patient specific quality assurance was performed on the plan using radiochromic film and our standard phantom, confirming excellent agreement between calculated and delivered dose.

**Results:** Total TV was 2.2 cm³. V₃₂Gy to brain was 13.9 cm³. Mean dose to brain was 4.81 Gy. Paddick conformity for the entire plan was 0.73. Maximum doses to brainstem, chiasm, and optics were 7.82, 7.52, and 4.20 Gy, respectively. From patient positioning on table to thermoplastic mask removal, beam on time was approximately 6 minutes, and total treatment time was approximately 20 minutes. The procedure was well-tolerated and without incident.

**Conclusion:** Improvements in linear accelerator technology and treatment planning capability have led to high-quality and highly efficient treatment of many more metastases than previously deliverable.

**Keywords:** CyberKnife, cerebral metastases, lung cancer

**Objectives:** The aim of the study was to assess the efficiency and safety of the CyberKnife stereotactic radiosurgery and radiotherapy, as well as to evaluate prognostic factors in patients with lung cancer brain metastases.

**Methods:** The analysis included 53 patients of median age of 61 (range 43 – 84), treated due to lung cancer brain metastases between 2011 and 2015. The time between the diagnosis of the primary tumor and brain metastases ranged from 0 to 89 months (mean 20 months, median 14 months). In 9 patients brain metastases were found prior to diagnosis of the primary tumor. All patients had high KPS score (mean and median – 80; 22.6% - KPS 100, 64.2% - KPS 80, 13.2% - KPS 70). The number of irradiated lesions in one patient ranged from 1 to 6. Mean total dose was 18.3 Gy, median – 18.0 Gy (range 6 – 26 Gy). 51% of the lesions were treated with single fraction, 49% using fractionated regimens. The planned dose was delivered in 1 – 4 fractions. Medical examination along with radiological evaluation of the treatment effects was performed in 23 patients (43%). The survival probability was calculated with the use of the Kaplan – Meier estimator.

**Results:** The median overall survival (OS) in the whole group was 15.1 months. Patients with a single lesion lived longer (median 24.0 months) than those with multiple brain metastases – median 7.2 months (p = 0.0079). Longer OS was observed in patients with controlled systemic disease (median 19.7 months) as compared to progressive systemic disease – median 5.5 months (p = 0.058). The analysis showed no association between KPS score or the histological type of the primary tumor and OS. Single fraction and fractionated treatment resulted in similar OS. Adding whole brain radiotherapy did not influence the OS. During radiological follow-up, progression of the irradiated lesions was found in 10 patients, 7 to 27 months after the treatment. Median local progression-free survival was 19.8 months.

**Conclusion:** Stereotactic radiosurgery and hypofractionated stereotactic radiotherapy have similar effectiveness in the treatment of lung cancer brain metastases. Patients with single metastasis and controlled systemic disease have the most favourable prognosis.

**Keywords:** CyberKnife, cerebral metastases, lung cancer
Poster Display - Metastases

P103 : SBRT for pelvic bone and lymph node oligometastases: Technique and IGRT results

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Keywords: SBRT oligometastasis lymphnode bone-metastasis

Purpose: Stereotactic body radiation therapy (SBRT) is increasingly applied to oligometastatic disease, like bone and lymph node metastases.. We developed a comprehensive set of treatment guidelines for bone and lymph node locations eligible for SBRT, based on our clinical experience with common SBRT sites (such as lung, spine and liver). To our knowledge, this is the first study on IGRT positioning data of bone- and lymph nodes SBRT treatments in the pelvic region.

Materials and Methods: Positioning data for 32 patients (n=16 bone, n=16 lymphnode) treated with SBRT were reviewed. Radiotherapy schedules ranged from 24 -45 Gy in 3 fractions to 25-50 Gy in 5 fractions. Patients were immobilized with a personal vacuum bag, knee-fix, head rest and arm support. The Gross Tumor Volume (GTV) was expanded with a 5mm and 7mm Planning Target Volume (PTV) margin for bone and lymph node treatments, respectively. Treatments were performed on an Elekta linear accelerator, using a 10MV, coplanar, dual arc, volumetric Modulated Arc Therapy (VMAT) technique. A Cone Beam CT (CBCT) based online imaging protocol was used for set-up, couch correction verification and intra-fraction motion (IFM) assessment. Rigid registrations were performed on the bony anatomy adjacent to the GTV. If the residual translation setup error (i.e. after couch correction) was larger than 2 mm, the correction-verification procedure was repeated and if residual rotation setup errors were larger than 3° the patient was repositioned. The coverage of GTV within PTV was checked visually. To calculate the IFM, the difference between translation and rotation errors of the inline (i.e. during treatment) or post treatment CBCT and the residual setup errors was calculated.

Results: Residual setup and IFM errors (translations and rotations) are summarized in the table 1 for bone and lymph node cases. Mean (M) errors are close to zero. Systematic (S) and random (s) components of these errors remain well below 0.5mm, 1.4° and 1.6mm, 0.7°, respectively. The correction-verification procedure was repeated in 3.8% and 10% of the fractions for bone and lymph node cases.

Conclusion: The residual setup and IFM errors of patients treated with SBRT for oligometastatic disease in the pelvic region (for bone or lymph nodes locations) are very small, demonstrating the reproducibility and robustness of the positioning protocol. Consequently, the contribution of these errors to the GTV-PTV margin is limited and margins may be reduced. Ongoing investigations include clinical data, robust planning techniques and image registration methods.

Poster Display - Physics

P104 : Comparison between two Gamma Knife planning algorithms

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Keywords: TMR 10, TMR classic, Gamma Knife.

Objectives : To compare dose distribution qualities for TMR 10 and TMR classic Gamma plans.

Methods: Leksell Gamma knife radiosurgery equipment was installed at PSMMC in Sep. 2013. The planning system available was TMR classic with which patients were planned and treated till Jan, 2015 for a period of 15 months. Since TMR 10 became available and the system got upgraded for use till to date. A dosimetric comparison was carried out for dose distributions performing single and multiple shots plans, controlling all other variables/factors using both planning algorithms. Diameters of multiple Isodose lines/levels and point doses at fixed coordinates were calculated to find any difference in measurements. Output, decay, time, shot sizes, shot numbers and shot volumes/weightages were kept consistent.

Results: Comparison was made through calculating doses on two algorithms TMR classic and TMR 10 and revealed a difference of mean 0.5 mm constricted isodose lines for TMR classic compared to TMR 10. This difference was consistent with all forms of factors evaluated including single versus multiple shots, rounded versus oblong shaped targets and for all three sizes of collimators. Effects of different grid sizes did not differ in two algorithmic calculations. Point doses calculated at different dose levels (within target, prescription point and at dose gradient), a mean
The overall residual rotational errors was 0.17 degree.

**Conclusion:** This study demonstrates the residual translational and rotational errors of Exactrac X-ray 6D IGRT system is very small.

**Poster Display - Physics**

**P106 : Make a change DCAT system for VMAT system using estimated APEX radiosurgery system and multi shape phantom and QA: A preliminary report**

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**Keywords:** DCAT, VMAT, APEX, Radiosurgery, Mimsoftware, Archeck

**Purpose:** In this study, we make a change Dynamic Conformal Arc Therapy (DCAT) for Volumetric Modulated Arc Therapy (VMAT) system. We estimated Conformity Index (CI) and Homogeneity Index (HI) with accuracy, usefulness using APEX system, Multi shape phantom and QA phantom for the radiosurgery.

**Material and Method:** We used the multi shape phantom and APEX system. We make a changed DCAT for VMAT System. We simulated multi shape (Star, Diamond, Half moon) phantom and Mim software (ver. 5.0) Contouring VOI (Virtual Organ at Interest). MONACO (ver. 5.0) was utilized as a radiation treatment planning system (RTPs). APEX system has the micro multi leaf collimator (mMLC) with leaf thickness of 2.5 mm. INFINITY Tx Machine was used. We performed two different techniques for the comparison.

**Results:** We confirmed difference between the DCAT and VMAT plan. the 3D assessment showed a significant difference between the DCAT and VMAT (Multi shape 98% with 3% / 3 mm criteria, Multi shape pass rate of above 95% with 2% / 2 mm criteria, both CI 0.3 and HI 1.0 results is accept ).

**Conclusions:** DCAT plan can not modulate the intensity of radiation while the gantry is rotating. And mMLC shape and gantry rotating speed is fixed at the each control point. However, we make a VOI and used another MONACO plan skill is changed the VMAT effect results. we can modulate the intensity of radiation through the optimized mMLC shape and gantry rotating speed. Therefore, our results show that the VMAT plan is superior to the DCAT plan. we conclude that APEX system should adapt the VMAT
system for the accurate radiosurgery

Poster Display - Physics

P107 : The modification in penumbra of Gamma Knife model C for functional radiosurgery

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Keywords: Gamma Knife, Functional radiosurgery, Penumbra

For functional radiosurgery using Gamma Knife, the maximum dose of 80Gy~130Gy is delivered to the target. Therefore, besides the area of 50% isodose, the penumbra area of 25% isodose is important because the 20Gy~32.5Gy is delivered to the area. The dose can cause the direct effect of necrosis and the indirect effect that the surrounding tissue will die from the vessel is occluded from radiation. The Gamma Knife model C has the hemispherical 5 ring distribution of 201 cobalt source, the first ring has 35 sources, the second ring has 39 sources, the third ring has 39 sources, the fourth ring has 44 sources and the fifth ring has 44 sources. All sources are focused at SAD (source axis distance) of 40cm. The distribution of the sources makes a nonlinear ellipse of radiation in X, Y and Z direction. The FWHM(full width at half maximum) and 25% of isodose was 4.8mm and 5.8mm in Z direction but in X and Y direction the value was 5.9mm and 8.8mm which meant that the penumbra of X and Y direction was bigger than in Z. To reduce this effect, we made a special distribution of sources by plugging the 5th ring and the 5th and 4th ring. As the treatment time in using all 5 rings is unit of 1, the time of plugging of 5th ring and of plugging 5th and 4th ring was 1.28 and 1.79 respectively. For 13 pts treatment using LOT was a re-irradiation for a recurrence in field. Concomitant systemic therapy was administered in 3 pts. Three tracking methods were used: 0-View tracking method (treats an ITV using Xsight Spine tracking for patient alignment) in 59 pts, 1-View tracking method (tracks targets that are visible in only one X-ray image) in 33 pts, and 2-View tracking method (tracks targets that are visible in two X-ray images) in 28 pts. The median dose/fraction was 15 Gy (range 4-18). In most cases the isodose prescription was at 80%. The median PTV was

Poster Display - Physics


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Aims: LOT (lung optimized treatment) is an evolution in Cyberknife® technology which allows treatment of lung cancer without invasive fiducial implantation procedures. The aim of this analysis was to evaluate the technical feasibility, toxicity profile and clinical outcome.

Methods: Between 1/2014 and 10/2016 115 patients (pts) (M/F 79/36) were treated with Cyberknife® using LOT at European Institute of Oncology (IEO). The median patient age was 72.6 years (range 31.8-90.3). Treated lesions were 120; 50 with histopathological confirmation (44 primitive pulmonary cancer, 8 pulmonary mets), 66 were untyped tumors. 101 pts treated a single lesion, while 5 pts treated multiple target lesions. For 13 pts treatment using LOT was a re-irradiation for a recurrence in field. Concomitant systemic therapy was administered in 3 pts. Three tracking methods were used: 0-View tracking method (treats an ITV using Xsight Spine tracking for patient alignment) in 59 pts, 1-View tracking method (tracks targets that are visible in only one X-ray image) in 33 pts, and 2-View tracking method (tracks targets that are visible in two X-ray images) in 28 pts. Median dose/fraction was 15 Gy (range 4-18). In most cases the isodose prescription was at 80%. The median PTV was
24.3 cm³ (range 2.7-161.1). Toxicity was evaluated by RTOG/EORTC and CTCAE V4.1. Tumor response was evaluated with RECIST V1.1 criteria.

**Results:** Toxicities and follow up data are available for 52 patients. The median follow-up was 5.1 months (range 1-15.4). Acute toxicity (within 6 m.) was observed in 21 of 44 pts with follow-up (47.7%): according to RTOG/EORTC criteria only G1 and G2 toxicity was registered (no G3 or G4); in CTCAE V4.1 two events of G3 toxicity were observed (cough, dyspnea). Late toxicity (after 6 m.) was observed in 10 of 19 pts with follow-up (52.6%): all events were G1 and G2 RTOG/EORTC events. (no G3 or G4); in CTCAE V4.1 one event of G3 toxicity was registered. According to RECIST V1.1 guideline complete response, partial response, stable disease and progressive disease was observed in 23.9%, 26%, 43.5% and 4.3% respectively.

**Conclusions:** This first analysis demonstrated high feasibility and minimal toxicity of LOT in lung cancers. Promising response rates have been registered. Further studies are necessary in order to confirm our results.

**Poster Display - Physics**

**P109 : The design of a new evaluation method for radiation treatment plan of stereotactic body radiation therapy**

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**Keywords:** risk index method, plan QA, patient specific QA

**Introduction:** The aim of this study is to develop a new evaluation method that quantifies a degree of risk at each organ at stereotactic body radiation therapy (SBRT) plan. A risk index method was designed to evaluate the possibility of under-dose to the treatment target or over-dose to the organs at risk (OAR) at the plan.

**Materials and Methods:** A risk index value was designed to quantify the possibility of the under-dose or over-dose at the target and the organs from the small setup errors. The risk index values at all voxels in the treatment target and organs at risk were calculated and the voxels were categorized to three status of “Pass”, “Fail” or “Pass with Risk”. Passing rates were calculated with the risk index values at 3D volumes of the treatment targets and the organs at risk to show the degree of dosimetric safety from the under-dose or over-dose. Various 3D dose distributions were acquired from a spine SBRT plan and a lung SBRT plan by simulating setup errors of 1 mm, 2mm and 3 mm, and the degree of the risk from setup errors were evaluated to show the feasibility of the suggested method.

**Results:** The risk index values at 3D volumes could show increased risk at the target or organs at risk quantitatively. For the lung SBRT plan, the passing rate of the treatment target was decreased from 93.47% to 85.14% as the setup errors were increased. The passing rate of some organs at risk showed slightly increased or decreased tendencies according to the position of the organs. The plan of spine SBRT showed similar results. The passing rate of the treatment target, spinal cord and esophagus were decreased, but left lung, right lung, and heart showed almost same passing rate as the setup errors were increased.

**Conclusion:** The developed method could give 3D information about where the possibility of under-doses in the treatment target and the possibility of over-doses to the organs at risk exist. The risk index method is expected to give great potential to planning strategy which can give safer and more deliverable treatment plan under setup errors.

**Poster Display - Physics**

**P110 : Characterization of the Cyberknife imaging system**

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**Keywords:** Cyberknife, imaging system, quality controls

**Objectives:** The aim of this work was to characterize the imaging system of a CyberKnife VSI® which consists of two X-ray tubes mounted to the ceiling, coupled with two in-floor Flat Panel Detectors (FPDs). The central axes of the X-ray beams intersect the centre of the FPDs with a 45-degree angle.

The quality controls of X-ray tubes were the ones recommended by Report AAPM TG 135, while the performance of the detectors was evaluated applying the Report No.6 of the Italian Association of Medical Physics (AIFM).
**Methods:** The X-ray beam of each tube was characterized using a multimeter with clinical parameter setting. All the images were acquired with the standard radiation quality RQA5 at different exposure levels. It was estimated the response function, the local and global non-uniformity of the signal, the local and global non-uniformity of the signal-to-noise-ratio, the presence of uncorrected bad pixels.

Images were converted into dose in order to analyze the noise components (electronic, quantum and structural) and to obtain the Noise Power Spectrum (NPS). The spatial resolution was evaluated by the Modulation Transfer Function (MTF) using both an edge test and a grid pattern phantom. Detective Quantum Efficiency (DQE) was calculated from MTF and normalized NPS. Furthermore, the geometric distortion was investigated and the Contrast to Noise Ratio (CNR) and contrast-detail curves were obtained through specific phantoms.

**Results:** The X-ray tubes measurements showed values well within the limits indicated in the Report AAPM TG 135. The analysis of the images exhibited a linear response function (R²> 0.99) with a negative slope and all the uniformity indexes were far below the reference limits set in the Report AIFM No.6.

Each component in noise analysis had the typical trend expected for FPDs: the quantum noise was the predominant one and it decreased increasing the dose. This result was also confirmed by the NPS curves. MTF values obtained from both methods confirmed the specifications provided by the manufacturer, but the grid pattern was chosen as the best candidate because of practical reasons. The CNR values increased with the incident exposure and the contrast detail curves trend was the expected one. No geometric distortion was detected.

**Conclusion:** The performance of a Cyberknife imaging system was analyzed and characterized in detail; in this way some reference values were here suggested. This study is a good starting point for the implementation of a quality control protocol.

**Keywords:** Quality Assurance, Cone Plan, Stereotactic Radiosurgery

**Introduction:** SRS is a complexed procedure requires accurate target definition, correct radiation beam simulation, exact target localization and precise dose delivery. In LINAC based SRS, on board imaging system such as CBCT and KV-pair was used for target localization. And the dose delivery accuracy was determined by accuracy of the localization and the isocenter discrepancy between radiation isocenter and geometric isocenter. In this study, a Lucy 3D QA Phantom was applied to estimate the geometrical variation of a practice with a LINAC-based SRS system.

**Methods and Materials:** Quality Assurance (QA) procedures of five SRS cone cases were selected for this study. The cone range in diameter were from 10mm, 12mm, 16mm, 18mm and 24mm. In each QA procedure, two GAFCHROMIC films were attached to both sides of the dosimetry inset for the chamber in the Lucy Phantom, and the thickness of the inset was 1cm. After alignment, a single 360 degree ARC plan was delivered to the phantom, so both of the film were irradiated with a chamber reading. Then the films were scanned with a Vidar DosimetryPro scanner, which was controlled by the RIT Software by Radiological Imaging Technology. Due to the isocenter variation for setup, the two film images showed difference in optical density, which reflected the dose difference due to different distances from the radiation isocenter. The images were analyzed by RIT Classic version 6.4. The ratio of distances from the two films to the radiation isocenter were computed with linear relationship assumption based on the maximum raw pixel values from each film image. And the distances from the film to the radiation isocenter were also calculated.

**Result:** In the selected cases, the average ratio of maximum raw pixel values from these two film was 1.11 with standard deviation at 0.14, and the computed average distance differences from the two films to the radiation isocenter was 0.48mm with standard deviation at 0.60mm. The chamber reading were satisfied the dosimetry requirement after this geometrical correction were applied.

**Conclusion:** A 3-dimension geometrical accuracy evaluation was reached by adding two 2-dimension-planes within a Lucy Phantom during a dosimetry accuracy estimation of quality assurance procedure. This simple philosophy could be applied to other quality control and quality assurance for image registration between different modalities and spatial distance between image slices during the SRS procedure.

**Poster Display - Physics**

**P111 : Lucy phantom estimation of geometric variation for LINAC-based brain stereotactic radiosurgery**

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**Poster Display - Physics**

**P112 : Implementation of a quality control protocol for imaging system of a cyberknife**

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**Keywords:** Cyberknife, quality control; imaging system

**Objectives:** The aim of this work was the definition of a quality control (QC) protocol for the imaging system of a Cyberknife VSI® (G4 configuration) to detect changes from its original level of performance. A deviation from the proper baseline may result in a clinically significant degradation in image quality, that contributes to a loss of target accuracy and/or a significant increase in radiation exposure.

AAPM Report TG 135 “Quality assurance for robotic radiosurgery” suggests only basic indications about quality controls for imaging system. Moreover, there are only few papers about this topic available in the existing literature.

**Methods:** The quality checks suggested in AAPM TG 135 were performed and the whole imaging system (X-ray tubes and Flat Panel Detectors FPDs) was characterized in order to set some reference values. Further measurements on FPDs were executed applying Report No.6 of Italian Association of Medical Physics as guideline.

For X-ray tube measurements a multimeter was used. Different radiological specific phantoms, adopted for image quality assessment, were employed and both original X-ray images and virtual projections were analyzed. Finding a suitable and reproducible setup for measurements was not easy: a home-made device was realized in order to position phantoms and multimeter at a fixed distance, perpendicular to the X-ray beam.

Thanks to that, it was possible to select the QCs to be performed, their frequency, tolerances and limit values. A rigorous protocol was drafted, implemented and tested in practice.

**Result:** Here the image QCs for FPDs included in the protocol are reported. The frequency of all the QCs is annual except for the last which is performed monthly

- Aspect ratio $\pm 3\%$
- Conversion function $R^2 > 0.99$
- Noise analysis Reference value
- Local & Global Non Uniformity of Signal NULS $<4\%$ NUGS $<8\%$
- Local & Global Non Uniformity of Signal-to-Noise-Ratio NULSNR $<8\%$ NUGSNR $<20\%$
- Artifact analysis No artifacts
- Spatial resolution Deviation from reference value $\pm 10\%$
- Low contrast sensitivity Deviation from reference value $\pm 20\%$
- Contrast detail curves Reference values
- Lag effect $< 0.5\%$
- Low & high contrast sensitivity and Spatial resolution Reference values: number of visible contrast details and lp/mm

**Conclusion:** In this work a QC protocol for the imaging system of Cyberknife VSI® was implemented. It will be interesting to verify if the selected checks and frequencies have a sufficient degree of sensitivity to pre-emptively detect small deviations from the baseline. Furthermore it will be mandatory to identify levels of action to prevent serious patient damages.

**Poster Display - Physics**

**P113 : Planning strategy for dose spillage control for liver stereotactic body radiotherapy**

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**Keywords:** Dosimetry Planning, Dose Spillage, Liver, Stereotactic Body Radiotherapy
Purpose: In this study, the dose spillage level was explored by adjusting surrounding tissue limitation function to reach the optimal conformity of the target in liver Stereotactic Body Radiotherapy (SBRT) with RapidARC treatment technique.

Materials and methods: A liver SBRT case was selected for this study. The PTV was 72.48cc, and liver volume was 1113cc. A subsidiary structure (shell) was utilized to avoid dose spillage during the optimization procedure. Three dose shells were added around the PTV from central to peripheral. The optimization setting radius of using one shell was 3mm, 5mm, 8mm, 10mm, and 15mm; two shells was 3mm and 3mm; 5mm and 5mm; 8mm and 8mm; 10mm and 10mm; and 15mm and 20mm. When 3 shells were used, the radius of the shells were combination of the 3mm, 3mm and 3mm; 5mm, 5mm and 5mm; 8mm, 8mm, and 8mm; 10mm, 12mm, and 15mm; and 15mm, 20mm, and 20mm. The plan optimization strategy was to add different priorities to the shells, and then to evaluate the dose spillage level, liver function index, and related dosimetry performance. Optimization was that 98% of the prescription dose would fall within the first (inner) shell, 50% of the prescription dose would fall within the second shell, and 40% of the dose would fall within the third shell when 3 shells were used. Dosimetry performance was described by the conformity index, which was defined as PIV/TV, where TV is target volume, and PIV is prescription isodose volume. The spillage index was defined by concerned dose level, which is defined to be 12Gy volume divided by target volume in this study. And the liver function index was defined to be liver volume subtracted volume of 15Gy and then divided by liver volume.

Result: When one shell was applied, the optimized plan resulted in conformity index = 0.97, minimum spillage index = 14.9, and corresponding functional index = 2.65; when two shells were applied, [setting at 8mm and 8mm] yielded minimum spillage index = 13.53 with conformity index = 1.01 and function index = 2.41; When three shells structure were applied, [setting at 8mm, 8mm, and 8mm] resulted in minimum spillage index = 13.62, conformity index = 1.02 and function index = 2.41.

Conclusion: Shell dose volume limit setting at 8mm was the best planning strategy for this SBRT RapidARC plan. A similar strategy could apply to different treatment sites.

Purpose: The developments of highly conformal and precise radiation therapy techniques promote the necessity of more accurate treatment target localization and tracking. It is unclear which system provides the best accuracy for tracking. The aim of this study is to evaluate the role of lung optimization treatment (LOT) simulation for Cyberknife stereotactic lung radiotherapy.

Material and Methods: From September 2014 to December 2016, 315 consecutive patients with lung metastases and lung primary cancer, referred to our department for Cyberknife stereotactic radiotherapy, were set out for lung optimization treatment simulation. For all patients a CT scan was performed in expiratory and inspiratory phase and registered to the planning CT. During the simulation Two x-ray tubes arranged orthogonally to each other locate the lung lesion and align it to the digitally reconstructed radiographs derived from CT scan obtained earlier in the same day. The Simulation process allow the clinician to determine the visibility of the target in three different tracking methods. If the target is visible in two projections, the Xsight® Lung Tracking System is used for treatment, if it is visible in only one projection, the 1-View Tracking algorithm is used. No visible target in either projection. Xsight spine tracking or better fiducial marker are requested.

Results: According to the accuracy of the LOT system we observed these results: for 165 patients (52%) the Xsight® Lung Tracking System was used for Cyberknife lung SBRT treatment, for 99 patients (31%) 1 view modality. In all others 51 patients (17%) fiducial markers have been necessary for tracking modality. Target margins were individualized according to tumor respiratory motion as follow: the GTVs were expanded by 3 mm in all directions to create the CTVs. We used different margins for PTVs. In the 2-view modality the CTV on expiratory
CT was expanded by 2mm in all directions, while for 1 view modality two different CTVs were generated on both CT scan to include the entire inhale-to-exhale tumor motion, and added together to create an ITV expanded by 2 mm in the direction followed by the XRay camera and 3mm providing the most flexible treatment options.

**Conclusion:** LOT simulation system and Xsight lung are considered the best choice in the management of lung lesions in our clinical practice with the advantage to dramatically reduce PTV margins and consequently the risk of potential toxicities related to the high level of doses delivered during SBRT practice.

**Poster Display - Physics**

**P115 : Epid-based in vivo dosimetry for comprehensive treatment verification of volumetric modulated arc stereotactic body radiotherapy (SBRT-VMAT)**

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**Keywords:** in vivo dosimetry, SBRT, VMAT, Quality assurance

**Introduction:** In vivo dosimetry (IVD) represents the last step of quality assurance process in radiotherapy clinic. This strategy has shown unique features to trace deviations between planned and actually delivered dose distributions. Extracranial stereotactic radiotherapy (SBRT) involves the delivery of high doses in a few fractions (1-5) for ablative purposes. SBRT treatments may strongly benefit from IVD as any uncertainties in dose delivery are more detrimental for treatment goals. We assessed the feasibility of EPID-based IVD for complex clinical VMAT treatments for SBRT.

**Methods and materials:** 15 patients with lung, liver, bone and lymphnodal metastases treated with Elekta VMAT were enrolled. All plans were generated with a single 360° arc. All targets were irradiated in 5 consecutive fractions, with total doses ranging from 40 to 50 Gy depending on anatomical sites. All patients passed pre-treatment 3%/3mm γ-analysis verification. IVD was performed using SOFTDISO (Best Medical Italy), a dedicated software implemented in our clinic for conformal, IMRT and VMAT techniques. IVD tests were evaluated by means of (i) R ratio between isocenter daily in-vivo dose and planned dose and (ii) γ-analysis between EPID integral portal images in terms of percentage of points with γ-value smaller than one (γ%) and mean γ-values (γmean), using a global 3%-3 mm criteria. Alert criteria of ±5% for R ratio, γ% <90% and γ mean > 0.67 were chosen.

**Results:** A total of 75 transit EPID images were acquired. The overall mean R ratio was equal to 0.999 ± 0.021 (1 SD) for all patients, with more than 98% of tests within 5% alert criteria. The portal images γ-analysis shows an overall γ mean of 0.29±0.13 with 100% of tests within alert criteria, and a mean γ equal to 96.9±5.2% with 96.0% of tests within alert criteria. In contrast to our past experience of patients with head-neck and pelvic treatments, where the systematic use of IVD revealed some discrepancies due to major anatomical variations or random anatomical changes, no relevant discrepancies were detected in SBRT patients. The results are supplied in quasi real-time, with IVD tests performed and displayed after only 1 minute from the end of arc delivery.

**Conclusions:** The present EPID-based IVD algorithm provided a fast and accurate procedure for SBRT-VMAT delivery verification in clinical routine. This strategy allows physics and medical staff to promptly act in case of major deviations of dose delivery.

**Poster Display - Physics**

**P116 : Development and clinical application of applicators for flattened beam IORT with increased degree of freedom of direction**

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Keywords: intraoperative radiotherapy, INTRABEAM system, applicator, dosimetric characteristic

The intraoperative radiotherapy (IORT) is a treatment technique to deliver radiation during surgery. The comfort of patient can be increased compared to fractionated external radiation therapy. The radiation generator of INTRABEAM system (Carl Zeiss Meditec AG, Germany) generates x-ray in an isotropic direction. We designed and developed a dedicated applicator to apply the INTRABEAM system to the thoracic and abdominal region where there are many critical organs. The applicators were customized for the irradiation direction as 0 and 45 degrees and depending on flattening or non-flattening by 3D printer. Dosimetric characteristics were evaluated, such as profiles, flatness, and leakage as well. The applicator was also designed to shield any other sides except the desired direction. Without applicator, the flatness tended to be 1.28 on the surface, while 1.47 on the 5 mm depth. However, the resultant flatness of applicator developed in this study was uniformly maintained from 1.22 to 1.30 up to the depth of 15 mm. It was also found that the leakage dose on the side except the beam direction was negligible. We applied the applicator to four patients with rectal, breast, and pancreas cancer treated with IORT from January to December 2015. The validity of the applicator had been assured to be effectively applied to the thoracic and abdominal region.

Poster Display - Physics

P117 : The correction factors estimated for small field’s dosimetry by using 6 and 18MV energies of a linear accelerator

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Keywords: Small field dosimetry, Correction factors (KNR, KNCSF), Diode dosimeters, inhomogeneous phantom

Background and purpose: Small field sizes are increasingly used in new radiotherapy (such as SRS/SBRT) to deliver higher dose gradient to patients. Estimating dosimetric parameters for such fields in non-reference conditions based on the conventional protocols used at large fields, as used in the reference condition, lead to significant errors. This study was to determine and compare small fields correction factors (KNR and KNCSF) measured with different types of active detectors.

Materials and Methods: Small field sizes were defined by circular cones down to 30 and 5mm diameters. Then, the KNR and KNCSF correction factors proposed recently for small field dosimetry formalism (TG155) were determined for different active detectors in a homogeneous as well as a non-homogeneous phantom. The non-homogeneous phantom was designed and made by using Perspex as the soft tissue and appropriate lung and bone tissue equivalent materials. Dosimetric measurements were made by using high resolution diodes, and ionizing chambers. The 6 and 18MV beams were produced by a 2100C/D Varian linear accelerator system with the circular collimators fixed at its head. Variation of the central axis dose in the 5 and 30 mm small fields, in the inhomogeneous phantom constructed of different inhomogeneous layers (composed of Cork and PTFE) for the 6 and 18MV energies was also investigated.

Results: The KNR correction factors for the circle field of 30mm estimated for the Pinpoint ionizing chambers, EDP-20 and EDP-10 diodes were 0.993, 1.020 and 1.054 at 6 MV; and 0.992, 1.054 and 1.005 at 18 MV respectively. The KNCSF correction factor for the circle field of 5mm estimated for the Pinpoint ionizing chambers, EDP-20 and EDP-10 diodes were 0.994, 1.023 and 1.040 at 6 MV; and 1.000, 1.014 and 1.022 at 18 MV respectively. The maximum variation in the percentage depth dose in the non-homogeneous phantom relative to the homogeneous phantom in the 5 and 30 mm field sizes due to the presence of 30mm Cork heterogeneity were 23.5 % and the 62.1%, respectively, while the PTFE heterogeneity caused a maximum variation of 8.17%, 7.15% for the 5 and 30 mm field size respectively.

Conclusion: Implementing the correction factors based on the new dosimetry protocol proposed for the small fields increases the dosimetric precision and accuracy of small field’s radiotherapy procedures of such small fields. In addition, the dosimetric measurements with the diodes and ionizing chamber indicated that the perturbations of doses at the central axis in the small fields increases due to the presence of heterogeneities within the non-homogeneous region and thereafter.

Poster Display - Physics

P118 : Multimodal treatment of cystic-nodular lesions for radionecrosis following cerebral AVM radiosurgery

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Keywords: intraoperative radiotherapy, INTRABEAM system, applicator, dosimetric characteristic

The intraoperative radiotherapy (IORT) is a treatment technique to deliver radiation during surgery. The comfort of patient can be increased compared to fractionated external radiation therapy. The radiation generator of INTRABEAM system (Carl Zeiss Meditec AG, Germany) generates x-ray in an isotropic direction. We designed and developed a dedicated applicator to apply the INTRABEAM system to the thoracic and abdominal region where there are many critical organs. The applicators were customized for the irradiation direction as 0 and 45 degrees and depending on flattening or non-flattening by 3D printer. Dosimetric characteristics were evaluated, such as profiles, flatness, and leakage as well. The applicator was also designed to shield any other sides except the desired direction. Without applicator, the flatness tended to be 1.28 on the surface, while 1.47 on the 5 mm depth. However, the resultant flatness of applicator developed in this study was uniformly maintained from 1.22 to 1.30 up to the depth of 15 mm. It was also found that the leakage dose on the side except the beam direction was negligible. We applied the applicator to four patients with rectal, breast, and pancreas cancer treated with IORT from January to December 2015. The validity of the applicator had been assured to be effectively applied to the thoracic and abdominal region.

Poster Display - Physics

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Background and purpose: Small field sizes are increasingly used in new radiotherapy (such as SRS/SBRT) to deliver higher dose gradient to patients. Estimating dosimetric parameters for such fields in non-reference conditions based on the conventional protocols used at large fields, as used in the reference condition, lead to significant errors. This study was to determine and compare small fields correction factors (KNR and KNCSF) measured with different types of active detectors.

Materials and Methods: Small field sizes were defined by circular cones down to 30 and 5mm diameters. Then, the KNR and KNCSF correction factors proposed recently for small field dosimetry formalism (TG155) were determined for different active detectors in a homogeneous as well as a non-homogeneous phantom. The non-homogeneous phantom was designed and made by using Perspex as the soft tissue and appropriate lung and bone tissue equivalent materials. Dosimetric measurements were made by using high resolution diodes, and ionizing chambers. The 6 and 18MV beams were produced by a 2100C/D Varian linear accelerator system with the circular collimators fixed at its head. Variation of the central axis dose in the 5 and 30 mm small fields, in the inhomogeneous phantom constructed of different inhomogeneous layers (composed of Cork and PTFE) for the 6 and 18MV energies was also investigated.

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Poster Display - Physics

P118 : Multimodal treatment of cystic-nodular lesions for radionecrosis following cerebral AVM radiosurgery

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Keywords: radionecrosis, neurosurgery, complication, epilepsy

The aim of this presentation is to report a case of radionecrosis of aggressive evolution.

We present a female, 13-years-old patient, with incidental diagnosis of right parieto-occipital AVM (Spetzler 2), treated by endovascular embolization and later radiosurgery (LINAC, dose 16 Gy, volume 12 cm³) in the first year since the diagnosis. Two years after radiosurgery she presented epilepsy with partial visual crises; the EEG demonstrated right parieto-temporo-occipital seizures. Neuroimages studies demonstrated sequela expansive lesion with a necrotic-cystic component and another nodular one, with mass effect, post-gadolinium enhancement and surrounding edema. It was interpreted as symptomatic radionecrosis, pharmacological antiepileptic treatment and high doses of steroids were indicated. One year later she persisted with seizures and growing necrotic-cystic that required stereotactic evacuation and CSF derivation placement. Despite of short transitory improvement, she added left hemianopsy, brachial palsy and contralateral neglect. The neuroimages demonstrated progression of the nodular lesion with increase of the mass effect, for this reason the post-actinic injury was resected.

In spite of marked improvement in the neuroimages and resolution of the brachial weakness, she persisted with daily partial seizures (average 3 per day) evolving in lost of consciousness sometimes. Actually epilepsy surgery is considered.

We conclude that the radiosurgery is a valid tool for the treatment of cerebral AVM, controlling the primary disease. Nevertheless, the radionecrosis can appear as one of the most serious associated complications, generating persistent neurological alterations in spite of an intensive clinical-surgical managing, demonstrated in this case as well as in previous reports. In view of eventual neurosurgical complications, the indication, planning and execution of cerebral radiosurgery must be realized with participation of a neurosurgeon.

Keywords: Icon, Gamma Knife, radiosurgery, CBCT, cone beam CT, image quality

Purpose: With the development of a cone-beam CT (CBCT) image guided Icon system, ablative doses of SRS can be delivered using a frameless technique. However, as is typical with CBCT systems using filtered back-projection (FBP), the standard Icon images suffer from blurriness, CT# inaccuracy, and low soft-tissue contrast detectability. In this study, an image reconstruction framework is proposed utilizing a novel high-resolution iterative reconstruction algorithm together with pre- and post-processing steps to overcome some of the image quality issues inherent in the Icon CBCT system.

Materials and Methods: The pre-processing step includes a shading and beam-hardening artifact correction applied on the X-ray projections. The projections are then reconstructed using a novel iterative algorithm that improves spatial resolution by explicitly accounting for image un-sharpness caused by different factors in the reconstruction formulation. The images are post-processed to correct the dome/capping artifact caused by the spatial variations in X-ray energy generated by the bowtie-filter. The proposed shading correction algorithm relies solely on the acquired projection images (i.e. no prior information required). It utilizes FBP reconstructed images to generate a segmented bone and soft-tissue map. Ideal projections are estimated from the segmented images and a smoothed version of the soft-tissue map. Ideal projections are then reconstructed using a novel iterative algorithm applied on the X-ray projections. The projections are processed to correct the dome/capping artifact caused by different factors in image homogeneity and to improve the soft-tissue visibility. The proposed framework was tested on CatPhan phantom, as well as patient images acquired on the Icon CBCT system.

Results: The CatPhan results show that the linearity of the reconstructed attenuation-map was improved from 0.8 to 0.95, resulting in more accurate CT#. The CT# mean absolute measurement error was reduced from 76.1 to 26.9HU. The contrast to noise ratio of the acrylic insert in the sensitometry module was improved from 1.75 to 7.76. The line-pair resolution was improved from 12 line-pair/cm in FBP to 14 line-pair/cm. Moreover, the resulting clinical brain images show substantial improvements in soft tissue contrast.
visibility, revealing structures such as ventricles and lesions which were otherwise un-detectable in FBP-reconstructed images.

Conclusion: The proposed reconstruction framework improved the CT# measurement accuracy and the soft-tissue contrast/visibility. Improved visibility of the brain structures can improve the evaluation of MR to CBCT co-registration. Moreover, the improved CT# values can make the application of the CBCT for daily dose delivery measurements more reliable.

Poster Display - Physics

P120 : Dose calculation results of planned target volume by Monte Carlo method in skull base tumors in comparison with pencil beam method

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Objectives: We investigated the Monte Carlo (MC) method of dose calculation for the planned target volume (PTV) in intensity-modulated radiotherapy (IMRT) for brain tumors in comparison with Pencil Beam (PB) method.

Methods: Twelve cases of skull base tumors (volume, 8.3 to 51.0 ml), including acoustic tumors, meningiomas, and metastatic tumors (4 cases each), were selected for dosimetric comparison. They were treated by Novalis IMRT during a period from January, 2013 through April, 2016. A total dose of 37 to 50 Gy was delivered in 10 to 20 fractions. Radiotherapy planning was made using iPlan version 4.1.4 (BrainLAB, Tokyo) with coplanar multi-beam IMRT. We investigated the dose for the PTV (mean dose, D98%, D95% D5% and D2% of PTV) calculated by MC, in comparison with that by original PB method.

Results: The differences in the mean values of the mean dose, D98%, D95%, D5% and D2% of PTV between PB and MC were minimal (mean dose, 2.96±0.506 Gy and 2.93±0.620 Gy; D95%, 2.84±0.602 Gy and 2.83±0.601 Gy; D5%, 0.148±0.035 Gy and 0.146±0.033 Gy; D2%, 0.058±0.010 Gy and 0.059±0.010 Gy). In the two cases, D5% of PTV was smaller by about 7.5% and 10% in MC compared with that in PB, while the difference was minimal in the remaining 10 cases. On the one hand, D2% of PTV was higher by 16% in 1 case, but when compared in absolute dose between two methods, the difference was only 0.01Gy.

Conclusions: In this study, we did not find remarkable differences in the PTV doses calculated by the two different methods, PB and MC, in IMRT planning for skull base tumors.

Poster Display - Physics

P121 : Evaluation of optic-guided real time isocenter positioning accuracy in spinal radiosurgery

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Keywords: isocenter positioning accuracy, spinal radiosurgery

Objectives: Stereotactic Radiosurgery requires precise target localization and positioning accuracy. We evaluate the real time isocenter positioning accuracy of the target using optic-guided patient positioning system during spinal radiosurgery. The system, ExacTrac(BrainLab, Germany), was based on real time detects multiple passive body markers attached on the selected patient skin landmarks.

Materials & Methods: We investigate the selected 8 metastatic tumor cases commonly closed to thoracic spinal code. All patients were stabilized with head & neck mask, vacuum cushion and treated with supine position. To evaluate the target point positioning accuracy in spinal radiosurgery, real time patient’s position monitoring was performed by comparing the current 3-dimensional positions of body markers in the treatment room with those of an initial reference positions in the CT scan images. For selected patient cases, we have checked isocenter translations per every 20 millisecond for 50 seconds during radiosurgery.

Results: The overall results of real time isocenter positioning translations were -0.24±0.17mm, -0.3±0.12mm, -0.24±0.15mm in x-, y- and z-directions and average
body rotation about the x-, y- and z-axis were 0.17±0.09, -0.26±0.07, 0.04±0.06 degrees, respectively.

Conclusion: The optic-guided isocenter positioning accuracy was acceptable in spinal radiosurgery procedure, even if we consider the systematic errors. Real time position monitoring system provides more reliable precision in clinical application.

Poster Display - Physics

P122 : Dosimetric evaluation of VMAT (volume modulated arc radiotherapy) for multiple brain metastases in comparison with multi-isocenter dynamic conformal arc and ABMP (automatic brain metastasis planning)

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Keywords: brain metastasis, multiple, VMAT, stereotactic radiosurgery

Objective: Simulation plan of VMAT (volume modulated arc radiotherapy) was made for multiple brain metastases on Eclipse (Varian, Tokyo). It was compared with original multi-isocenter dynamic conformal arc (MI-DCA) plan on iPlan (BrainLAB, Tokyo) (iPlan-MI-DCA) and simulation single-isocenter DCA plan by Automatic Brain Metastasis Planning (ABMP, BrainLAB, Tokyo) (ABMP-SI-DCA).

Material & Method: Dosimetric comparison was made among 3 plans on 2 cases of 9 small brain metastases (totally 18 tumors). The mean volume of GTV (gross tumor volume) was 0.06 ml and the mean volume of PTV (planning target volume with 2 mm margin) was 0.40 ml. D95 [dose covers 95% volume of PTV] was set with 95% dose of 22 Gy (100%). Non-coplanar 3 arcs, couch angle of 90 degree (from vertex), 330 (from right), and 30 (from left) with 179 degree range, were employed in VMAT. Besides Normal Tissue Objective function of Eclipse, virtual OARs (organs at risk) in rings surrounding each PTV were made during optimization for better dose concentration to each target.

Result: Conformity for each PTV was good in all 3 plans. The means of gradient index, $V_{1/2}$ of prescription dose / $V_{1/2}$ of prescription dose, were 7.3, 5.4, and 4.6 in VMAT, iPlan-MI-DCA, and ABMP-SI-DCA respectively, showing tendency of wider low-dose spread around PTVs in VMAT The means of maximum dose in PTV were 31.4 Gy, 22.8 Gy, and 24.5Gy respectively, showing tendency of higher dose delivery inside PTVs.

Conclusion: VMAT is expected to treat multiple brain metastases with a short treatment time. More detailed evaluation in various situations, such as different numbers and sizes of tumors, and different arc geometries in planning, is necessary to clarify the efficacy of VMAT.

Poster Display - Physics

P123 : A patient-specific audit test for stereotactic radiosurgery treatment modalities

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Keywords: 3D dosimetry, polymer gel, stereotactic radiosurgery, audit test, Gamma Knife, CyberKnife

Study’s objectives: The scope of this study is to investigate the effectiveness of a 3D relative dosimetry end-to-end test for auditing purposes to Stereotactic Radiosurgery (SRS) modalities.

Methods: Anonymized CT DICOM data of a real patient were used to construct two identical hollow head phantoms of a radiologically bone equivalent material using a 3D printer. Both phantoms were filled with water equivalent polymer gel 3D dosimeters. Irradiations were performed as end-to-end audit tests for the Gamma Knife Perfexion (GK PFX) and CyberKnife G4 (CK) SRS treatment modalities and were implemented in collaboration with the Greek Atomic Energy Commission. Corresponding irradiation plans consisted of 4 and 7 small brain targets, simulating hypothetical multiple metastases cases. Gel dose read-outs gels were performed by departments'
MRI units using specially developed multi-echo pulse sequences, lasting a reasonable scan time of the order of 20 minutes. Measured relative 3D dose maps for both phantoms (derived by corresponding R2 relaxation rates) were compared against calculated ones (exported from the Treatment Planning Systems) in terms of Dose Volume Histograms (DVHs), 1D dose profiles, 2D isodoses maps and 3D gamma indices using passing criteria of 5% dose difference and 2 mm distance to agreement.

Results: Excellent spatial agreement (well within 1 mm) was observed for all the irradiated targets in both modalities with maximum disagreement of approximately 0.8 mm observed for a small peripheral target located away from the MR scanner’s isocenter and irradiated with the GK PFX unit, due to the MR-related geometric distortions and specifically Bo inhomogeneity which affect polymer gel/ MRI measurements. In addition, dosimetric comparison between measured and calculated datasets showed a slightly increased gel over-response in low dose areas (<2 Gy) of the CK modality due to the limited low-dose resolution of the polymer gel. However, the mean 3D gamma index passing rate for all targets and modalities was 93%. DVH comparison resulted in an acceptable agreement within all targets (except for the aforementioned small target with the 0.8 mm spatial disagreement, as expected) and organs-at-risk for both phantoms/irradiations.

Conclusion: An end-to-end patient-specific audit test was implemented by a national external auditor to validate 3D spatial and dosimetric accuracy of SRS treatment techniques and specifically for demanding multiple brain metastases cases. The introduced methodology was found efficient for the purpose of external auditing in terms of workflow and accuracy despite the fact that gel showed an over-response in low dose areas.

Poster Display - Physics

P124: Recommendations for the Gamma Knife® Icon™ high definition motion management threshold based on a multi-center study of nose marker versus target movement: An on-going study

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Introduction: Uncertainty in geometric accuracy of mask-immobilized treatments on the Gamma Knife® Icon™ is primarily caused by intra-fraction movement of the patient. Patient position is monitored using the High Definition Motion Management (HDMM) system via an infra-red reflective marker on the nose. This research uses clinical data from multiple Gamma Knife centers to address the unknown relationship between nose movement and intracranial target movement, building upon the established method from a preliminary phantom study[1]. This will allow Gamma Knife centers to make an informed choice when choosing a threshold level, above which, treatment is paused.

Methods: Log files of patient treatments are interrogated using an in-house MATLAB® script. Information regarding stereotactic coordinates of the nose marker, center of matrix and shot positions, plus the transformation matrix for each CBCT made prior and during treatment is extracted.

Prior to treatment delivery, or if patient movement exceeds the pre-defined threshold, a CBCT is required to correct for positional changes. The vector shift of stereotactic coordinates of the nose marker, center of the matrix and shot positions are calculated for each CBCT using the transformation matrix.

For all patients the ratio between the vector shift of the nose marker and the center of matrix is displayed in stereotactic space in order to determine any spatial variation in the ratio. This is repeated for patients with target volumes larger than 20 cc in order to determine any spatial variation in the ratio within the individual target, taking shot positions instead of center of matrix.

Results: Whilst a preliminary phantom study[1] suggests that intracranial targets generally move less than the nose, in certain scenarios target movement could be larger. The stereotactic reference space showing the ratios for all patients is presented, along with variations of the ratio within large targets.

Keywords: gamma knife icon, mask treatment, high definition motion management, target movement, nose marker, threshold level, multi-center study

Poster Display - Physics

P125: Intrafraction patient movement during frameless intracranial stereotactic radiotherapy recorded by a surface imaging system

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Keywords: SRS, OSMS, Align RT, surface imaging systems, intrafraction motion, frameless, FFF, stereotactic radiotherapy

Objectives: To assess patient movement during frameless volumetric arc therapy (VMAT) of intracranial stereotactic radiotherapy using an Optical Surface Monitoring System (OSMS).

Methods: OSMS uses three cameras to track a region of interest on patients to determine translational (lateral (LAT), longitudinal (LNG), vertical (VRT)) and rotational (Rotation, Pitch, Roll) deviations, called Real Time Deltas (RTDs), from a reference position. After kV image-guided patient setup, an OSMS reference surface was captured and used to track patient movement throughout treatment. RTDs were recorded at discrete time points during treatment including before and after each beam, mid-beam when an OSMS camera is blocked by the gantry, and at end of treatment after the patient was returned to the initial reference position.

Results: We observed 106 fractions of 63 treatment plans delivered by flattening filter free (FFF) beams on an Edge linear accelerator (Varian, Palo Alto, CA). The average change in position from reference capture to end of treatment was LAT = 0.01 ± 0.19 mm, LNG = -0.05 ± 0.34 mm, and VRT = 0.04 ± 0.14 mm with a mean magnitude of 0.34 mm and 95% less than 0.77 mm. Rotational offsets from reference to end of treatment were Rotation = 0.02 ± 0.21°, Pitch = -0.01 ± 0.25° and Roll = 0.02 ± 0.16°. The average time between reference capture and end of treatment was 4.76 minutes. For non-zero couch angles, average RTDs before beam on were LAT = -0.02 ± 0.4 mm, LNG = -0.66 ± 0.52 mm, and VRT = -0.11 ± 0.15 mm. Couch walkout was investigated as a potential source of the increased longitudinal offset but was not found to be correlated during phantom studies.

Conclusion: Overall, intrafraction patient motion assessed by OSMS is consistent with previous kV image-guided studies. The largest deviations reported by OSMS were in the longitudinal direction, suggesting systematic error in tracking patient position along this direction when the couch is rotated. This was not found to be due to couch walk-out; therefore, other sources for this discrepancy are currently under investigation.

Poster Display - Physics

P126: First ‘DRY’ installation of the Gamma Knife Icon: Experience and benefit

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Keywords: ICON, workflow, MRI, mask, frame

Purpose: In oktober 2016, the first ‘dry’ installation of the Gamma Knife was performed at our hospital: the ICON was installed without the 192 Co-60 sources. We will describe how this opportunity enabled us to create a unique workflow and integrate the GK into our radiotherapy department well before system start.

Method: Except for the sources, a complete and functional ICON was installed by Elekta. We customized the ICON workflow to include off-site mask making, Philips Ingenia 3T MR-RT scanner, dedicated contouring software, Mosaix based treatments and automated procedures. Further, we were able to pre-test CBCT and HDMM functionalities, design procedures, and train the ICON-team.

Results: We designed an efficient mask making routine in a specially equipped mouldroom that corresponds perfectly with the ICON procedure. A priori, the Philips Ingenia 3T MR-RT scanner is not compatible with the G-frame. Instead of a head coil, we use flex coils in combination with the anterior and posterior coil. A customized adaptor for patient positioning accommodates both frame- and mask-based setups. Sequences are fine-tuned such that geometric integrity is guaranteed. We use dedicated software that combines advanced registration and contouring tools and allows for creating margins and scripting. Depending on indication and preference, this software is now integrated in the GK workflow.
Workflows for frame- and mask-based treatments with Mosaiq were developed. We found Mosaiq to provide a reliable environment under normal conditions and established robustness in ad hoc scenarios.

We integrated the GK into our ICT-infrastructure to ensure reliable data transfer in accordance with current information security requirements. E.g., we developed a digital, PDF-based approval routine and prepared for automated instead of manual data transfer.

Pre-testing of CBCT and HDMM demonstrated the robustness and reproducibility of these systems and allowed for comparison of linac and ICON CBCT-QA procedures.

Planning-, workflow procedures were tailored to patient population, logistics and safety standards. For example, planning and image guidance protocols were developed for mask-based treatment of brain metastases based on clinical experience and dry-ICON sessions.

Hands on training sessions were organized to train the GK team on all procedures. This included extensive practice of emergency procedures without any exposure to radiation.

Conclusion: The ‘dry’ installation of the GK-ICON offered a unique opportunity to thoroughly prepare the infrastructure, department and team so that the clinical start may follow the loading of the machine swiftly and smoothly. We expect to have our ‘system start’ late march.

Poster Display - Physics

P127 : A dosimetric comparison between Leksell GammaPlan TMR10 and Convolution algorithms

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Keywords: Gamma Knife, TMR10, Convolution, Dosimetry, Algorithm, Comparison

The objectives of this work were to investigate the differences between the two calculation algorithms available on Leksell GammaPlan (LGP), TMR10 and Convolution, and dosimetrically verify them in realistic patient-like conditions.

An anthropomorphic and tissue equivalent head phantom (STEEV, CIRS, Norfolk, VA, USA) was employed to conduct end-to-end tests at four Gamma Knife centres in the UK. Four treatment plans were generated for an 8cc target on LGP using TMR10. All plans were delivered to the phantom and eight alanine pellets were used to measure point doses for each plan, four in the target and four in the brainstem. The plans were subsequently recalculated on LGP with the convolution algorithm and the measured doses were scaled using the ratio of beam-on times between the two plans. The accuracy of calculation algorithms was assessed by comparison of measured doses to LGP for TMR10, and comparison of scaled-doses to LGP for convolution.

The measured doses show, on average, clinically acceptable agreement with TMR10 calculated doses both inside the target (1.1%) and the brainstem (2.4%). The rescaled doses compared to convolution show, on average, higher percentage differences both in the target (5.4%) and the brainstem (7.2%).

<table>
<thead>
<tr>
<th>Measurement Vs TPS</th>
<th>Mean of 4 pellets in Target</th>
<th>Mean of 4 pellets in Brainstem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TMR10</td>
<td>Convolution</td>
</tr>
<tr>
<td>Centre 1</td>
<td>0.9%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Centre 2</td>
<td>1.7%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Centre 3</td>
<td>1.0%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Centre 4</td>
<td>0.9%</td>
<td>5.7%</td>
</tr>
<tr>
<td>Average</td>
<td>1.1%</td>
<td>5.4%</td>
</tr>
</tbody>
</table>

The results call for further investigation of the convolution algorithm. Further work should be conducted to evaluate the agreement of two-dimensional and three-dimensional measured dose distributions to convolution algorithm predictions.

Poster Display - Physics

P128 : Methodological and technical aspects of MR studies in patients before and after treatment on the Gamma Knife in the wide geography of residence and scanning MR systems of a different class

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Keywords: neuronavigation system, radiosurgery, square matrix, sequence
Purpose: Nowadays, planning of radiosurgical treatment is impossible without neuronavigation systems. Basic diagnostic tools are the data of MRI visualization. For precise surgery planning most neuronavigation programs make specific demands to the MRI that differ from standard scanning conditions. Our network of diagnostic centers suggests that a patient can have an opportunity to be scanned in any of them without a geographical reference. So a strict compliance with all technical aspects of MR imaging on any system is required. We set up a unified Protocol of examination on 1.5 T MR tomographs of different classes to achieve a unified quality standard.

Materials and methods: Created examination Protocol represents a set of three sequences, one of which was performed after the injection of a contrast media. At that, depending on the pathological changes, the examination can be supplemented with some specific sequences, on the recommendation of a radiosurgery physician. Depending on the type of the study – before or after a treatment, different coils, and, accordingly, different sets of adapted sequences are used. The difference in the choice of coils is due to the necessity of scanning a patient before a treatment with a special localiser for a further coregistration of tomography and planning station coordinates.

Results: the main specifications are as follows:
- square matrix and the scan field;
- slice thickness 1 mm and isotropic resolution;
- a sufficient number of slices when scanning in the sagittal plane to cover bone structure and labels
- axial plane is preferred
- the use of slab-selective mode
- using turbo spin echo and 3d vibe sequence
- slice oversampling is not less than 20% to compensate overlay crosstalk
- spatial resolution of at least 1.0x1.0x2.0 mm for T2 and 1.0x1.0x1.0 mm for T1

The preferred choice of MR visualization is made in favor of the 1.5 T compared to 3T due to the lesser susceptibility to distortion. Three-dimensional sequence is executed one time, the other projection can be recovered by using MPR without loss of quality due to isotropic resolution. The whole survey does not exceed 30 minutes including contrast.

Conclusion: Compliance with the specific requirements during MR visualization and the use of a unified standard imaging allows you to collect diagnostic data compatible with any neuronavigational software which increases the accuracy of the planning of a radiosurgical intervention.

Poster Display - Physics

P129 : Usefulness of FLAIR and 3D T1 20-minute delayed images after MRI enhancement in Gamma Knife brain metastasis treatment

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Keywords: Brain metastasis, Gamma knife, MRI delayed images

Objective: Gamma knife radiosurgery is safe and effective in treating patients with metastatic brain tumors. Metastatic brain tumor Gamma knife therapy is difficult to distinguish from meta lesion of less than 1 mm because of difficulty in accuracy of boundary dose in treatment. In this study, we aimed to present the appropriate range of treatment for gamma knife radiosurgery by comparing 3D T1, delayed FLAIR and 3D T1 20 minute delayed images with MRI contrast injection. Materials and Methods: From January 2016 to December 2016, MRI images of 15 patients with less than 1 mm of brain metastasis were analyzed. Symphony 1.5T was used and images were acquired with a Brain coil. After administration of MRI contrast agent, 3D T1 tra, delayed FLAIR and delayed 20 minute 3D T1 tra were examined. The images were analyzed by Syngo Program. Results: The enhancement range of the 20-minute delayed image was increased from a minimum of 3% to a maximum of 8%, and the average volume of the 20-minute delayed images increased by 5%. In delayed enhancement FLAIR images, 12 of 15 patients were found at the same lesion (80%) and three new lesions were found on the 20-minute delayed image. Conclusion: If metastatic lesions are bordered by 3D T1, FLAIR, and 3D T1 20-minute delay images after contrast injection, the 20-minute delayed image will be helpful for planning the gamma knife radiosurgery treatment. It is useful to detect lesions.

Poster Display - Radiobiology

P130 : A comparison study of algorithms calculating the dose TMR10 and Convolution in the planning system Leksell GammaPlan

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**Keywords:** Gamma-knife, Leksell GammaPlan, TMR10, Convolution, planning

**Purpose/Objective:** Until recently, planning of irradiation and calculation of doses for the Gamma Knife was held to TMR10 algorithm without taking into account the heterogeneity of brain tissue. But this assumption makes an error in the calculation of dose distributions. At one of the recent version of the planning system Leksell GammaPlan, Company Elekta introduced a new Convolution algorithm that takes into account heterogeneity in the dose calculation. The algorithm works on the basis of the differential thin beam and includes the calculation of primary and scattered dose. We investigated differences in the doses calculated with these two algorithms on the group of patients with vestibular schwannomas.

**Materials/Methods:** In this study we include 13 patients with vestibular schwannomas. For all patients after fixation of the frame in addition to standard MRI studies were performed CT examination. CT used to define the contours of the head. Planning and treatment were carried out according to the algorithm TMR10. After the plans were recalculated using the Convolution algorithm. The resulting plans were compared according to different dosimetric parameters (mean dose, minimum and maximum dose in the tumor and critical organs, radiation time).

**Results:** Based on the collected statistics were discovered the overstatement of the value of average dose in the tumor volume calculated by the algorithm TMR10 relative to one calculated by the Convolution algorithm with value 5.5±1.0%. It was also found strong overestimation of the average dose in the critical structures (the cochlea) calculated with TMR10 on an average of 0.4 Gy. It suggests that the real value of the tolerance dose for the critical structure differ from that obtained from statistics of the treatment with Gamma Knife when planning was done using TMR10 algorithm.

**Conclusion:** The use of the Convolution algorithm in routine planning is important. But to implement this algorithm in the clinical practice it is necessary to interpret the dosimetry data obtained by the dose calculation algorithm TMR correctly. It is not easy to do, because the differences between these two algorithms are not systematic. This is especially important for patients with pathologies located in areas of large heterogeneities (acoustic schwannoma, etc.).

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**Poster Display - Radiobiology**

**P131 : Late complications following Gamma Knife radiosurgery in a single institute**

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**Keywords:** Late complications, Gamma knife radiosurgery

**Introduction:** Gamma Knife Radiosurgery (GKS) is has been used to treat many intracerebral disease entities nowadays. Patients with benign lesions treated with GKS have longer life expectancy are usually expected to have longer life-span, and resultantly late complications of GKS is not commonly reported may be concerned.

**Methods:** Our institute experienced GKS in 8965 cases from 2001. 12. 27 to 2016. 12. 31. The disease entities are following: 4431 metastatic brain tumors, 561 glial tumors, 133 other malignant tumors, 1312 meningiomas, 697 vestibular schwannomas, 383 other benign tumors, 403 pituitary and suprasellar benign tumors, 247 functional diseases such as trigeminal neuralgia etc, and 798 arteriovenous malformations. Since 2002, patients treated with GKS who were followed-up more than 5 years were reviewed retrospectively. Their magnetic resonance images were reviewed serially and late complications such as new neoplasm and adverse radiological events were investigated.

**Results:** Among 300 preliminary review, few late complications were noted. Multiple cavernous angiommas was were found in a patient, 4 four had multiple enhancing lesions probably related to radiation change. Two patients developed mastoid effusion after radiation of cerebellopontine angle were observed in two patients and one develop maxillary sinusitis after radiation to sphenoid meningioma were detected in a patient. Four patients with vestibular schwannoma showed changing of cystic and necrotic portion to solid tumor. And 2 showed cystic degenerations of schwannoma. New development of pituitary adenoma and aneurysm was noted without evidence of relation to radiation.

**Conclusion:** There were few late complications of GKS. However, most of them were minor complications which didn’t need further intervention. GKS seems to be proven in long-term safety but and further review follow-up should be is required.
Poster Display - Radiobiology

P132 : Distant intracranial failure in melanoma brain metastases treated with stereotactic radiosurgery in the era of immunotherapy and targeted agents

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Keywords: melanoma, brain metastases, immunotherapy

Purpose: Stereotactic radiosurgery (SRS) in combination with immunotherapy (IMT) or targeted therapy is increasingly being used in the treatment of melanoma brain metastases (MBMs). The synergistic properties of combination therapy are not well understood. We compare distant intracranial failure rates of intact MBMs treated with: (1) SRS, (2) IMT + SRS, (3) SRS + targeted therapy.

Methods/Materials: Combination therapy was defined as delivery of SRS within three months of IMT (anti-CTLA-4/anti-PD-1 therapy) or targeted therapy (BRAF/MEK inhibitors). Primary end point was distant intracranial failure, which was defined as any new MBM identified on brain MRI. Outcomes were evaluated using Kaplan Meier method and Cox proportional hazards.

Results: Sixty-four melanoma patients with 215 MBMs were treated between April 2006 and February 2016. The number of MBMs within each treatment group was as follows: SRS: 121, SRS + IMT: 38 and SRS + targeted therapy: 56. There was no difference in the number or volume of MBMs per SRS session between treatment groups (p>0.05). Median follow-up was 9.7 months for all patients and 14.7 months for those remaining alive at the time of analysis. 85% of patients underwent more than one follow-up brain MRI. MBMs treated with SRS + IMT experienced an approximate 50% reduction in risk of distant intracranial failure compared to SRS (HR: 0.58, 95% CI: 0.35 – 0.95, p=0.03), and compared to SRS + targeted therapy (HR: 0.53, 95% CI: 0.31 – 0.90, p=0.019). There was no difference in one-year local control between treatment groups (SRS vs. SRS + IMT vs. SRS + targeted therapy: 76% vs. 82% vs. 82%, p=0.591).

Conclusions: Combination therapy consisting of SRS and immunotherapy is associated with decreased distant intracranial failure. Prospective studies with larger patient numbers are needed to validate this result.

Poster Display - Radiobiology

P133 : Hyperradiosensitivity-based radiotherapy for central nervous system germinoma: a pilot study

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Keywords: HRS, germinoma, hyperradiosensitivity, fractionation

Low-dose hyper-radiosensitivity (HRS) is a phenomenon of dramatically enhanced radiosensitivity to doses below 0.3Gy that does not conform to the linear-quadratic model. It is believed to be caused by failure of the target cells to activate their repair mechanisms below a certain threshold of DNA damage, and is commonly present in human and non-human cells and tissues. Even if the observed cell kill in vitro may be up to 30X higher than expected, it is still very low and therefore the clinical applicability can be questioned and has, until now, never been convincingly demonstrated.

Primary intracranial germinomas are rare tumours that are histologically indistinguishable from seminomas and occur in childhood and adolescence in the supra-chiasmatic and pineal region, and that seed thought the cerebrospinal fluid to implant to the ventricle walls and dura. Germinoma cells are exquisitely radiosensitive and radiotherapy is the treatment of choice in all stages, targeting the ventricle walls and in disseminated cases the whole craniospinal axis. These large target volumes imply significant radiation burden, causing toxicity and risk of tumor induction. Whilst tumor control is excellent, research efforts are therefore directed towards lowering toxicity.

Based on our experience with a single case with CNS germinoma, we started a pilot study that exploits HRS by using 0.2Gy dose fractions as a prophylactic dose and to the GTV. GTV response was assessed without
interrupting radiotherapy at 10 and 20 X 0.2Gy. GTV was then consolidated with either 20X 2Gy, later in the study with 20 X 0.2Gy.

All four adult patients diagnosed with CNS germinoma or referred for treatment in our hospital agreed to participate in the trial.

All tumors showed immediate and marked response to 10 X 0.2Gy and one complete remission was noted after 20 X 0.2Gy. One patient participated twice after a recurring with a distant metastasis outside of the PTV. He was successfully retreated exclusively with 0.2Gy fractions and remains free of disease 5y after diagnosis.

**Conclusion:** Prevention of ependymal implants in the ventricle walls can be achieved with doses as low as 20x0.2Gy. Long term tumor control could be achieved solely with 0.2Gy fractions in a disseminated patient. Prophylactic irradiation of the craniospinal axis could be effective at accumulated doses 10 lower than what is currently in use. Primary central germinoma may be the first example of the clinical exploitation of HRS to decrease toxicity in radiosensitive tumors. A randomised study is warranted.

**Poster Display - Radiobiology**

**P134 : Stereotactic body radiation therapy for mediastinal lymph node metastases: How do we fly in a “no-fly zone”?**

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**Keywords:** Stereotactic body radiation therapy; Metastatic lymph node treatment; No-fly zone; Toxicity assessment; Outcome evaluation

**Purpose:** The aim of our study was to evaluate the feasibility of stereotactic body radiation therapy (SBRT) in the treatment of mediastinal lymph nodes in the so-called no-fly zone (NFZ) in cancers with various histology. The primary endpoint was treatment-induced toxicity and the secondary endpoint was efficacy of the treatment.

**Materials and methods:** Forty-two patients were retrospectively analyzed. Patients were treated with SBRT with different techniques (IMRT or Dynamic Arc). Institutional dose constraints for organs at risk derived by published data were used and strictly respected. Overall survival (OS), cause-specific survival (CSS), progression-free survival (PFS) and local control (LC) were collected for each patient from the follow-up reports available. Clinical and dosimetric factors potentially related to the endpoints were collected for each patient. The correlation between treatment-related variables and toxicity was investigated by logistic regression, Chi-squared test or Fisher’s exact test. The impact of potential predictive factors on LC, PFS and OS were estimated by Cox proportional-hazard regression.

**Results:** Median follow-up time was 16 months (range 1-41). Four patients had esophageal toxicity (3 acute G1, 1 late G1). Ten patients had G1 pulmonary toxicity (5 acute and 5 late). Six patients had G2 pulmonary toxicity (5 acute and 1 late toxicity). Among the 11 patients who underwent retreatment in the thoracic region, no case of esophageal toxicity was observed, whereas 11 patients showed G1-G2 pulmonary toxicity. Treatment site and irradiation technique were significantly correlated with G≥2 and G≥1 toxicity, respectively. OS rate was 88.1% and corresponded to CSS. LC rate was 66.7% and median LC time was 22 months (range 1-41 months). Fifteen patients (35.7%) were disease-free at a median time of 25 months (range 1-41 months). The biologically effective dose and the target dose coverage indexes showed a statistically significant correlation with LC.

**Conclusion:** SBRT is a safe treatment and can be considered as an option for a selected group of patients with oligo-metastases or oligo-recurrences in the NFZ. Hypofractionation and re-irradiation can be considered also in the NFZ, if accurate treatments with strict dose constraints are applied.
Poster Display - Radiobiology

P135 : Partial breast irradiation with CyberKnife after breast conserving surgery: a pilot study in early breast cancer

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Keywords: Partial breast irradiation, CyberKnife, cosmetic outcome, skin toxicity

Purpose: The large majority of recurrences after breast-conserving surgery for patients presenting a low recurrence rate risk are close to the original tumor site. Irradiation strategies potentially reducing short and long term toxicities and improving cosmetic outcomes by limiting the target volume to the surgical cavity have therefore to be considered. In this context our institution implemented Accelerated Partial Breast Irradiation (APBI) using a CyberKnife (CK) platform.

Methods: From June 2013 to June 2014, a total of 20 patients were enrolled in the study for APBI and followed for 2 years. After surgical removal of the tumor, gold seeds were implanted around the lumpectomy cavity to drive and adapt dose delivery taking into account the patient’s breathing pattern by using the Synchrony respiratory tracking system. The clinical target volume was contoured on the post-operative CT and a 5 mm margin was added to obtain the Planning Target Volume (PTV). The heart, bilateral lungs, thyroid, skin and ipsi-lateral and contra-lateral breasts were contoured as Organs At Risk (OARs). The PTV was treated with a dose of 30 Gy, delivered in five consecutive fractions to the isodose encompassing the 95% of the target volume. Cold and hot spots minimization inside the PTV and constrained dose to the OARs were also treatment plan optimization objectives. Patient’s follow-up included acute and late skin toxicity and cosmetic results assessment, as well as evaluation of loco-regional or distant relapse and radiation-induced lung injury.

Results: Using the CyberKnife system with the variable aperture Iris collimator, the treatment time including patient set-up on treatment couch was approximately 60 min. All patients received the prescription dose of 30 Gy in five fractions delivered to the PTV without exceeding the dose-volume constraints to the OARs. Mild and almost always transient skin toxicity (erythema and fibrosis) was observed, with no need for therapeutic intervention. No radiation-induced lung injury was recorded in the chest CT performed after three months from the end of radiotherapy. After the first month poor rating was never recorded by patients for cosmetic evaluation. After a mean of 27.7 months of follow-up late cosmetic results were good with negligible toxicity. Neither radiation-induced lung injury, nor local or distant relapse were documented.

Conclusion: This study suggests that CK-APBI is a very promising technique in the treatment of early breast cancer, with mild acute and late toxicity and very good cosmetic results.

Poster Display - Radiobiology


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Keywords: Radiosurgery, Eclipse, MLC, Multi-Target, DLG, Metastasis, TPS, Truebeam

Purpose/Objective(s): Volumetric Arc Therapy (VMAT) is increasingly used in radiosurgery to treat multiple target volumes using a single isocenter. The resulting complex MLC patterns make accurate dose calculation a challenge. Varian Eclipse TPS has two MLC parameters which fine tune VMAT dose calculation: dosimetric
Materials/Methods: A test machine was setup in Eclipse TPS to vary DLG and look at the change in dose for multiple different targets and plan types. DLG values between 0 mm and 2 mm were examined. We first established that a linear relationship exists between DLG value and calculated dose using a subset of cases. For the remaining cases we used two DLG values to calculate the slope of the linear relationship and interpolated other DLG values. The slope we defined as the DLG sensitivity index (DLGSI) for % dose change per millimeter change in DLG. We determined the DLGSI for 26 targets in 21 treatment plans. These plans included multi-target SRS, on and off-axis single target SRS, non-SRS Brain, Liver SBRT and Spine SBRT. A dose measurement was made for each target using a Delta 4 by ScandiDos. By comparing predicted dose to the measured dose an optimum DLG value was determined for each target.

Results: A substantial variation in DLGSI was seen for different plan types and targets. SRS plans were found to have the greatest sensitivity to DLG with multi-target SRS being the most sensitive. Average DLGSI for multi-target SRS was 16.3%/mm. For single target SRS the DLGSI dropped to 7.2%/mm. The average DLGSI for all non-SRS plans was found to be 3.5%/mm. While no single optimum DLG value exists for all targets the best compromise value we found to be 0.6 mm.

Conclusions: While the majority of VMAT plans are relatively insensitive to DLG value we have found that SRS plans, particularly multi-target SRS, are highly sensitive to DLG. When starting to do SRS with VMAT it is very important to evaluate the optimum DLG setting for Varian HDMLC.

Keywords: Meningioma - Radiosensitivity – Radiobiology – Cell cultures

Meningiomas are a heterogeneous group of tumors and they account for 30% of all cancers of the Central Nervous System. These tumors are treated surgically, but in some cases radiotherapy (RT) is also administered. Experimental investigations on the biology of meningiomas and the biological basis of the RT action did not have wide application due to the scarcity of in vitro and in vivo models. Recently some improvement has been achieved thanks to cell cultures. Based on literature data, we used the immortalized cell lines derived from aggressive variants of the tumor, the IOMM-Lee and the CH-157. So, the aim of this study is to evaluate the response to the radiation of these meningioma cells. They were irradiated in single fraction with increasing doses from 2 Gy to 15 Gy using two different linear accelerators, Synergy® (SYN) and Cyber Knife® (CK). They have a different dose rate: 3 Gy/min and 10 Gy/min respectively. We obtained the survival curves accordingly to the data of clonogenic tests. Then were carried out the study of apoptosis and cell proliferation, with Annexin V – PI and MTS respectively. Our results showed a similar dose-response of both meningioma cell lines, with increasing cell death at increasing doses. Moreover, the IOMM-Lee showed a more radiation resistance than the CH-157. Indeed, the cellular death of CH-157 was obtained at a very low dose irradiation. For this reason, we conducted following investigations using IOMM-Lee cell line only. Another element seems to have an important role in radiation response: the dose-rate delivery. In fact, with the higher dose-rate the response to radiation was greater than that obtained with the lower one. Furthermore, in our experiments the necrosis has had a role less important than apoptosis: the rate of apoptotic cells is greater than that of the necrotic cells at any dose of irradiation and at any time of analysis. So, we can underline the need to investigate more specifically the pathways associated with apoptosis and DNA damage repair. These findings need to be confirmed and validated by further studies with a greater number of samples and with experiments focused not only on cell lines, but also on primary cultures. In conclusion, we can confirm a dose-response effect due to the early and late apoptosis.
Poster Display - Spine

P138 : Comparison of spinal stereotactic body radiotherapy (SBRT) planning techniques: Intensity-modulated radiation therapy, modulated arc therapy, and helical tomotherapy

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Keywords: stereotactic body radiotherapy; intensity-modulated radiation therapy; modulated arc therapy; helical tomotherapy; spine

Background: Stereotactic body radiotherapy (SBRT) delivers a highly conformal, hypofractionated radiation dose to a small target with minimal radiation applied to the surrounding areas. Therefore, using the proper treatment planning techniques for SBRT is important. Intensity modulation techniques, such as static intensity-modulated radiation therapy (IMRT), modulated arc therapy (mARC), and helical tomotherapy (HT), are useful for spinal SBRT because of a rapid dose fall-off and spinal cord avoidance. This study aimed to compare the planning characteristics for hypofractionated spinal SBRT administered using three treatment techniques.

Materials and Methods: The factors evaluated for spinal SBRT planning were dose coverage, cord avoidance, target conformity, homogeneity, and dose spillage.

Results: Target coverage was 82.74 ± 3.35%, 80.92 ± 80.95%, and 85.01 ± 7.274% for IMRT, mARC, and HT, respectively. HT was therefore a powerful technique with respect to target coverage. The spinal cord dose for HT (mean, 1763.96; standard deviation, 164.48) was significantly different from those for mARC (mean, 1991.75; standard deviation, 248.00) and IMRT (mean, 2053.24; standard deviation, 164.48). In addition, the partial spinal cord volume at 20 Gy for HT (mean, 0.12, standard deviation, 0.01) was significantly different from those for mARC and mARC (0.5 ± 0.10 and 0.56 ± 0.25, respectively). The conformity index was 1.30 ± 0.118, 1.08 ± 0.052, and 1.36 ± 0.231 for IMRT, mARC, and HT planning, respectively. mARC showed the highest conformity (p = 0.000).

Conclusions: HT used a narrow field pan beam and exhibited remarkable improvement of target coverage and cord dose, offering an important benefit to spinal SBRT. mARC had the highest target conformity and better high- and intermediate-dose spillage than HT and IMRT did, respectively. The HT and mARC planning techniques each have different advantages and disadvantages. Therefore, users should choose the appropriate planning techniques accordingly.

Poster Display - Spine

P139 : The use of simultaneous X-ray volumetric imaging during treatment in spine SBRT

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Keywords: X-ray volumetric imaging, CBCT, spine, SBRT

Purpose: To study the advantage of using simultaneous kilo-voltage (kV) during mega-voltage (MV) treatment in spine stereotactic radiotherapy (SBRT)

Methods: 9 spine SBRT patients were treated for three to five fractions in Elekta Agility MLC with altogether 25 images using simultaneous X-ray volumetric imaging (XVI) during MV irradiation. The intra-fractional positional errors were analyzed and input to treatment planning system (Monaco v5.0, Elekta AB, Stockholm, Sweden) to evaluate the dosimetric effect of not applying the shifts. Paired student t-test was used to evaluate the statistical significance of maximum dose to cord+2mm and PTV coverage after applying the shift. Statistical significant was considered with p < 0.05.

Results: The average intra-fractional positional errors were 0.02 mm, -0.11 mm and -0.17 mm in X, Y and Z directions respectively. p < 0.05 was found in cord+2mm while > 0.05 in PTV coverage.

Conclusion: Simultaneous XVI could be served as an alternative for intra-fractional monitoring and it has the potential to minimize the positional errors in spine SBRT in order to protect the organ-at-risks and provide more accurate dose delivery. The moderate conformity of the plans may be the reason of statistical insignificance of PTV coverage.
Poster Display - Spine

P140 : Optimization of isodose level in spine SBRT

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Keywords: optimization, isodose, IDL, Spine, SBRT

Purpose: To study the dosimetric effect of different prescription isodose levels (IDLs) in spine stereotactic body radiotherapy (SBRT).

Methods: 6 spine SBRT (2 cervical spine, 2 thoracic spine and 2 lumbar spine) cases at 65%, 75% and 85% IDL with prescription of 24 Gy in three fractions were optimized in Monaco v5.0 (Elekta AB, Stockholm, Sweden). The three IDLs were achieved by using target penalty on the PTVs while keeping the beam geometry and the organ-at-risk parameters the same. The plans were then delivered on Elekta Agility MLC linear accelerator and measured with Octavius 4D system and SRS1000 (PTW, Freiburg, Germany). Maximum dose to cord (Cord), PTV coverage, Modulation (M) reported in Monaco, Paddick’s Conformity Index (CI), Gradient Index (GI), Monitor Unit (MU) and Gamma Analysis (GA) with 1.5%/1.5mm (local dose) were compared among the three groups.

Results: The average values at corresponding IDLs are: Cord = 21.3Gy, 21.2Gy and 21.2Gy; PTV coverage = 94.4%, 95.6% and 94.1%; M = 3.6, 3.0 and 2.9; CI = 0.75, 0.76 and 0.79; GI = 4.79, 4.74 and 5.1; MU = 4010, 3267 and 2752; GA = 93.3%, 93.1 and 93.2%.

Conclusion: Different IDLs provided similar OARs doses, PTV coverage and gamma analysis results. On the other hand, the highest IDL gave the best conformity but the worst fall-off, although the magnitude is not significant. Besides, the lower the IDLs, the more the modulation and MU required.

Poster Display - Spine

P141 : Dosimetric impact of modulation on 3D gamma and DVH in spine SBRT

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Keywords: Dosimetric, modulation, gamma, dvh, spine, SBRT

Purpose: To study the dosimetric impact of modulation on 3D gamma index and dose-volume histogram (DVH) due to the imperfection of delivery system in spine stereotactic body radiotherapy (SBRT).

Methods: Eighteen plans of spine SBRT with prescription of 24 Gy in 3 fractions at different reported modulation levels were created in Monaco v5.0 (Elekta AB, Stockholm, Sweden) by using target penalty to boost the dose within PTV to 65%-85% isodose level. They were then delivered on Elekta Agility MLC linear accelerator and measured with liquid-filled detector array (PTW, Freiburg, Germany) having 2.5 x 2.5 mm² resolution. The measurements were subsequently reconstructed into a 3D dose distribution on both phantom and patient’s CT images. Correlation (r) between isodose level (IDL), Gamma Index (GI) (1.5mm/1.5% local dose), absolute percentage change in cord (%cord) and in PTV coverage (%PTV) against modulation (M) with statistical significant at p<0.05.

Results: Both IDL and %cord showed moderate correlated with M (r = -0.54 and -0.48 respectively with p<0.05) while other two were statistically insignificant.

Conclusion: Gamma passing rate is not sensitive to the plan modulation. The weak correlation of PTV coverage with modulation is perhaps due to the imperfect conformity. The optimal modulation would be around 3.5 to compromise the change in dose to cord and the risk of vertebral fracture from extremely low isodose level.

Poster Display - Spine

P143 : SBRT (Stereotactic Body Radio Therapy) of spinal metastases in the postoperative setting. Challenges and solutions in clinical practice.

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Keywords: Spinal SBRT, post operative, co-registration, margins, MR, CT, CBCT

Poster Display - Spine

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Keywords: Spinal SBRT, post operative, co-registration, margins, MR, CT, CBCT
With the advent of SBRT, metastatic spine lesions became well suited targets for this new treatment modality. Thanks to the advances in image guided radiotherapy, durable local control is today often the aim. This in turn has pushed the surgical management.

However, the management of spinal metastases with spinal cord compression or impression in the thecal-sac has been posing challenges, in particular in a post surgical scenario where a segmental resection is followed by the vertebral stabilization with titanium implants.

The challenges of delivering an ablative target dose and restrict dose to medulla/cauda equine (OAR (Organs At Risk)), requires small geometrical uncertainties. Components of the latter are: delineation of the tumor and OAR, especially difficult amid the presence of titanium implants. MRI T2 based sequences has become the imaging modality of choice for the delineation task. Furthermore, the registration of MR and CT images (for dose calculation) and uncertainties in the CBCT-online imaging at set-up implies the use of a PRV (Planning Risk Volume) for OAR. The PRV-margin has a bearing with the fixation method and has also to account for internal motion of the OAR. This margin and the relative position of the tumor to the OAR steers the dose gradient needed between target and medulla.

Target and OAR delineation is performed as high resolution segments on MR T2 with 3mm thick slice and 0.16 mm transversal resolution. These structures are transferred to a co-registered CT with 2mm slice thickness and 0.17 mm transversal resolution. PRV 2mm around medulla is defined, based on the observed behaviour of patients on the stereotactic bodyframe. At the onset of the post-operative SBRT in vertebra at Karolinska an additional step was introduced, which is a co-registration of the CT with a pre-planning CBCT. This step prior to planning reveals important information of the inter fractional positional errors that can be expected for a specific patient. If no rotation (below 0.2 degrees) is present this CBCT image is used as reference image for the ensuing online matchings. The reason for this is the high spatial resolution of the CBCT when a reduced field of view mode is used. Automatic matching between CBCTs rules out user induced matching errors.

Matching errors and intra fractional movement was observed to be less than 0.5 mm. Pre planning CBCTs and co-registration to CT provides information of paramount importance when discussing margins and the acceptable and safe dose gradient.

Poster Display - Spine

P144 : Stereotactic radiotherapy for spinal arterio-venous malformation: Report of 5 cases

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Keywords: spine, arteriovenous malformation, stereotactic radiotherapy, nidus

Preliminary results of stereotactic radiotherapy (SRT) for spinal arteriovenous malformation (AVM) were presented in 5 cases. Two were male and three were female. The median of age was 32 years (range 23 to 54 years). Spinal intramedullary AVM were located in cervical spine in three and in thoracic in two. SRT with 20 Gy in 4 fractions was delivered to the nidus in every case. At the end of the median follow-up period of three years (range 2 to 7.5 years) the neurological symptoms and signs were improved or same as before treatment, though temporary adverse effect was developed between a half year and one year after SRT in one case. The nidus was disappeared three years after SRT in one case. The nidus was decreased in size in one. In the other three cases the niduses were unchanged. In conclusion, SRT with 20Gy in 4 fractions was thought to be a safe treatment, though this study dealt with only a small number of patients with short term follow-up period.

Poster Display - Spine

P145 : Suggestion of optimal planning target volume margins for single-fraction stereotactic radiosurgery of the spine

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Keywords: setup error, intrafraction motion, patient alignment, stereotactic radiosurgery, spine

Purpose: To suggest optimal planning target volume (PTV) margins in single-fraction stereotactic radiosurgery (SRS) of the spine.

Patients and Methods: From December 2014 to July 2016, 40 patients received 42 fractions of single-fraction SRS for spinal tumors in thoracic and lumbosacral spines using a volumetric modulated arc therapy technique and patient immobilization. Before each treatment, kilovoltage cone-beam CT (CBCT) images were obtained for a 4 degrees of freedom (DoF) correction of patients alignment (translations and yaw) using planning CT as reference. After each correction, additional CBCT was acquired to verify adequate patients alignments just before treatment delivery (pretreatment CBCT). Immediately following SRS, CBCT was acquired again (posttreatment CBCT). Residual setup errors (SE) between planning CT and CBCT were determined by a 6 DoF manual matching. Intrafraction motions (IM) were calculated as differences in SE between pretreatment and posttreatment CBCT. For comparison, three clinical target volumes (CTV) were created by translating and rotating original CTV by pretreatment SE alone (CTV_SE), IM alone (CTV_IM) and both SE and IM (CTV_SEIM), respectively. The impact of various PTV margins on CTV coverage was evaluated. A provisional criterion of adequate CTV coverage was that PTV encompasses at least 97% of CTV.

Results: Time interval between pretreatment and posttreatment CBCT was 6.8±2.5 min (mean±2SD). The 2SDs of translation were 0.7 mm, 0.8 mm, 1.1 mm (SE) and 0.7 mm, 0.8 mm, 1.1 mm (IM) in lateral, vertical and longitudinal directions, respectively. The SDs of rotation were 1.7°, 1.1°, 1.6°(SE) and 1.1°, 0.8°, 1.1°(IM) for pitch, roll and yaw, respectively. Without margins, PTV showed adequate coverage for CTV_SE, CTV_IM, and CTV_SEIM in 48% (20/42), 71% (30/42) and 48% (20/42) of fractions, respectively. With 1-mm uniform margins, PTV was adequate in 95% (40/42), 98% (41/42) and 100% (42/42) of fractions for CTV_SE, CTV_IM and CTV_SEIM, respectively. A 2-mm uniform margin was adequate for three CTVs in all fractions.

Conclusions: With appropriate immobilizations and 4DoF corrections, a uniform 1-mm PTV margin may ensure adequate CTV coverage in most treatment sessions of spine SRS. Combination of short treatment time and small IM may obviate the need of treatment interruption for additional image guidance. A 1-mm PTV margin is still needed to address IM even in case of ideally perfect 6 DoF patient alignments.
and extraocular intraorbital pathology. Development of the optimal radiosurgical treatment strategy in such cases may be done by comparative evaluation of outcomes in collaborative multicenter studies.

Poster Display - Various
P147 : First year of Gamma Knife radiosurgery in KSA

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Keywords: Trigeminal Neuralgia, CP angle tumours, AVMs, Pituitary Adenoma, Metastasis.

Objective: In order to review cases treated with Gamma Knife Radiosurgery in an year on a facility being used for the first time in the Kingdom.

Methods: Leksell Gamma Knife Perfexion system, has been installed at PSMMC in July, 2013.

First patient treated at this machine was on Nov. 3rd, 2013. And 19 patients have been successfully treated at the end of one year, which includes; 7 patients of Arteriovenous malformation (AVMs), CP angle Schwannomas ; 6, CP angle Meningioma; 2, Trigeminal neuralgia; 2, Pituitary Adenoma; 1, and one case of Recurrent single focus of metastasis from Colon cancer.

A Radiosurgery data-base has been established. All the patients who received their treatments are kept on regular follow up, being updated in the database based on their follow up visits in combined clinic at Radiation Oncology Department, PSMMC.

Results: Mean Doses delivered were as follows : AVMs; 18 Gy, CP Angle tumours : 12 Gy, TNs : 80 Gy, Pituitary Macroadenoma : 13Gy, Metastasis : 16 Gy. These doses are marginal doses prescribed at 50 % isodose levels. RT0G/Timmerman's Tables of dose constraint levels using single fraction treatment for Organs at risk in brain were used.

All the patients, had safe course of treatment with no acute complications.

As Expected, Trigeminal Neuralgias(N : 2) treated at our facility have been found to experience quickest relief of symptoms within 2-3 months achieving BNI scores of II and III.

All the CP angle Tumors were found to have stable radiological findings on 6 month follow up MRI with 37.5% (N: 3/8)patients commented stable hearing compromise but marginal improvement in tinnitus and vertigo.

28.5% (N : 2/7) patients of AVMs felt better in headaches and requirement of anticonvulsants (both had elapsed 6 months or more of follow up).

One patient of AVM(referred from another hospital) reported to have worsening headaches, although reduced seizure activity, for which he underwent work up and found no complications. He felt improvement in symptoms on neuropathic medications prescribed by his neurologist at his primary hospital.

Conclusion: Gamma Knife Radiosurgery is a safe and effective modality of treatment for benign and malignant brain diseases with certain specific indications. More patients including metastatic brain lesions should be considered for treatment with this modality expecting good cognitive outcomes.

Poster Display - Various
P148 : Early experience of Gamma Knife Icon radiosurgery

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Keywords: Gamma Knife, Frameless radiosurgery, Early experience

Introduction: Icon is the newest model of Gamma Knife equipped with a cone beam CT (CBCT) and high definition motion management system. It is possible to perform a frameless mask based Gamma Knife surgery (GKS). The authors report the early experience of clinical cases of GKS executed with Gamma Knife Icon.

Materials and Method: Between March 2016 and December 2016, 670 procedures were performed with GK Icon and 199 (29.7%) cases were mask-based procedures. There were 78 brain metastases, 66 meningioma, 31 vestibular schwannoma cases. Among the mask based GKS,
75 (37.7%) cases were fractionated into 3 to 5 sessions. Various aspects on mask-based GKS such as tumor volume, prescription dose, irradiation time, number of lesions, and patient age were compared with frame-based procedures. The accuracy of mask based GKS was assessed by co-registering conventional CT images of an anthropomorphic phantom to Icon CBCT images and measuring locations of the irradiated points. The error related with the image co-registration was in order of a millimeter.

**Results:** Distribution of indications of mask-based GKS was similar with that of frame-based system. Though the mean tumor volume of mask-based procedures was similar to that of the frame-based procedures (3.6 ± 6.0 cm³ versus 3.0 ± 5.9 cm³), shorter irradiation time per procedure was used for mask-based patients (29.9 ± 18.7 min versus 49.1 ± 33.7 min). It is because more lesions were treated in fractionated procedures in mask-based GKS (37.7% versus 25.7%). While only four (5.5%) patients of vestibular schwannoma patients were treated with fractionation in frame-based GKS, 16 (51.6%) patients were fractionated in mask-based procedures. The main reason for fractionation was that the target was closed to an organ at risk or it was too big for a single session irradiation. The mean target volume of fractionated cases was 6.1 ± 8.4 cm³ while it was 2.2 ± 3.3 cm³ in single session treatments among mask-based procedures. The average number of interrupts during an irradiation session was 1.4 +/- 1.9 times. Three patients were converted from the mask-based to frame-based because of involuntary movements during CBCT imaging before irradiation.

**Summary:** Frameless mask-based GKS could be performed with Gamma Knife Icon with accuracies comparable to frame-based GKS. With careful selection of patients to keep the irradiation time not to be too long, most of the mask-based patients could finish the frameless GKS with high satisfaction rate.

**Keywords:** radiosurgery, cardiac implantable electronic devices, implantable radiovert-debrillator, cardiac resynchronization therapy, CyberKnife

**Objective:** Cardiac implantable electronic devices (CIEDs) are more and more common among patients referred to radiotherapy. Due to continuous development of new models of the CIEDs and introduction of new types of medical accelerators there is an urgent need for up-to-date information on the susceptibility of modern CIEDs to ionizing radiation, especially in patients subjected to new techniques of radiotherapy or irradiated with new kinds of devices.

The aim of our study was to test a set of modern CIEDs in the setting of robotic radiosurgery for target volumes localized in the cranium and cervical spine.

**Material and methods:** A set of four CIEDs from two different vendors was placed on an anthropomorphic phantom to simulate the real position of the devices in a patient. Five treatment plans were made to simulate irradiation of a convexity meningioma, brain metastasis, trigeminal neuralgia, and tumors located in the upper and lower cervical spine. The treatment plans were optimized to avoid direct irradiation of the CIEDs. The phantom was irradiated with 6 MV photons and after each treatment the devices were interrogated to test for possible malfunctions. A set of thermoluminescent dosimeters was also placed on the chassis of each device in order to verify the calculations of the treatment planning system.

**Results:** All the devices functioned correctly after the irradiation in spite of proximity of the irradiated target volumes and movement of the working accelerator above the CIEDs which potentially could be a source of electromagnetic interference.

The mean values of dosimetric measurements made on the surface of the devices were as follows: 4.3, 4.9, 5.6, 9.5, and 8.5 cGy for the convexity meningioma, brain tumor, trigeminal neuralgia, and tumors located in the upper and lower cervical spine, respectively. The doses calculated by the treatment planning system were 1.8, 2.3, 8.2, 11.2, and 10 cGy, respectively.

**Conclusions:** The preliminary results indicate that an operating CyberKnife device poses no direct threat
to modern CIEDs even in case of irradiation of target volumes close to a CIED. The results require confirmation on a larger set of CIEDs from various vendors to make them more generalizable.

The treatment planning system underestimates the dose to CIEDs in case of locations distant from the target volume which should be taken into account in clinical practice.

Poster Display - Various

P150: End-tidal carbon dioxide should be monitored during Gamma Knife Radiosurgery; a case presentation and proposal from anesthesiologists

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Keywords: Gamma Knife Radiosurgery, patient safety, respiratory monitoring

Objectives: Gamma Knife Radiosurgery (GKRS) is generally performed under minimal sedation with local analgesia provided by non-anesthesiologists. Patients with restricted airway access who are isolated from medical personnel are a considerable risk. Especially in the pediatric population, careful observation of both respiration and ventilation is required because moderate sedation is frequently used. Thus, early detection and intervention are essential for safe respiratory management. There is no standard for basic monitoring during GKRS, with peripheral oxygen saturation (SpO₂) as the sole respiratory monitor. According to the practice guideline for sedation and analgesia by non-anesthesiologists released by American Society of Anesthesiologists, the adequacy of ventilation should be evaluated by continuous observation of qualitative clinical signs and monitoring for the presence of exhaled carbon dioxide during moderate or deep sedation. Since 2016, we have adopted Capnostream® (Medtronic) to evaluate both oxygenation and ventilation during GKRS. This dual parameter monitor of SpO₂ and end-tidal carbon dioxide (EtCO₂) is used in all cases as a standard respiratory monitor. We herein demonstrate a pediatric case to clarify the effectiveness of EtCO₂ monitoring during GKRS.

Methods: A 9-year-old boy underwent GKRS due to arteriovenous malformation on left medial occipito-temporal lobe (Spetzler-Martin grade 2, Pollock-Flickinger score 0.75) with 22Gy at 50% isodose (P1V 0.98 cc). As the patient was considered too young to receive GKRS under minimal sedation with local analgesia, monitored anesthesia care with a combination of dexmedetomidine and remifentanil was planned. Supplemental oxygen was provided through nasal cannula and SpO₂ and EtCO₂ were continuously monitored using Capnostream® along with electrocardiogram, heart rate, and noninvasive blood pressure.

Results: Conscious sedation with stable cardiorespiratory status was successfully provided at the beginning of the procedure. However, additional sedation (midazolam, 1 mg) and analgesia (fentanyl, 120 mcg in total) were required because the patient was agitated when we fixed a Leksell frame with topical analgesia. Approximately 1 minute after midazolam administration, respiratory depression was detected as his respiration rate decreased below 10 and EtCO₂ level dropped from 38 to 16 mmHg, while SpO₂ remained 98%. Hypopnea was detected by capnogram almost 2 minutes in advance of desaturation, therefore prompt respiratory support with jaw-lift could recover his respiratory status without pharmacological reversal or invasive airway management.

Conclusion: Sole monitoring of SpO₂ is insufficient to detect respiratory decline. From an anesthesiological point of view, simultaneous EtCO₂ monitoring with SpO₂ enhances patient safety and improves the clinical efficiency of GKRS.

Poster Display - Various

P151: Clinical experience of 3D printing at neurosurgery

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Keywords: 3D printing, virtual and physical models, neuro-oncology, eye’s tumours

Introduction: 3D printing technology helps to make of prostheses, assistive devices, production of hearing aids,
prostheses, nose, ears, eyes, teeth, breast reconstruction, of bone substitutes. Method of 3D printing cells (bioprinting) also helps in treating skin injuries and regenerative medicine in which the patient’s stem cells form filling printers.

Methods and Results: 3D printing we used in neuro-oncology at radiosurgical planning performance. Tumour’s shape and boundaries with virtual model of 3D printing increases the accuracy of the therapeutic doses and subsequently significantly reduces irradiation to risk structure.

3D printing helps in deciding which modality of irradiation is the safest therapy for patient. It helps the surgeon to decide the way of radiotherapy (e.g. Linac treatment, Gamma knife, Cyberknife or proton beam irradiation).

Mentioned 3D methods contribute to a better understanding of localization and progression of tumours compared to only 2D view, which also helps for undergraduate and postgraduate education.

In collaboration with physicians from the Ophthalmological clinic of the Faculty of Medicine in Bratislava, we have created a set of 3D physical models of eye and tumours for radiosurgical operations, that we have also been used for the postgraduate teaching of physicians and medical students.

We are preparing a new model in rehabilitation and physiotherapy for better differentiation of the shoulder joint pain origin which will be determined on therapeutic pain procedure with the shoulder joint for targeted rehabilitation, using the model comparison of 3D printing shoulder joint and cervical spine.

Conclusion: We used 3D printing in neuro-oncology with radiosurgical planning performance. With the 3D model printing, we increased the accuracy of the therapeutic dose and at the same time we calculated the lowest dose to risk structures. 3D printing method helps determine which modality radiation is optimal. For operations of the eye’s melanoma we created a set of 3D physical models of the eye and tumour. In the near future, 3D printing will also help us for targeted rehabilitation.

Keywords: Gamma Knife Icon, mask fixation,

Purpose: In Japan, since Leksell Gamma Knife Type B was introduced in 1990, version up has been repeated from type C, 4C to Perfexion. Leksell Gamma Knife Icon was developed and it became possible to treat without frame. Our hospital has been using from December 2016, and we will report on its initial use experience.

Material and results: We started treatment with Gamma Knife Icon from December 5, 2016. At our hospital, treatment of the large lesion requiring fractionated irradiation or treatment for cases with less than 1 hour irradiation time has been performed with mask fixation system. During the 77 gamma knife treatments performed by February 24, 2017, the mask system was applied to 28 patients (36.4%) according to the above-mentioned criteria. The breakdown was 8 cases (28.5%) with large tumor requiring fractionation, 19 cases (67.6%) with a few lesions, and 1 the other case (3.6%). In principle, irradiation was performed at 35 Gy / 5 fx for large metastatic brain tumors, whereas for tumors with a small number of small lesions, margin of about 1 mm was taken and a single irradiation at 20 Gy was performed. Treatment was rarely interrupted by patient movement, and it was able to be treated smoothly. In the only one case, it was not able to withstand compression by the mask, requiring sedation.

Conclusion: Even with fixation with a mask, the movement of the patient was unexpectedly small. The range of treatment could be expanded from fractionated irradiation to day treatment. Gamma Knife Icon was useful for widening the range of treatment.

Poster Display - Various

P153 : Bedside computed tomography in traumatic brain injury: Experience of 10,000 consecutive cases in neurosurgery at a level 1 trauma center in India

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Keywords: computed tomography and traumatic brain injury

Introduction: Patients with traumatic brain injury (TBI) need frequent computed tomography (CT) of the head for assessment and management. In view of the associated polytrauma, hemodynamic instability, and various
indwelling catheters and tubes, shifting of patients for CT scans may be difficult.

**Aims and Objectives:** To assess the role of mobile CT (Ceretom®; NeuroLogica Corporation, Boston, MA, USA) in a trauma center with respect to patient management.

**Materials and Methods:** In this retrospective study over 67 months (June 2009 to January 2015), the number of CT scans done, the time taken for CT and downtime were evaluated. Also, for the first 1000 mobile CT scans, the clinical and radiological records of all patients with TBI who underwent imaging using the mobile CT scanner in the intensive care units (ICUs) were analyzed.

**Observations and Results:** A total of 10,000 mobile CT scans were done on the mobile CT scanner till January 5, 2015. Of the first 1000 patients evaluated, 75.3% had severe TBI, 15.1% had moderate TBI, and 9.6% had mild TBI. 78.1% patients were on ventilator, with 80.2% requiring sedation and 8.4%, an inotropic support. An in situ intracranial pressure monitoring was present in 21.1% of patients. In all, 12.4% of patients had long bone fractures requiring skeletal traction; and, the tube thoracostomy was in-situ in 7.4%. No adverse events related to line malfunction/pullout occurred. The mean time for the performance of imaging using the mobile CT scan was 11.6 minutes compared with 47.8 minutes when patients were shifted to a conventional CT scan suite. The machine was nonfunctional 94 times, with an average downtime of 4.2 hours (range 2–72 hours). The lifecycle cost per mobile CT scan was Rs. 1340.

**Conclusions:** A mobile CT has considerably changed the management response time in the neurosurgical intensive care unit (ICU) setup and decreased patient transfer times and the associated complications. Inclusion of a mobile CT scanner in the armamentarium of a neurosurgeon as a “bedside tool” can dramatically change decision making and the response time. It should be considered as the standard of care in any largevolume emergency department or neurosurgical facility.

**Poster Display - Various**

**P154 : Is the hypothalamic hamartoma (HH) fine topography in hypothalamic complex predictive of clinical presentations severity and response to radiosurgery?**

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**Background:** HHS associated to epileptic comorbidity are highly variable from patient to patient in term of clinical presentation severity and quality of responds to Radiosurgery.

**Materials and Methods:** Between October 1999 and October 2007, 57 patients were investigated, included and treated by Gamma Knife in Timone University Hospital.

Inclusion criteria were: patients presenting with a conspicuous HH on their MRI scan, an ongoing or past history of gelastic seizure, the demonstration of drug resistance of the underlying epilepsy and patients being aged between 3 and 50. The parents (or patients when possible) were required to sign the informed consent. Exclusion criteria were: patients already included in another official trial, patients with a psychiatric disorder too severe to be amenable to radiosurgery and to allow satisfactory follow up, patients unable to carry out EEG recording with a minimum of one video-recorded seizure and pregnant women.

Follow up of more than 3 years was available for 48 patients.

We evaluated for each patient the electroclinical presentation and the severity of the epilepsy, the pattern of psychiatric comorbidity and the neuropsychological performances before the Radiosurgery. At the last follow up the quality of epileptic, psychiatric and cognitive improvement was assessed. The topography of the HHs, its extension to mammillary tuberal and supraoptic hypothalamic, its lateral extension contact to pituitary stalk were evaluated.

**Results:** Preliminary results are showing that all the patients have an involvement of the mammillary hypothalamus and mammillary bodies. All the patients with Precocious Puberty have HH involving the tuberal hypothalamus. Statistical study of the relationship between our anatomic parcellation and clinically relevant features will be presented.

**Conclusions:** Our preliminary data are demonstrating the importance of taking into account the precise
Topography and anatomical extension of HH in order to better predict clinical presentation, evolution, optimum surgical strategy and prognosis.

**Poster Display - Various**

**P155 : Initial experience with Cyberknife at Fundación Arturo López Pérez in Chile: Three cases with cervical schwannomas**


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In Santiago the first Cyberknife equipment (model M6) was installed at Fundación Arturo López Pérez in 2016. The first patient was treated on March 21, 2016.

So far sixty adults have received Cyberknife radiosurgery, intra and extracranial.

Interestingly three cases have been young adults (mean 35 years old, 2 female one man) with the diagnosis of cervical schwannomas. None of them has stigmata or diagnosis of Neurofibromatosis. Two patients had a confirmatory biopsy.

Since this treatment has not very extensively been published in the literature the aim of this work is to review the pathogenesis, incidence, diagnosis, radiology characteristics and treatment of spinal schwannomas and the possible indications, therapeutic doses and results of radiosurgery. A brief bibliographic review will be presented, specially a discrete number of case reports informing about radiosurgery treatments in similar cases.

We also will present our three treatments in detail, regarding contouring and doses.

In summary we will offer a review of an infrequent pathology treated with Radiosurgery and the characteristics surrounding it’s therapeutics.

For this complicated surgical location, radiosurgery presents as a reasonable and safe option for patients with symptomatic or enlarging schwannomas, clinically effective.

**Poster Display - Vascular**

**P156 : Dose distribution to the normal brain and radiological response in staged volume radiosurgery of large avms**

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**Keywords:** radiation, necrosis, radiosurgery

**Purpose:** The purpose of this study is to estimate the dose distribution to the normal brain parenchyma and radiological response following cyber knife Radiosurgery of large AVMs.

**Material and Methods:** A total of 15 patients were included in this study that underwent staged volume cyber knife Radiosurgery. All patients were pre-diagnosed for arterio-venous malformation (AVM), with a surgical and neuro interventional opinion. An immobilization device was made for every patient and then was performed a contrast enhanced Computed Tomography and Magnetic resonance Imaging. Tumor delineation was performed on Multiplan 4.0 with division of AVM nidus into two volumes.

**Results:** In our study included patients were 13(86.7%) male and 2(13.3%) female with mean age of 41 years with a mean AVM volume for first stage Radiosurgery of 12.44ml and a median volume of 11.20ml. however the second stage mean and median AVM volume stood, 12.99ml and 11.66ml respectively. The isodose line ranged from 73 to 81 for first stage of AVM and 62 to 82 for the second stage with a prescription dose of 16 Gy. The maximum normal brain volume 1643ml and a minimum volume of 1219ml. post Radiosurgery MRI T2 weighted hyper intensity was observed in 4(26.66%) patients which remained asymptomatic. No neurologic deficit or post contrast hyperintensity observed in the patients on follow-up MRI.

**Conclusion:** In a mean follow-up period of 6 months patients treated with staged volume technique at our institute were not observed with radiation induced necrosis or any neurologic deficit. The only complication was post radiation T2 weighted changes which were asymptomatic. In our patients with large AVMs staged volume Radiosurgery reduced the risk of radiation necrosis.
ISRS 2017

Poster Display - Vascular

P157: Stereotactic radiosurgery for intracranial dural arteriovenous fistulas: Its clinical and angiographic perspectives

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Keywords: Dural ∙ Arteriovenous fistula ∙ Gamma Knife ∙ Stereotactic radiosurgery

Background: To assess the efficacy of stereotactic radiosurgery (SRS) for intracranial dural arteriovenous fistulas (DAVFs), the authors retrospectively reviewed our 7-year experience. We evaluated obliteration rate, improvement in clinical symptoms, and complications.

Methods: Thirty patients with DAVF underwent SRS using Gamma Knife between 2009 and 2015. Twenty-three patients were treated with SRS alone and seven patients underwent SRS for residual or recurrent DAVFs after embolization or surgery. Chemosis, diplopia, and pulsating tinnitus were the most common symptoms. Median target volume was 2.9 cm³ (range, 0.8–13.6 cm³) and median radiation dose to the target was 17 Gy (range, 12–20 Gy). Median follow-up period was 33 months (range, 6–82 months).

Results: At the last neuroimaging follow-up, DAVFs were totally obliterated in 23 patients (77%), and subtotally in seven (23%). At the last clinical follow-up, 21 patients (70%) showed complete recovery and nine (30%) showed incomplete recovery in symptoms or signs. None experienced worsening symptoms or signs. Asymptomatic perilesional edema after SRS occurred in one patient (3%). Total obliteration rates after SRS were 43% at 1 year, 79% at 2 years, and 95% at 5 years. Improvement rates of neurological function after SRS were 12% at 1 month, 52% at 2 months, 72% at 3 months, and 96% at 6 months. A multivariate analysis revealed that Borden type 1 (p = 0.019, hazard ratio, 3.254, 95% confidence interval, 1.216-8.707) was significantly associated with symptom improvement.

Conclusions: SRS for intracranial DAVFs provided a high obliteration rate and a relatively low risk of radiation-induced complications. In selected benign cases without cortical venous drainage, SRS is a safe and effective treatment for symptom relief and fistula obliteration, even though the time course of improvement is longer than those of embolization and surgery.

Poster Display - Vascular

P158: Stereotactic radiosurgery for dural carotid cavernous sinus fistulas

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Keywords: Dural ∙ Carotid-cavernous sinus fistula ∙ Gamma Knife ∙ Stereotactic radiosurgery

Objective: We reviewed our 7-year experience to assess the efficacy of stereotactic radiosurgery (SRS) for dural carotid cavernous fistulas (DCCFs). We analyzed the clinical outcome, complications, and angiographic results.

Methods: We performed a retrospective analysis of 18 consecutive patients with DCCF treated by SRS alone using Gamma Knife between 2009 and 2015. Median target volume was 2.6 cm³ (range, 0.6–11.6 cm³) and median radiation dose to the target was 17 Gy (range, 14–19 Gy). Median follow-up period was 30 months (range, 6–65 months).

Results: Fifteen patients (83%) achieved a total obliteration of the DCCF and a subtotal obliteration of the DCCF was achieved in three patients (17%). Total obliteration rates after SRS were 53% at 1 year, 90% at 2 years, and 100% at 5 years. Twelve patients (67%) showed complete recovery from symptoms or signs and six patients (33%) showed incomplete recovery. Improvement rates of neurological function after SRS were 56% at 1 month, 72% at 3 months, and 94% at 6 months. None of the patients experienced radiation-related complications. A multivariate analysis revealed that absence of cortical venous drainage (p = 0.023, hazard ratio, 3.902, 95% confidence interval, 1.157-13.166) was significantly associated with symptom improvement.

Conclusion: SRS for DCCFs offered a high obliteration rate with low risk of radiation-induced complications. In patients with benign DCCFs that are not amenable to embolization or microsurgery, SRS is a safe and effective treatment for complete obliteration of the arteriovenous shunt and for improving the quality of life.

Poster Display - Vascular

P159: The outcomes of radiosurgery for arteriovenous malformations – Experience of a tertiary cancer centre from India

Sanjay Hunugundmath (1), Sumit Basu (1), Bhooshan Zade (1), Rahul Sharma (2), Ashok Bhanage (2), Sathiyanarayanan Vatyam (3)
Abstracts

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Keywords: Arteriovenous malformations, Stereotactic radiosurgery, Obliteration rates, Hemorrhage

Objectives: To assess the treatment outcomes in the patients diagnosed with arteriovenous malformations (AVMs) treated by LINAC based stereotactic radiosurgery (SRS).

Methods and Materials: We retrospectively analyzed 30 patients diagnosed with AVM treated with LINAC based radiosurgery between 2008 to 2016. Male to female ratio was 23:7. Out of 30 patients 18 patients had only SRS, 12 patients had oxymolization followed by SRS. There were 9 (30%) patients with hemorrhages, 5 patients (17%) presented with neurological deficits. The median age at presentation was 30 years (range 14-60 years). The median PTV volume was 6.8 cc (range 0.9 - 54 cc). The median dose prescribed was 18 Gy (range 16 – 24 Gy). Modified radiosurgery based AVM grading score was calculated for all the patients. The median modified AVM score was 1.47 (range 0.5 - 5.68). The follow up was done by clinical examination as well as serial MRI angiography or DSA for all the patients.

Results: The median follow of the entire cohort was 60 months (range 24-96 months). The obliteration rates for patients followed up for 3 years and 5 years was 75% and 86.1% respectively. The obliteration rates based on Modified radiosurgery based AVM grading scale for a score of ≤ 1, > 1 to ≤ 2, and > 2 was 84.7%, 60% and 54% respectively. On Logistic regression, there was no statistical correlation between obliteration rates and AVM score, but there was a trend favouring better obliteration rates for AVM score of ≤ 1. On univariate analysis, age (<35 years) (p=0.007) and PTV volume (< 7 cc) (p=0.04), had better obliteration rates. 3 patients had hemorrhage, from the AVM after irradiation. None of them were fatal. 3 patients had neurological deficits post irradiation which was reversible.

Conclusion: SRS is a preferred non invasive treatment modality for younger group of patients (<35 years) and for smaller volume AVM (<7 cc), with acceptable morbidity. Patients with low modified radiosurgery based AVM score have better obliteration rates, though more patient numbers and long term follow up is warranted for better outcomes with SRS.

Poster Display - Vascular

P160 : Unusual late complications after Gamma knife radiosurgery for AVM

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Keywords: Gamma knife radiosurgery, dural arteriovenous fistula, growing organized hematoma

Objective: To evaluate late complications after Gamma knife radiosurgery (GKRS) for cerebral arteriovenous malformation (AVM) other than delayed cyst formation or signal change in MRI.

Methods and Materials: Between May 1992 and June 2012, 844 GKRS was done for cerebral AVMs. We retrospectively analyzed our data and evaluated any complications 3 years after GKRS.

Results: Among 844 procedures, 2 cases (0.2%) of dural arteriovenous fistula and 11 cases (1.3%) of growing organized hematoma were noted. DAVF was emerged at 16 and 36 months each. Growing organized hematoma was emerged at mean 14.4 years (range 7.6 – 24.4) after 1st GKRS. Eight among 11 patients under went open craniotomy for the removal operation, and 9 patients had repeated GKRS for the remnant AVMs (2 times: 6, 3 times: 1, 4 times: 2).

Conclusions: Late complications after GKRS for cerebral AVMs are well known though the incidence is low. We recommend long-term follow-up of patients who undergo GKRS for cerebral AVMs, since cyst formation or expanding hematoma could be emerged irrespective of obliteration status. Once these delayed lesions emerged, the follow-up should be done with caution, and it seems that early operative management is needed than conservative especially for the growing organized hematoma.

Poster Display - Vascular

P161 : The Bleeding Risk in using SRS to treat AVM

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Keywords: Gamma knife radiosurgery, dural arteriovenous fistula, growing organized hematoma

Objective: To evaluate late complications after Gamma knife radiosurgery (GKRS) for cerebral arteriovenous malformation (AVM) other than delayed cyst formation or signal change in MRI.

Methods and Materials: Between May 1992 and June 2012, 844 GKRS was done for cerebral AVMs. We retrospectively analyzed our data and evaluated any complications 3 years after GKRS.

Results: Among 844 procedures, 2 cases (0.2%) of dural arteriovenous fistula and 11 cases (1.3%) of growing organized hematoma were noted. DAVF was emerged at 16 and 36 months each. Growing organized hematoma was emerged at mean 14.4 years (range 7.6 - 24.4) after 1st GKRS. Eight among 11 patients under went open craniotomy for the removal operation, and 9 patients had repeated GKRS for the remnant AVMs (2 times: 6, 3 times: 1, 4 times: 2).

Conclusions: Late complications after GKRS for cerebral AVMs are well known though the incidence is low. We recommend long-term follow-up of patients who undergo GKRS for cerebral AVMs, since cyst formation or expanding hematoma could be emerged irrespective of obliteration status. Once these delayed lesions emerged, the follow-up should be done with caution, and it seems that early operative management is needed than conservative especially for the growing organized hematoma.
Keywords: AVM, Rebleed

Stereotactic radiosurgery (SRS) is useful in treating small AVM, especially when the nidus of the AVM is compact. However, it does not offer protection from AVM rupture during the latent period before the obliteration of the malformation. This study addressed the risk of AVM rupture after SRS, cyberrknife, treatment.

Method: We reviewed all patients with AVM treated with SRS from July 2010 to September 2013 in a single institution. We evaluated the efficacy of the treatment, the complication rate, symptom reduction, and bleeding/re-bleeding rate.

Results: The study population included 13 patients; Eleven of these patients had prior bleed. The median age was 41.5 years (11-67). The median Spetzler-Martin grade was 3 (2-4). The median prescription dose was 16.5 Gy (16-18.5). The median target volume was 9.0 cm³ (3.50-18.26). All but two are treated with a single session; two patients were treated with volume staging. The median follow up was 3.7 years (mean 3.3+/- 1.5). Six of the treated AVM obliterated after single treatment (50%) including the one that had volume staging. One AVM was partially obliterated with a small residual nidus. The median time to response was 16 months (range 9-29) The median time to obliteration was 45 (14-52). Two of the treated AVM ruptured at 6 and 13 months after treatment, both of these events were rebleed. We estimated the odds ratio of symptom reduction is 0.055 (95%CI 0.0029-1.050, p=0.026) and a Risk ratio of 0.28 (95% CI 0.077-1.010, p=0.036) in favor of bleed reduction.

Conclusion: This a small study lacking the statistical power. But, it underscores the usefulness of SRS as an effective therapeutic option, and the peril of catastrophic bleed. Even then, the annual bleeding rate in the latent period after SRS is estimated to be 5.2% /yr, and the rebleed rate of 8.6%/yr. These are very compatible to those reported in the literature.

Poster Display - Vascular

P162 : Increased association of hemorrhage with repeat Cyberknife SRS for incompletely obliterated arteriovenous malformation

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Keywords: CyberKnife, stereotactic radiosurgery, arteriovenous malformation, partial obliteration, repeat treatment, hemorrhage

Objective: Arteriovenous malformations (AVM) initially treated by stereotactic radiosurgery (SRS) can be further treated with repeat SRS, embolization, and open surgery. Whether a minimally invasive SRS-retreatment strategy yields the safest long-term results has yet to be determined. We investigate how the hemorrhage rate following repeat CyberKnife SRS compares to that of other treatment strategies.

Methods: A single-institution retrospective review was conducted over the period spanning February 2002 to August 2013, during which we identified 114 patients who underwent primary treatment for AVM, among whom 13 received repeat SRS and four received an alternative adjuvant therapy (embolization or open surgery). Patients undergoing repeat SRS were treated with a median single fraction at a prescription dose of 19 Gy and a median max dose of 24.7 Gy.

Results: Patients were followed for a median 20.6 months after treatment of lesions measuring a median 2.9 cm (0.8 – 8.0 cm) and a median Spetzler-Martin grade 3 (1-5). There were 42.4% who had previously experienced hemorrhage. Prior to the repeat SRS session, half (50%) of the patients had undergone embolization treatment and 21% had undergone open surgery. At first follow-up, 7.8% were with radiographic evidence of obliteration and 33% with partial obliteration. Among those with repeat SRS and no additional intervention, 30.7% (4/13) and 2% (2/101) experienced subsequent hemorrhage (p = 0.002), respectively, with repeat SRS being the only significant predictor in our cohort. Repeat SRS did not predict obliteration.

Conclusions: Our experience with repeat SRS for incompletely obliterated AVM after primary SRS suggests there are subpopulations that may exhibit an increased rate of hemorrhage. Meanwhile, this elevated hemorrhage rate is on par with the already high overall hemorrhage rate from prior to retreatment, perhaps indicating a continuation of AVM-natural history. Thus, ongoing studies with larger cohorts are needed to identify the individual risk factors or optimal sequence of treatment modalities that will lead to safe obliteration of these complex lesions.
Poster Display - Vascular

**P163 : Comparative analysis of clinical outcome and dosimetric characteristics in the treatment of large or giant cerebral AVM using stereotactic radiosurgery**

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**Keywords:** stereotactic radiosurgery, Comparative analysis, large or giant cerebral AVM

**Objectives:** The aim of this study is to analyze the dosimetric characteristics which are relevant to clinical outcome in treatment of large and giant cerebral arteriovenous malformations (AVMs) using single (SRS) and hypofraction (HFRS) stereotactic radiosurgery.

**Methods:** Since December 2005 to April 2015, a total of 17 patients with large (10-15cm³, n=9) and giant (>15 cm³, n=8) AVMs were included in this study. For large cerebral AVMs with median target volume of 13.3 cm³, SRS was performed and HFRS was performed for giant cerebral AVMs with median volume of 37.0 cm³. Clinical features including demographic features, type of nidus, angiographic features, obliteration rate, complication rate and radiosurgery-based modified AVM score were comparatively evaluated with dosimetric features, GTV and BED. The 12 patients of 17 patients were followed more than 12 months. Median follow-up period was 36 months (range, 15-104 months).

**Results:** Complete obliteration was achieved in 3 cases with SRS and 3 cases with HFRS. Mean modified AVM score was 1.86 (range 1.4-2.31) in SRS group and 4.73 (range 2.49-8.32) in HFRS group. Obliteration rate showed significantly proportional distribution according to the prescription dose (BED>126), and showed inverse distribution according to the modified AVM score (>3.0). Complications are one radiation necrosis with cyst formation,

**Conclusions:** Although the optimal therapeutic strategies are still remaining great challenge to achieve successful obliteration with low complication, multi-modal approaches with volume staged SRS was expecting to overcome the obstacle of the intractable large cerebral AVM.