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BIBLIOGRAPHY

Leksell Gamma Knife® Radiosurgery Bibliography

Meningioma

2012–2020

≥ 30 patient cohorts

Includes Gamma Knife-focused abstracts posted to PubMed during 2012 to 2020

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2020

[1] Long-term results of gamma knife radiosurgery for foramen magnum meningiomas.

Neurosurg Rev. 2020 Nov 26. pii: 10.1007/s10143-020-01446-5.
Akyoldas G, Samanci Y, Yilmaz M, Sengoz M, Peker S
PMID: 33244665 DOI: 10.1007/s10143-020-01446-5

Outcomes of 37 patients of foramen magnum meningioma (FMM) were evaluated, and the related literature was reviewed to determine the efficacy of Gamma Knife radiosurgery (GKRS) for treating patients with FMM. We present the largest series reported from a single institution with the longest follow-up to date. The database of patients who underwent GKRS for FMM between 2007 and 2019 was evaluated retrospectively. A total of 37 patients with radiological and pathological features consistent with FMM were included in this series. Thirty-three patients were female, and 4 were male. The median age was 58 years (range, 23-74 years). The most common symptom at diagnosis was headache (64.9%). Twelve patients had a history of microsurgical resection. The median duration from the initial onset of symptoms to GKRS was 12 months (range 1-140 months). Among the 37 tumors, eight (21.6%) were located ventrally, 24 (64.9%) laterally, and five (13.5%) dorsally. The median target volume was 3.30 cm(3) (range, 0.6-17.6 cm(3)). Thirty-five patients (95%) were treated with single fraction GKRS, and two patients (5%) were treated with hypofractionated GKRS. The median clinical follow-up was 80 months (range, 18-151 months), while the median radiological follow-up was 84 months (range, 18-144 months). At the last clinical follow-up after GKRS, 27 patients (73%) had improved symptoms, and none had worsened pre-GKRS symptoms. At the last radiological follow-up after GKRS, 23 tumors (62.2%) remained stable, 13 (35.1%) decreased in size, and 1 (2.7%) increased in size. Tumor control, including stable and regressed tumors, was achieved in 97.3% of patients. Our cohort demonstrates that GKRS is an effective and safe treatment for patients with either primary or recurrent/residual FMM.

[2] Outcomes from treatment of asymptomatic skull base meningioma with stereotactic radiosurgery.

Acta Neurochir (Wien). 2020 Nov 19. pii: 10.1007/s00701-020-04648-4.
Pikis S, Bunevicius A, Sheehan J
PMID: 33211178 DOI: 10.1007/s00701-020-04648-4

BACKGROUND: Optimal management of asymptomatic skull base meningiomas is controversial. We evaluated the safety and efficiency of Gamma Knife radiosurgery (GKRS) for the management of asymptomatic skull base meningiomas. **METHODS:** This retrospective study involved patients managed with GKRS for asymptomatic, skull base meningiomas from 1997 to 2019. Patient clinico-radiologic data, tumor characteristics, and procedural details were analyzed. Favorable outcome was defined as lack of procedure-related mortality or permanent neurologic morbidity and radiologic evidence of tumor control. Tumor progression and regression were defined as an increase or decrease of > 20% in volume from baseline to the last neuroimaging study respectively. Tumor volumes within +/- 20% of baseline volume were considered stable. **RESULTS:** Thirty-seven patients (30 women), median age 68 years old (range 42-83 months) were managed with a single-session GKRS for 40 asymptomatic, skull base meningiomas. At a median clinical follow-up of 58.5 months (range 14-150 months), no mortality associated with the procedure or the treated tumor was noted. Permanent neurologic morbidity was 2.75%. There was a statistically significant decrease in mean tumor volume ($p < 0.001$) from 4.04 cc (SD 3.09 cc) prior to radiosurgery to 2.73 cc (SD 2.24 cc) at last follow-up. Higher margin dose was associated with tumor regression at last follow-up (HR = 1.351; 95%CI [1.094-1.669]; $p = 0.05$). **CONCLUSION:** As compared to natural history studies, GKRS affords long-standing tumor control and neurologic preservation in the vast majority of patients treated for asymptomatic, skull base meningiomas. Further study is necessary to identify the optimal management of asymptomatic skull base meningiomas.

[3] Treatment Outcome of Gamma Knife Radiosurgery for Petroclival Meningiomas: Retrospective Analysis of a Single Institution Experience.

Brain Tumor Res Treat. 2020 Oct;8(2):83-92.
Ha MH, Jang WY, Jung TY, Kim IY, Lim SH, Moon KS, Jung S
PMID: 33118341 DOI: 10.14791/btrt.2020.8.e16

BACKGROUND: Although Gamma Knife radiosurgery (GKRS) has been widely used for intracranial meningiomas as an alternative or adjuvant treatment, guidelines have not been established for the selection of patients with petroclival meningioma (PCM) for GKRS. In this study, we reported the factors related to tumor progression and postoperative complications in PCM patients treated by GKRS, with a review of the literatures. **METHODS:** Between 2004 and 2019, 64 patients (52 patients for alternative and 12 patients for adjuvant treatment) with PCM underwent GKRS in our institution. The clinical and radiological factors were retrospectively analyzed. The mean radiologic follow-up duration was 58.4 months (range, 6-164 months). The mean tumor volume and diameter before GKRS were 13.4 cm(3) and 2.9 cm, respectively. The median marginal dose was 12 Gy (range, 10-14 Gy) with a 50% median isodose line. Fractionation was used in 19 cases (29%, two fractionations in 5 cases & three fractionations in 14 cases). **RESULTS:** Progression was noted in 7 cases (10.9%) and the progression-free survival rates were 91.1% at 5 years and 69.6% at 10 years. Although large in volume, moderate to severe peritumoral edema and male gender were somewhat related to progression, they did not reach statistical significance. Ten patients (15.6%) developed complications after GKRS. The most common complication was cranial nerve deficit (n=8), followed by hemiparesis, cognitive dysfunction, and hydrocephalus. Large size (maximal diameter >/=5 cm) [hazard ratio (HR) 0.091, 95% confidence interval (CI) 0.014-0.608; p=0.013] and multiplicity (HR 0.102, 95% CI 0.018-0.573; p=0.009) were independent factors for developing complications after GKRS. **CONCLUSION:** GKRS can be considered an effective and safe treatment for large-volume PCM. However, for patients with large size or multiple masses, the treatment method should be determined with caution because the probability of complications after GKRS may increase.

[4] Ten-year follow-up after Gamma Knife radiosurgery of meningioma and review of the literature.

Acta Neurochir (Wien). 2020 Sep;162(9):2183-2196.
Lippitz BE, Bartek J Jr, Mathiesen T, Forander P
PMID: 32591948 DOI: 10.1007/s00701-020-04350-5

OBJECTIVES: With regard to the generally slow growth of meningioma, it is essential to analyse clinical treatment results in a long-term perspective. The purpose of the present analysis is to provide clinical data after Gamma Knife radiosurgery of meningioma in a 10-year perspective together with a review of the current literature. **METHODS:** The current study is a retrospective analysis of 86 consecutive Swedish patients with meningiomas treated using Gamma Knife radiosurgery at the Karolinska Hospital Stockholm between March 1991 and May 2001. A total of 130 tumours were treated in 115 treatment sessions. The median radiological follow-up was 10 years (1.8-16.5 years), and the median clinical follow-up was 9.4 years (2.1-17.4 years). **RESULTS:** After a median follow-up period of 10 years, local tumour control was achieved in 87.8% of meningiomas (108/123 tumours). The median latency between initial treatment and local (in-field) recurrence (n = 15) was 5.8 years (1.9-11.5). Recurrences adjacent but outside the initial radiation field occurred in 15.1% of patients (13/86) at a median of 7.5 years (1.3-15.7). New meningiomas were seen in 10.5% after a median of 5.4 years (0.9-10.8). In 72% of patients, no further treatment was required, 17.4% (15/86) underwent a second Gamma Knife treatment, 4.7% (4/86) required later open surgery and 5.8% (5/86) required both secondary treatments. Eighty-six percent of patients were neurologically unchanged or improved. A significantly lower rate of local (in-field) recurrences was seen in meningiomas treated with a prescription dose of > 13.4 Gy (7.1% vs. 24%, $p = 0.02$). **CONCLUSIONS:** The current retrospective analysis provides a 10-year follow-up and comprises one of the longest available follow-up studies of radiosurgically treated meningiomas. The current series documents a persistent high local tumour control after Gamma

Knife treatment, while providing an estimation of a necessary minimum dose for long-term tumour control in meningiomas. The study confirms the validity of previous short-term data in a long-term perspective.

[5] Initial Gamma Knife Radiosurgery for Large or Documented Growth Asymptomatic Meningiomas: Long-Term Results From a 27-Year Experience.
Front Oncol. 2020 Nov 24;10:598582.
Fu J, Wu L, Peng C, Yang X, You H, Cao L, Deng Y, Yu J
PMID: 33330094 DOI: 10.3389/fonc.2020.598582
OBJECTIVE: The aims of this study were to investigate the long-term outcomes of initial Gamma Knife radiosurgery (GKRS) for large (>/=20 mm) or documented growth asymptomatic meningiomas. **DESIGN AND METHODS:** This was a single-center retrospective study. Fifty-nine patients with large (>/=20 mm) or documented growth asymptomatic meningiomas undergoing initial GKRS were enrolled. The median age was 56 (range, 27-83) years. The median time of follow-up was 66.8 (range, 24.6-245.6) months, and the median tumor margin dose was 13.0 Gy (range, 11.6-22.0 Gy). **RESULTS:** Tumors shrunk in 35 patients (59.3%) and remained stable in 23 (39.0%). One patient (1.7%) experienced radiological progression at 54 months after GKRS. The PFS was 100%, 97%, and 97% at 3, 5, and 10 years, respectively. Nine patients (15.3%) occurred new neurological symptoms or signs at a median time of 8.1 (range, 3.0-81.6) months. The symptom PFS was 90% and 78% at 5 and 10 years, respectively. Fifteen patients (25.4%) occurred peritumoral edema (PTE) at a median time of 7.2 (range, 2.0-81.6) months. One patient underwent surgical resection for severe PTE. In univariate and multivariate analysis, Only tumor size (>/=25 mm) and maximum dose (>/=34 Gy) were significantly associated with PTE [hazard ratio (HR)= 3.461, 95% confidence interval (CI)=1.157-10.356, p=0.026 and HR=3.067, 95% CI=1.068-8.809, P=0.037, respectively]. **CONCLUSIONS:** In this study, initial GKRS can provide a high tumor control rate as well as an acceptable rate of complications in large or documented growth asymptomatic meningiomas. GKRS may be an alternative initial treatment for asymptomatic meningiomas.

[6] Comparison of clinical outcomes in patients who underwent Gamma Knife radiosurgery for parasellar meningiomas with or without prior surgery.
BMC Neurol. 2020 Apr 24;20(1):153.
Hu YJ, Xie YB, Zhang LF, Ding C, Chen J
PMID: 32331512 DOI: 10.1186/s12883-020-01731-2
BACKGROUND: Parasellar meningioma is a common benign tumour in brain. Both surgery and radiosurgery are important treatment modalities for this tumour. The study was designed to investigate whether prior surgery would affect treatment outcomes of patients with parasellar meningiomas after management with Gamma Knife radiosurgery. **METHODS:** A total of 93 patients who received Gamma Knife surgery were included in this retrospective study. There were 30 males and 63 females, with a median age of 48.6 years (range, 15.2-78.7 years). Prior surgery was performed in 45 patients. The median tumor volume was 5.02 cm(3) (range 1.07-35.46 cm(3)) and median marginal dose was 12 Gy (range 10-15 Gy). The mean imaging follow-up and clinical follow-up periods were 40.7 and 52.7 months, respectively. **RESULTS:** In the group without prior surgery, 31 patients had improvement of preexisting symptoms; and in the group with prior surgery, 20 patients were noted to improve. The difference in symptom improvement between the two groups reached statistical significance (P = 0.009). Patients with prior surgery were more likely to have stable symptoms after Gamma Knife surgery (P = 0.012). Tumor recurrence was reported in 8 patients out of 45 patients with prior surgery, and 3 patients out of 48 patents without prior surgery (P = 0.085). After Gamma Knife surgery, 5 and 4 patients in two groups developed new neurological symptoms, respectively (P = 0.651). Cox regression analysis identified follow-up period as prognostic factor of progression-free survival. Ordinal logistic regression analysis identified surgery prior to Gamma Knife surgery as an unfavorable factor of symptom change. **CONCLUSION:** Gamma Knife radiosurgery provided long-term effective tumor control and better symptom recovery compared with those with prior surgery. Patients with surgery before Gamma Knife radiosurgery were more likely to have stable symptoms. Further analyses indicated that long follow-up is essential to determine the efficacy of radiosurgery for parasellar meningiomas. Further study needs to include more patients with longer follow-up to draw a more solid conclusion.

[7] Gamma Knife Radiosurgery for Anterior Clinoid Process Meningiomas: A Series of 61 Consecutive Patients.
World neurosurgery. 2020;133:e529-e534
Akyoldas G, Hergunsel OB, Yilmaz M, Sengoz M, Peker S
PMID: 31562964 DOI: 10.1016/j.wneu.2019.09.089
OBJECTIVE: Gamma Knife radiosurgery (GKRS) outcomes for anterior clinoid process (ACP) meningiomas have not been specifically reported within any meningioma series. We present the initial and largest series in the literature that describes the presenting features, radiosurgery parameters, and radiologic and long-term clinical outcomes for 61 patients with ACP meningiomas treated with GKRS. **METHODS:** Medical records were reviewed for 61 consecutive patients at a single center who underwent GKRS for ACP meningioma between 2008 and 2016. **RESULTS:** Of 61 patients with ACP meningiomas, 49 (80%) were treated with GKRS as primary treatment, and 12 (20%) were treated with GKRS as an adjuvant therapy. Before GKRS, 29 patients presented with visual impairment and 50 patients presented with headache. Median patient age was 54.9 years. Median tumor volume was 3.2 cm(3), and median margin dose was 12.0 Gy. The median radiologic follow-up time after GKRS was 75 months. During follow-up, tumor volume regressed in 37 cases (61%) and remained unchanged in 24 cases (39%). None of the patients experienced tumor volume progression. Tumor volume <3 cm(3) was an independent predictor of tumor volume regression after GKRS (univariate analysis, P = 0.047; multivariate analysis, P = 0.049). Of 29 patients who presented with visual impairment, 16 (55%) improved after GKRS. None of the 61 patients developed new neurologic deficits after GKRS. **CONCLUSIONS:** GKRS provides a high rate of tumor volume control for ACP meningiomas as well as a low complication rate. Excellent tumor volume control was associated with smaller tumor size only.

2019

[8] Gamma Knife stereotactic radiosurgery for cerebellopontine angle meningioma.
Clinical neurology and neurosurgery. 2019;187:105557
Jahanbakhshi A, Azar M, Kazemi F, Jalessi M, Chanideh I, Amini E
PMID: 31731053 DOI: 10.1016/j.clineuro.2019.105557
OBJECTIVE: Meningiomas comprise 6-15 % of cerebellopontine angle (CPA) tumors. Surgical treatment is a real challenge because this area is occupied by several critical neurovascular elements. Currently, surgery is the first choice of treatment, however several factors may be present that necessitate choosing the alternative treatments such as Gamma Knife Stereotactic Radiosurgery (GKS). **PATIENTS AND METHODS:** Ninety-three patients with CPA meningioma who were treated by GKS for a period of 8 years, were retrospectively reviewed. Factors affecting clinical and radiological improvement were analyzed. **RESULTS:** The median tumor volume was 6cm(3). The mean values for maximal and marginal dose were 20.2 and 13.6Gy, respectively. The mean follow-up time was 31.5 months. Tumor control (lack of progression) was achieved in 96.8% of the patients and 55.9% of the patients showed tumor regression on follow-up MRI. The actuarial 3-year progression-free survival (PFS) rate was 96%. Clinical improvement was seen in 49.5% of the patients while 11.8% experienced worsening or new-onset symptoms. Adverse radiation effects were seen in 4.3% of the patients. A worse symptomatic outcome, male sex, a lower tumor coverage, and marginal doses <13.5Gy were associated with worse radiologic outcomes. Worse radiologic outcomes and higher tumor volumes, especially tumor volumes >/=8.5cc, were

associated with worse symptomatic outcomes. The male sex was associated with a lower PFS. **CONCLUSION:** Gamma Knife radiosurgery, either primarily or post-operatively, offers a decent long-term tumor control in CPA meningioma, and is associated with an acceptable complication profile, especially in tumors with lower volumes.

[9] Gamma Knife Radiosurgery for Postoperative Remnant Meningioma: Analysis of Recurrence Factors According to World Health Organization Grade.
World neurosurgery. 2019;132:e399-e402
Park CK, Jung NY, Chang WS, Jung HH, Chang JW
PMID: 31476462 DOI: 10.1016/j.wneu.2019.08.136
OBJECTIVE: The effectiveness of tumor control after Gamma Knife radiosurgery (GKS) for intracranial meningioma is well established. Moreover, GKS is an alternative to reduce surgical-remnant meningioma recurrence. Nevertheless, the tumor can recur even after GKS and is associated with its histologic malignancy. We here investigated the risk factors associated with recurrence from remnant lesions after GKS, assessing recurrence patterns according to histological grades. **METHODS:** From January 2007 to January 2017, 218 patients underwent GKS for surgical-remnant lesions. To evaluate post-GKS lesion recurrence, pre-GKS magnetic resonance images were compared with those at follow-up. We retrospectively analyzed the histologic classification of meningioma and patients' clinical characteristics (sex, age, tumor location, target volume, and prescription dose). **RESULTS:** Of the 218 patients, 13 (5.9%) developed post-GKS recurrence within a mean follow-up period of 37.4 months. The recurrence patterns were as follows: adjacent to the 50% marginal-dose field (9 patients); within the 50% marginal-dose field (2 patients); and outside the field (2 patients). Six of 196 World Health Organization grade I meningioma cases, 6 of 20 grade II cases, and 1 of 2 grade III cases developed recurrence. Thus 32% of high-grade meningioma cases (grades II and III) developed recurrence during the follow-up period. Histologic grade was significantly associated ($P < 0.001$) with recurrence. **CONCLUSIONS:** The study findings indicate that the post-GKS meningioma recurrence likelihood is high when the meningioma has malignant histologic features. In addition, considering the recurrence patterns, it is important to define a precise target for GKS.

[10] Treatment of Asymptomatic Meningioma With Gamma Knife Radiosurgery: Long-Term Follow-up With Volumetric Assessment and Clinical Outcome.
Neurosurgery. 2019;85(5):E889-E899
Gupta A, Xu Z, Cohen-Inbar O, Snyder MH, Hobbs LK, Li C, Nguyen QT, Sheehan JP
PMID: 31062018 DOI: 10.1093/neuros/nyz126
BACKGROUND: Some patients are diagnosed with asymptomatic meningioma(s) after undergoing a screening CT and MRI for minor ailments or postresection. **OBJECTIVE:** To help clinicians in decision making for treatment of asymptomatic meningiomas. **METHODS:** A single center retrospective cohort study of 117 patients with 122 tumors treated with Gamma Knife radiosurgery (GKRS; Elekta AB, Stockholm, Sweden). Patients were followed with longitudinal imaging and clinical evaluations. Tumor volumetry and developments of new signs or symptoms after GKRS were the end points in the study. **RESULTS:** Median patient age at GKRS was 60 yr (range 21-86 yr) with a median clinical follow-up of 53 mo (range 20-252 mo). The median pre-GKRS tumor volume was 3.6 +/- 3.8 cc (+/-standard deviation). Tumors were treated with a median margin dose of 14 +/- 2 Gy. At last follow-up, median tumor volume was 2.5 +/- 3.6 cc. Radiological progression-free survival (PFS) rates were 97% and 94.4% at 5 yr and 10 yr, respectively. Clinical PFS rates were 86% and 70% at 5 yr and 10 yr, respectively. Development of neurological complications was seen in 21 (18%) patients, and 11 (52%) of them had undergone surgical resection prior to GKRS. **CONCLUSION:** GKRS is a reasonable treatment strategy for asymptomatic meningiomas and compares favorably to natural history studies in terms of tumor control and neurological preservation. It results in relatively low morbidity in previously untreated meningiomas and serves as an appealing alternative treatment modality for recurrent meningiomas in asymptomatic patients.

[11] Factors Associated with Treatment Failure and Radiosurgery-Related Edema in WHO Grade 1 and 2 Meningioma Patients Receiving Gamma Knife Radiosurgery.
World neurosurgery. 2019;130:e558-e565
O'Connor KP, Algan O, Vesely SK, Palejwala AH, Briggs RG, Conner AK, Cornwell BO, Andrews B, Sughrue ME, Glenn CA
PMID: 31299310 DOI: 10.1016/j.wneu.2019.06.152
BACKGROUND: Before the advent of radiosurgery, neurosurgical treatment of meningiomas typically involved gross total resection of the mass whenever surgery was deemed possible. Over the past 4 decades, though, Gamma Knife radiosurgery (GKRS) has proved to be an effective, minimally invasive means to control the growth of these tumors. However, the variables associated with treatment failure (regrowth or clinical progression) after GKRS and GKRS-related complications, such as cerebral edema, are less well understood. **METHODS:** We retrospectively collected data between 2009 and 2018 for patients who underwent GKRS for meningiomas. After data collection, we performed univariate and multivariable modeling of the factors that predict treatment failure and cerebral edema after GKRS. Hazard ratios (HR) and P values were determined for these variables. **RESULTS:** Fifty-two patients were included our analysis. The majority of patients were female (38/52,73%), and nearly all patients presented with a suspected or confirmed World Health Organization grade 1 meningioma (48/52, 92%). The median tumor volume was 3.49 cc (range, 0.22-20.11 cc). Evidence of meningioma progression after treatment developed in 5 patients (10%), with a median time to continued tumor growth of 5.9 months (range, 2.7-18.3 months). In multivariable analysis, patients in whom treatment failed were more likely to be male (HR = 8.42, P = 0.045) and to present with larger tumor volumes (HR = 1.27, P = 0.011). In addition, 5 patients (10%) experienced treatment-related cerebral edema. On univariate analysis, patients who experienced cerebral edema were more likely present with larger tumors (HR = 1.16, P = 0.028). **CONCLUSIONS:** Increasing meningioma size and male gender predispose to meningioma progression after treatment with GKRS. Increasing tumor size also predicts the development of postradiosurgery cerebral edema.

[12] Gamma Knife Radiosurgery for Patients with Multiple Intracranial Meningiomas.
World neurosurgery. 2019;128:e495-e500
Chen W, Wang X, Liu F, Chen J
PMID: 31048056 DOI: 10.1016/j.wneu.2019.04.184
OBJECTIVE: The aim of this study was to evaluate the safety and efficacy of Gamma Knife radiosurgery (GKRS) in patients with multiple intracranial meningiomas (MIMs). **METHODS:** The authors performed a retrospective analysis of 42 consecutive patients (7 men and 35 women) with MIMs who underwent GKRS. The median age of the patients at the time of GKRS was 57.5 years (range, 27-77 years). A total of 115 tumors among 42 patients were identified through imaging or postoperative histopathologic examination, of which 90 were treated with GKRS. **RESULTS:** Follow-up imaging studies were available for 75 tumors in 36 patients (83.3%), with a mean follow-up period of 45.0 months (range, 6.6-90.4 months); 41 patients (97.6%) received clinical follow-up for 16.7 to 106.7 months (average, 57.1 months). Local tumor control was achieved in 68 tumors (90.7%) at the last follow-up. On univariate analysis, surgical resection before GKRS more than once ($P = 0.048$) and high World Health Organization (WHO) classification (grades II and III) ($P = 0.001$) were associated with tumor progression. Patients with worsening clinical manifestation showed correlation with peritumor edema ($P < 0.001$) and had >2 lesions treated by GKRS ($P < 0.001$) on univariate analysis. **CONCLUSIONS:** GKRS is a safe and effective treatment for MIMs. Variables including surgical resection before GKRS more than once, high grade WHO classification, peritumor edema, and >2 tumors treated by GKRS are predictors of unfavorable outcome after GKRS.

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[13] Tumor Control and Cranial Nerve Outcomes After Adjuvant Radiosurgery for Low-Grade Skull Base Meningiomas.
World neurosurgery. 2019;127:e221-e229
Faramand A, Kano H, Niranjan A, Park KJ, Flickinger JC, Lunsford LD
PMID: 30880202 DOI: 10.1016/j.wneu.2019.03.052
OBJECTIVE: We evaluated the tumor control and cranial nerve (CN) outcomes after adjuvant stereotactic radiosurgery (SRS) for petroclival, cavernous sinus, and cerebellopontine angle meningiomas. **METHODS:** From our prospectively maintained database of 2022 patients with meningioma who had undergone Leksell SRS during a 30-year interval, we found 43 patients with petroclival, 94 with cavernous sinus, and 13 patients with cerebellopontine angle meningiomas who had undergone adjuvant SRS after surgical resection of the meningioma. The patients included in the present report had had >/=1 CN deficit at the initial presentation and a minimum follow-up period of 12 months. The median age at SRS was 54 years (range, 22-81). SRS was performed for residual tumor in 104 patients (69%) and recurrent tumor in 46 patients (31%). The median tumor volume treated with SRS was 8.1 cm(3) (range, 0.3-42), and the median margin dose was 13 Gy (range, 10-20). **RESULTS:** Tumor control was achieved in 135 patients (90%) at a median follow-up point of 75 months. The progression-free survival rate after SRS was 99.5% at 1 year, 98% at 3 years, 95% at 5 years, and 90% at 10 years. Overall, 29 of the 150 patients (19%) reported improvement in CN function. Deterioration in CN function after SRS developed in 15 patients (10%). The rate of deterioration was 3.5% at 1 year, 5.5% at 3 years, and 7% at 5 years. **CONCLUSIONS:** Adjuvant SRS provides effective tumor control and a low rate of new or worsening CN deficits.

[14] Gamma Knife radiosurgery for intracranial benign meningiomas: follow-up outcome in 130 patients.
Neurosurgical focus. 2019;46(6):E7
Ge Y, Liu D, Zhang Z, Li Y, Lin Y, Wang G, Zong Y, Liu E
PMID: 31153153 DOI: 10.3171/2019.3.FOCUS1956
OBJECTIVE: The authors retrospectively analyzed the follow-up data in 130 patients with intracranial benign meningiomas after Gamma Knife radiosurgery (GKRS), evaluated the tumor progression-free survival (PFS) rate and neurological function preservation rate, and determined the predictors by univariate and multivariate survival analysis. **METHODS:** This cohort of 130 patients with intracranial benign meningiomas underwent GKRS between May 2012 and May 2015 at the Second Hospital of Tianjin Medical University. The median age was 54.5 years (range 25-81 years), and women outnumbered men at a ratio of 4.65:1. All clinical and radiological data were obtained for analysis. No patient had undergone prior traditional radiotherapy or chemotherapy. The median tumor volume was 3.68 cm3 (range 0.23-45.78 cm3). A median margin dose of 12.0 Gy (range 10.0-16.0 Gy) was delivered to the tumor with a median isodose line of 50% (range 50%-60%). **RESULTS:** During a median follow-up of 36.5 months (range 12-80 months), tumor volume regressed in 37 patients (28.5%), was unchanged in 86 patients (66.2%), and increased in 7 patients (5.4%). The actuarial tumor progression-free survival (PFS) rate was 98%, 94%, and 87% at 1, 3, and 5 years, respectively, after GKRS. Tumor recurred in 7 patients at a median follow-up of 32 months (range 12-56 months). Tumor volume >/= 10 cm3 (p = 0.012, hazard ratio [HR] 8.25, 95% CI 1.60-42.65) and pre-GKRS Karnofsky Performance Scale score < 90 (p = 0.006, HR 9.31, 95% CI 1.88-46.22) were independent unfavorable predictors of PFS rate after GKRS. Of the 130 patients, 101 (77.7%) presented with one or more neurological symptoms or signs before GKRS. Neurological symptoms or signs improved in 40 (30.8%) patients, remained stable in 83 (63.8%), and deteriorated in 7 (5.4%) after GKRS. Two (1.5%) patients developed new cranial nerve (CN) deficit. Tumor volume >/= 10 cm3 (p = 0.042, HR = 4.73, 95% CI 1.06-21.17) and pre-GKRS CN deficit (p = 0.045, HR = 4.35, 95% CI 0.84-22.48) were independent unfavorable predictors for improvement in neurological symptoms or signs. Six (4.6%) patients developed new or worsening peritumoral edema with a median follow-up of 4.5 months (range 2-7 months). **CONCLUSIONS:** GKRS provided good local tumor control and high neurological function preservation in patients with intracranial benign meningiomas. Patients with tumor volume < 10 cm3, pre-GKRS Karnofsky Performance Scale score >/= 90, and no pre-GKRS CN deficit (I-VIII) can benefit from stereotactic radiosurgery. It can be considered as the primary or adjuvant management of intracranial benign meningiomas.

[15] Gamma knife radiosurgery for the treatment of cavernous sinus meningiomas: post-treatment long-term clinical outcomes, complications, and volume changes.
Journal of neuro-oncology. 2019;143(2):261-270
Hung YC, Lee CC, Guo WY, Shiau CY, Chang YC, Pan DH, Sheehan JP, Chung WY
PMID: 31020456 DOI: 10.1007/s11060-019-03090-6
PURPOSE: To evaluate the outcomes of patients who underwent Gamma Knife radiosurgery (GKRS) for the treatment of cavernous sinus (CS) meningiomas. **METHODS:** We retrospectively reviewed the clinical and radiological outcomes of 95 patients with CS meningiomas at Taipei Veterans General Hospital between 1993 and 2011. The study cohort comprised 27 men and 68 women with a median age of 50 years (range 29-79 years). The median pre-GKRS tumor volume was 6.6 ml (range 0.9-35.7 ml). The median margin dose was 12 Gy (range 11-21 Gy). The clinical factors related to favorable outcomes were assessed. **RESULTS:** The median follow-up period was 59 (range 12-209) months. At the final follow-up, the tumor volume regressed in 70 patients (74%) and progressed in eight (8%). Kaplan-Meier analysis revealed that the progression-free survival rates at 5 and 10 years were 92.7% and 81.2%, respectively. Three patients (3.2%) experienced exacerbated cranial nerve dysfunction following radiosurgery. Confined tumors were found to be an independent prognostic factor for tumor control and shorter times to regression in the multivariable analyses. No risk factor for tumor progression was identified in either the univariate or multivariate analyses. **CONCLUSIONS:** GKRS provides good long-term tumor control and is associated with low cranial nerve-related morbidity development rates in patients with small- to medium-sized CS meningiomas. Confined tumor could be an independent prognostic factor for tumor control and shorter times to regression in multivariate analysis. Life-long follow-up is mandatory in such settings, even for outpatients with shrunken or stabilized tumors.

[16] Petroclival meningiomas: long-term outcomes of multimodal treatments and management strategies based on 30 years of experience at a single institution.
Journal of neurosurgery. 2019;:1-8
Kim JW, Jung HW, Kim YH, Park CK, Chung HT, Paek SH, Kim DG, Lee SH
PMID: 31075775 DOI: 10.3171/2019.2.JNS182604
OBJECTIVE: A thorough investigation of the long-term outcomes and chronological changes of multimodal treatments for petroclival meningiomas is required to establish optimal management strategies. The authors retrospectively reviewed the long-term clinical outcomes of patients with petroclival meningioma according to various treatments, including various surgical approaches, and they suggest treatment strategies based on 30 years of experience at a single institution. **METHODS:** Ninety-two patients with petroclival meningiomas were treated surgically at the authors' institution from 1986 to 2015. Patient demographics, overall survival, local tumor control rates, and functional outcomes according to multimodal treatments, as well as chronological change in management strategies, were evaluated. The mean clinical and radiological follow-up periods were 121 months (range 1-368 months) and 105 months (range 1-348 months), respectively. **RESULTS:** SA posterior transpetrosal approach was most frequently selected and was followed in 44 patients (48%); a simple retrosigmoid approach, undertaken in 30 patients, was the second most common. The initial extent of resection and following adjuvant treatment modality were classified into 3 subgroups: gross-total resection (GTR) only in 13 patients; non-GTR treatment followed by adjuvant radiosurgery or radiation therapy (non-GTR+RS/RT) in 56 patients; and non-GTR without adjuvant treatment (non-GTR only) in 23 patients. The overall progression-free survival rate was 85.8% at 5 years and 81.2% at 10 years. Progression or recurrence rates according to each

subgroup were 7.7%, 12.5%, and 30.4%, respectively. **CONCLUSIONS:** The authors' preferred multimodal treatment strategy, that of planned incomplete resection and subsequent adjuvant radiosurgery, is a feasible option for the management of patients with large petroclival meningiomas, considering both local tumor control and postoperative quality of life.

[17] Seizures After Stereotactic Radiosurgery for Benign Supratentorial Meningiomas: An Uncontrollable Type of Seizure?
World neurosurgery. 2019;123:e549-e556
Hwang K, Kim DG, Paek SH, Kim CY, Yun CH, Oh CW, Juh R, Han JH
PMID: 30528526 DOI: 10.1016/j.wneu.2018.11.211
OBJECTIVE: We investigated seizure outcomes of patients with supratentorial meningiomas (ST-MNGs) treated with stereotactic radiosurgery (SRS). **METHODS:** One hundred and thirty-three patients with a total of 144 ST-MNGs, who were treated with SRS between 2009 and 2016, were included in this study. The mean age was 59.0 +/- 11.9 years (range, 13-87 years). The mean follow-up duration was 49.8 +/- 24.5 months (range, 9-96 months). The median tumor volume was 2.60 cm(3) (range, 0.06-32.40 cm(3)), and the median marginal dose was 14.0 Gy (range, 11.0-20.0 Gy). Postradiosurgery peritumoral edema (PRPTE) was developed in 43 lesions (29.9%). **RESULTS:** New seizure attacks developed in 16 patients (12.0%) after SRS (first seizure attack in 14 [87.5%]; seizure aggravation in 2 [12.5%]). In 15 patients with new seizure attacks (93.8%), PRPTE was proved on magnetic resonance imaging. The mean interval between SRS and new seizure attack was 6.6 +/- 7.1 (range, 0.23-28.8) months. Simple partial seizure was the most common type of seizure (n = 9 [56.3%]). Five patients (31.3%) were seizure-free with antiepileptic drug (AED) medication (3 [18.8%] withdrew AEDs during the follow-up period); however, the remaining 11 patients (68.7%) did not achieve seizure-free outcomes even with AED medication. Moreover, seizures became intractable in 8 patients (50.0%). From multivariate analysis, the significant predictors of post-SRS seizure attack were PRPTE (odds ratio, 53.99; 95% confidence interval, 5.214-559.1; P = 0.001) and brain-tumor contact-surface index (odds ratio, 2.466; 95% confidence interval, 1.183-5.138; P = 0.016). **CONCLUSIONS:** The clinical outcomes of seizures after SRS for ST-MNGs fall short of our expectation, and seizures seem to be uncontrollable and even intractable.

2018

[18] Volumetric changes and clinical outcome for petroclival meningiomas after primary treatment with Gamma Knife radiosurgery.
Journal of neurosurgery. 2018;129(6):1623-1629
Sadik ZHA, Lie ST, Leenstra S, Hanssens PEJ
PMID: 29372884 DOI: 10.3171/2017.7.JNS17380
OBJECTIVE: Petroclival meningiomas (PCMs) can cause devastating clinical symptoms due to mass effect on cranial nerves (CNs); thus, patients harboring these tumors need treatment. Many neurosurgeons advocate for microsurgery because removal of the tumor can provide relief or result in symptom disappearance. Gamma Knife radiosurgery (GKRS) is often an alternative for surgery because it can cause tumor shrinkage with improvement of symptoms. This study evaluates qualitative volumetric changes of PCM after primary GKRS and its impact on clinical symptoms. **METHODS:** The authors performed a retrospective study of patients with PCM who underwent primary GKRS between 2003 and 2015 at the Gamma Knife Center of the Elisabeth-Tweesteden Hospital in Tilburg, the Netherlands. This study yields 53 patients. In this study the authors concentrate on qualitative volumetric tumor changes, local tumor control rate, and the effect of the treatment on trigeminal neuralgia (TN). **RESULTS:** SLocal tumor control was 98% at 5 years and 93% at 7 years (Kaplan-Meier estimates). More than 90% of the tumors showed regression in volume during the first 5 years. The mean volumetric tumor decrease was 21.2%, 27.1%, and 31% at 1, 3, and 6 years of follow-up, respectively. Improvement in TN was achieved in 61%, 67%, and 70% of the cases at 1, 2, and 3 years of follow-up, respectively. This was associated with a mean volumetric tumor decrease of 25% at the 1-year follow-up to 32% at the 3-year follow-up. **CONCLUSIONS:** GKRS for PCMs yields a high tumor control rate with a low incidence of neurological deficits. Many patients with TN due to PCM experienced improvement in TN after radiosurgery. GKRS achieves significant volumetric tumor decrease in the first years of follow-up and thereafter.

[19] Pretreatment texture analysis of routine MR images and shape analysis of the diffusion tensor for prediction of volumetric response after radiosurgery for meningioma.
Journal of neurosurgery. 2018;129(Suppl1):31-37
Speckter H, Bido J, Hernandez G, Rivera D, Suazo L, Valenzuela S, Miches I, Oviedo J, Gonzalez C, Stoeter P
PMID: 30544300 DOI: 10.3171/2018.7.GKS181327
OBJECTIVE: The goal of this study was to identify parameters from routine T1- and T2-weighted MR sequences and diffusion tensor imaging (DTI) that best predict the volumetric changes in a meningioma after treatment with Gamma Knife radiosurgery (GKRS). **METHODS:** In 32 patients with meningioma, routine MRI and DTI data were measured before GKRS. A total of 78 parameters derived from first-level texture analysis of the pretreatment MR images, including calculation of the mean, SD, 2.5th and 97.5th percentiles, and kurtosis and skewness of data in histograms on a voxel-wise basis, were correlated with lesion volume change after a mean follow-up period of 3 years (range 19.5-63.3 months). **RESULTS:** Several DTI-derived parameters correlated significantly with a meningioma volume change. The parameter that best predicted the results of GKRS was the 2.5th percentile value of the smallest eigenvalue (L3) of the diffusion tensor (correlation coefficient 0.739, p </= 0.001), whereas among the non-DTI parameters, only the SD of T2-weighted images correlated significantly with a tumor volume change (correlation coefficient 0.505, p </= 0.05, after correction for family-wise errors using false-detection-rate correction). **CONCLUSIONS:** DTI-derived data had a higher correlation to shrinkage of meningioma volume after GKRS than data from T1- and T2-weighted image sequences. However, if only routine MR images are available, the SD of T2-weighted images can be used to predict control or possible progression of a meningioma after GKRS.

[20] Hearing preservation after Gamma Knife radiosurgery for cerebellopontine angle meningiomas.
Journal of neurosurgery. 2018;129(Suppl1):38-46
El-Shehaby AMN, Reda WA, Abdel Karim KM, Nabeel AM, Emad Eldin RM, Tawadros SR
PMID: 30544298 DOI: 10.3171/2018.7.GKS181308
OBJECTIVE: The objective of this study was to assess hearing function after Gamma Knife treatment of cerebellopontine angle (CPA) meningiomas and assess factors affecting hearing outcome. Additionally, the authors opted to compare these results with those after Gamma Knife treatment of vestibular schwannomas (VSs), because most of the information on hearing outcome after stereotactic radiosurgery (SRS) comes from reports on VS treatment. Hearing preservation, to the best of the authors' knowledge, has never been separately addressed in studies involving Gamma Knife radiosurgery (GKRS) for CPA meningiomas. **METHODS:** This study included all patients who underwent a single session of GKRS between 2002 and 2014. The patients were divided into two groups. Group A included 66 patients with CPA meningiomas with serviceable hearing and tumor extension into the region centered on the internal auditory meatus. Group B included 144 patients with VSs with serviceable hearing. All patients had serviceable hearing before treatment (Gardner-Robertson [GR] Grades I and II). The median prescription dose was 12 Gy (range 10-12 Gy) in both groups. The median follow-up of groups A and B was 42 months (range 6-149 months) and 49 months (range 6-149 months), respectively. **RESULTS:** At the last follow-up, the tumor control rate was 97% and 94% in groups A and B, respectively. Hearing

preservation was defined as maintained serviceable hearing according to GR hearing score. The hearing preservation rate was 98% and 66% and the 7-year actuarial serviceable hearing preservation rate was 75% and 56%, respectively, between both groups. In group A, the median maximum cochlear dose in the patients with stable and worsened hearing grade was 6.3 Gy and 5.5 Gy, respectively. In group B, factors affecting hearing preservation were cochlear dose </= 7 Gy, follow-up duration, and tumor control. The only determinant of hearing preservation between both groups was tumor type. **CONCLUSIONS:** GKRS for CPA meningiomas provides excellent hearing preservation in addition to high tumor control rate. Hearing outcome is better with CPA meningiomas than with VSs. Further long-term prospective studies on determinants of hearing outcome after GKRS for CPA meningiomas should be conducted.

[21] Long-Term Outcomes After Gamma Knife Radiosurgery for Benign Meningioma: A Single Institution's Experience With 424 Patients.
Neurosurgery. 2018;83(5):1040-1049
Seo Y, Kim DG, Kim JW, Han JH, Chung HT, Paek SH
PMID: 29538718 DOI: 10.1093/neuros/nyx585
BACKGROUND: Gamma knife radiosurgery (GKRS) is recognized as an important treatment modality for meningioma. **OBJECTIVE:** To analyze the long-term outcomes in meningioma patients treated with GKRS to determine the risk factors related to treatment failure and peritumoral edema (PTE) development. **METHODS:** Between 1998 and 2010, 770 consecutive patients were treated with GKRS for intracranial meningioma. After the exclusion of patients with follow-up periods of less than 5 yr and those with neurofibromatosis, multiple meningiomas, nonbenign meningioma, or radiotherapy, a total of 424 patients were enrolled in this study. The median follow-up duration was 92 mo. The median tumor volume was 4.35 cm3, and the median marginal dose was 14 Gy. **RESULTS:** The overall local tumor control rate was 84%. The actuarial tumor control rates were 91.7% and 78.9% at 5 and 10 yr, respectively. The tumor control rate of a radiologically diagnosed tumor was higher than that of a grade I tumor (82% vs 70.1% at 10 yr, P = .001). In multivariate analysis, factors associated with tumor progression were female sex (hazard ratio: 0.5, P = .025) and a previous history of craniotomy (hazard ratio: 1.9, P = .009). Symptomatic PTE was identified in 36 (8.5%) patients, and the factor associated with poor PTE was the presence of PTE before GKRS (odds ratio: 4.6, P < .001). Permanent complication rate was 4%. **CONCLUSION:** GKRS appears to be an effective treatment modality for meningioma with long-term follow-up. However, the identification of delayed tumor progression in our study suggests that extended follow-up data should be collected after GKRS.

[22] Stereotactic radiosurgery for WHO grade I posterior fossa meningiomas: long-term outcomes with volumetric evaluation.
Journal of neurosurgery. 2018;129(5):1249-1259
Patibandla MR, Lee CC, Tata A, Addagada GC, Sheehan JP
PMID: 29303453 DOI: 10.3171/2017.6.JNS17993
OBJECTIVE: Research over the past 2 decades has been characterizing the role of stereotactic radiosurgery (SRS) in the treatment of benign intracranial tumors, including meningiomas. However, few studies have examined the long-term outcomes of SRS treatment for posterior fossa meningiomas (PFMs). Furthermore, previous studies have typically used single diameter measurements when reporting outcomes, which can yield misleading results. The authors describe the use of SRS in the treatment of benign WHO grade I PFMs and correlate volumetric analysis with long-term outcomes. **METHODS:** This study is a retrospective analysis of a prospectively maintained IRB-approved database. Inclusion criteria were a diagnosis of WHO grade I PFM with subsequent treatment via single-session SRS and a minimum of 3 follow-up MRI studies available. Volumetric analysis was performed on the radiosurgical scan and each subsequently available follow-up scan by using slice-by-slice area calculations of the meningioma and numerical integration with the trapezoid rule. **RESULTS:** The final cohort consisted of 120 patients, 76.6% (92) of whom were female, with a median age of 61 years (12-88 years). Stereotactic radiosurgery was the primary treatment for 65% (78) of the patients, whereas 28.3% (34) had 1 resection before SRS treatment and 6.7% (8) had 2 or more resections before SRS. One patient had prior radiotherapy. Tumor characteristics included a median volume of 4.0 cm3 (0.4-40.9 cm3) at treatment with a median margin dose of 15 Gy (8-20 Gy). The median clinical and imaging follow-ups were 79.5 (15-224) and 72 (6-213) months, respectively. For patients treated with a margin dose >/= 16 Gy, actuarial progression-free survival rates during the period 2-10 years post-SRS were 100%. In patients treated with a margin dose of 13-15 Gy, the actuarial progression-free survival rates at 2, 4, 6, 8, and 10 years were 97.5%, 97.5%, 93.4%, 93.4%, and 93.4%, respectively. Those who were treated with </= 12 Gy had actuarial progression-free survival rates of 95.8%, 82.9%, 73.2%, 56.9%, and 56.9% at 2, 4, 6, 8, and 10 years, respectively. The overall tumor control rate was 89.2% (107 patients). Post-SRS improvement in neurological symptoms occurred in 23.3% (28 patients), whereas symptoms were stable in 70.8% (85 patients) and worsened in 5.8% (7 patients). Volumetric analysis demonstrated that a change in tumor volume at 3 years after SRS reliably predicted a volumetric change and tumor control at 5 years (R2 = 0.756) with a p < 0.001 and at 10 years (R2 = 0.421) with a p = 0.001. The authors also noted that the 1- to 5-year tumor response is predictive of the 5- to 10-year tumor response (R2 = 0.636, p < 0.001). **CONCLUSIONS:** Stereotactic radiosurgery, as an either upfront or adjuvant treatment, is a durable therapeutic option for WHO grade I PFMs, with high tumor control and a low incidence of post-SRS neurological deficits compared with those obtained using alternate treatment modalities. Lesion volumetric response at the short-term follow-up of 3 years is predictive of the long-term response at 5 and 10 years.

[23] Cranial nerve outcomes after primary stereotactic radiosurgery for symptomatic skull base meningiomas.
Journal of neuro-oncology. 2018;139(2):341-348
Faramand A, Kano H, Niranjan A, Johnson SA, Hassib M, Park KJ, Arai Y, Flickinger JC, Lunsford LD
PMID: 29691775 DOI: 10.1007/s11060-018-2866-9
OBJECTIVE: To evaluate cranial nerve (CN) outcomes after primary stereotactic radiosurgery (SRS) for petroclival, cavernous sinus, and cerebellopontine angle meningiomas. **METHODS:** From our prospectively maintained database of 2022 meningioma patients who underwent Leksell stereotactic radiosurgery (SRS) during a 30-year interval, we found 98 patients with petroclival, 242 with cavernous sinus, and 55 patients with cerebellopontine angle meningiomas. Primary radiosurgery was performed in 245 patients. Patients included in this report had at least one CN deficit at the time of initial presentation and a minimum of 12 month follow up. Median age at the time of SRS was 58 years. Median follow up was 58 months (range 12-300 months), Median tumor volume treated with SRS was 5.9 cm(3) (range 0.5-37.5 cm(3)), and median margin dose was 13 Gy (range 9-20Gy). **RESULTS:** Tumor control was achieved in 229 patients (93.5%) at a median follow up of 58 months. Progression free survival rate (PFS) after SRS was 98.7% at 1 year, 96.4% at 3 years, 93.7% at 5 years, and 86.4% at 10 years Overall, 114 of the 245 patients (46.5%) reported improvement of CN function. Patients with CP angle meningiomas demonstrated lower rates of CN improvement compared to petroclival and cavernous sinus meningioma patients. Deterioration of CN function after SRS developed in 24 patients (10%). The rate of deterioration was 2.8% at 1 year, 5.2% at 3 years, and 8% at 10 years. **CONCLUSION:** Primary SRS provides effective tumor control and favorable rate of improvement of preexisting CN deficit.

[24] Outcomes of stereotactic radiosurgery for foramen magnum meningiomas: an international multicenter study.
Journal of neurosurgery. 2018;129(2):383-389
Mehta GU, Zenonos G, Patibandla MR, Lin CJ, Wolf A, Grills I, Mathieu D, McShane B, Lee JY, Blas K, Kondziolka D, Lee CC, Lunsford LD, Sheehan JP
PMID: 28862549 DOI: 10.3171/2017.3.JNS163008
OBJECTIVE: Meningiomas are the most common benign extramedullary lesions of the foramen magnum; however, their optimal management remains undefined.

Given their location, foramen magnum meningiomas (FMMs) can cause significant morbidity, and complete microsurgical removal can be challenging. Anterior and anterolateral FMMs carry greater risks with surgery, but they comprise the majority of these lesions. As an alternative to resection, stereotactic radiosurgery (SRS) has been used to treat FMMs in small case series. To more clearly define the outcomes of SRS and to delineate a rational management paradigm for these lesions, the authors analyzed the safety and efficacy of SRS for FMM in an international multicenter trial. **METHODS:** Seven medical centers participating in the International Gamma Knife Research Foundation (IGKRF) provided data for this retrospective cohort study. Patients who were treated with Gamma Knife radiosurgery and whose clinical and radiological follow-up was longer than 6 months were eligible for study inclusion. Data from pre- and post-SRS radiological and clinical evaluations were analyzed. Stereotactic radiosurgery treatment variables were recorded. **RESULTS:** Fifty-seven patients (39 females and 18 males, with a median age of 64 years) met the study inclusion criteria. Thirty-two percent had undergone prior microsurgical resection. Patients most frequently presented with cranial neuropathy (39%), headache (35%), numbness (32%), and ataxia (30%). Median pre-SRS tumor volume was 2.9 cm(3). Median SRS margin dose was 12.5 Gy (range 10-16 Gy). At the last follow-up after SRS, 49% of tumors were stable, 44% had regressed, and 7% had progressed. Progression-free survival rates at 5 and 10 years were each 92%. A greater margin dose was associated with a significantly increased likelihood of tumor regression, with 53% of tumors treated with > 12 Gy regressing. Fifty-two percent of symptomatic patients noted some clinical improvement. Adverse radiation effects were limited to hearing loss and numbness in 1 patient (2%). **CONCLUSIONS:** Stereotactic radiosurgery for FMM frequently results in tumor control or tumor regression, as well as symptom improvement. Margin doses > 12 Gy were associated with increased rates of tumor regression. Stereotactic radiosurgery was generally safe and well tolerated. Given its risk-benefit profile, SRS may be particularly useful in the management of small- to moderate-volume anterior and anterolateral FMMs.

[25] Gamma Knife stereotactic radiosurgery for cavernous sinus meningioma: long-term follow-up in 200 patients.

Journal of neurosurgery. 2018;:1-10
Park KJ, Kano H, Iyer A, Liu X, Tonetti DA, Lehocky C, Faramand A, Niranjan A, Flickinger JC, Kondziolka D, Lunsford LD
PMID: 30028261 DOI: 10.3171/2018.2.JNS172361
OBJECTIVE: The authors of this study evaluate the long-term outcomes of stereotactic radiosurgery (SRS) for cavernous sinus meningioma (CSM). **METHODS:** The authors retrospectively assessed treatment outcomes 5-18 years after SRS in 200 patients with CSM. The median patient age was 57 years (range 22-83 years). In total, 120 (60%) patients underwent Gamma Knife SRS as primary management, 46 (23%) for residual tumors, and 34 (17%) for recurrent tumors after one or more surgical procedures. The median tumor target volume was 7.5 cm3 (range 0.1-37.3 cm3), and the median margin dose was 13.0 Gy (range 10-20 Gy). **RESULTS:** Tumor volume regressed in 121 (61%) patients, was unchanged in 49 (25%), and increased over time in 30 (15%) during a median imaging follow-up of 101 months. Actuarial tumor control rates at the 5-, 10-, and 15-year follow-ups were 92%, 84%, and 75%, respectively. Of the 120 patients who had undergone SRS as a primary treatment (primary SRS), tumor progression was observed in 14 (11.7%) patients at a median of 48.9 months (range 4.8-120.0 months) after SRS, and actuarial tumor control rates were 98%, 93%, 85%, and 85% at the 1-, 5-, 10-, and 15-year follow-ups post-SRS. A history of tumor progression after microsurgery was an independent predictor of an unfavorable response to radiosurgery (p = 0.009, HR = 4.161, 95% CI 1.438-12.045). Forty-four (26%) of 170 patients who had presented with at least one cranial nerve (CN) deficit improved after SRS. Development of new CN deficits after initial microsurgical resection was an unfavorable factor for improvement after SRS (p = 0.014, HR = 0.169, 95% CI 0.041-0.702). Fifteen (7.5%) patients experienced permanent CN deficits without evidence of tumor progression at a median onset of 9 months (range 2.3-85 months) after SRS. Patients with larger tumor volumes (>/= 10 cm3) were more likely to develop permanent CN complications (p = 0.046, HR = 3.629, 95% CI 1.026-12.838). Three patients (1.5%) developed delayed pituitary dysfunction after SRS. **CONCLUSIONS:** This long-term study showed that Gamma Knife radiosurgery provided long-term tumor control for most patients with CSM. Patients who underwent SRS for progressive tumors after prior microsurgery had a greater chance of tumor growth than the patients without prior surgery or those with residual tumor treated after microsurgery.

[26] Salvage therapy outcomes for atypical meningioma.

Journal of neuro-oncology. 2018;138(2):425-433
Chen WC, Hara J, Magill ST, Wu A, Aghi MK, Theodosopoulos PV, Perry A, McDermott MW, Sneed PK, Raleigh DR, Braunstein SE
PMID: 29480505 DOI: 10.1007/s11060-018-2813-9
Atypical menginomas demonstrate increased clinical aggressiveness characterized by recurrence and diminished survival. The optimal management of atypical meningioma in the recurrent setting is especially not well defined. To characterize outcomes following salvage treatment of recurrent atypical meningioma and to identify risk factors for further recurrence. Retrospective chart review was performed on 65 patients who underwent salvage treatment of atypical meningioma at a single institution. Data were analyzed using the Kaplan-Meier method and Cox proportional hazards modeling. Sixty-five patients with recurrent atypical meningioma and median imaging follow-up of 4.0 years (range 1.9-6.6 years) underwent 62 surgeries and 114 radiation treatments (RT) for salvage therapy. Salvage modality was surgery (21%), surgery/RT (25%), or RT alone (54%), associated with 2 year local freedom from recurrence (LFFR) of 36, 59, and 73%, respectively (P = 0.01). Twenty percent of patients experienced CTCAE grade >/= 3 toxicity with salvage therapy. Thirty-nine percent of patients experienced >/= 3 recurrences. The median disease-free survival intervals after first and second salvage treatments were 2.9 and 1.3 years, respectively. On univariate Cox analysis, prior subtotal resection, prior RT, tumor diameter > 2.5 cm, and multifocal local recurrence were associated with recurrence after salvage therapy. On multivariate logistic regression, only multifocal local recurrence was associated with further recurrence. Recurrent atypical meningioma is clinically and pathologically more aggressive than primary atypical meningioma, and the likelihood of durable local control with salvage therapy is lower. Future efforts should identify patients at risk of recurrence, and aggressive upfront treatment should be employed.

[27] Clinical and radiological outcomes of proactive Gamma Knife surgery for asymptomatic meningiomas compared with the natural course without intervention.

Journal of neurosurgery. 2018;:1-10
Kim KH, Kang SJ, Choi JW, Kong DS, Seol HJ, Nam DH, Lee JI
PMID: 29775154 DOI: 10.3171/2017.12.JNS171943
OBJECTIVE: This study aimed to verify the effect of proactive Gamma Knife surgery (GKS) in the treatment of asymptomatic meningioma compared with the natural course without any therapeutic intervention. **METHODS:** From January 2006 to May 2017, 354 patients newly diagnosed with asymptomatic meningioma were reviewed and categorized into GKS (n = 153) and observation (n = 201) groups. Clinical and radiological progression rates were examined, and changes in volume were analyzed. **RESULTS:** Clinical progression (i.e., clinician-judged progression), combining symptomatic progression (n = 43) and clinician-judged increase in size using images routinely acquired (n = 34), occurred in 4 patients (2.6%) and 73 patients (36.3%) in the GKS and observation groups, respectively (p < 0.001). The clinical progression-free survival (PFS) rates in the GKS and observation groups were 98.7% and 64.6%, respectively, at 5 years (p < 0.001), and 92.9% and 42.7%, respectively, at 10 years (p < 0.001). The radiological tumor control rate was 94.1% in the GKS group, and radiological progression was noted in 141 patients (70.1%) in the observation group. The radiological PFS rates in the GKS and observation groups were 94.4% and 38.5%, respectively, at 5 years (p < 0.001), and 88.5% and 7.9%, respectively, at 10 years (p < 0.001). Young age,

absence of calcification, peritumoral edema, and high T2 signal intensity were correlated with clinical progression in the observation group. Volumetric analysis showed that untreated tumors gradually increased in size. However, GKS-treated tumors shrank gradually, although transient volume expansion was observed in the first 6 months. Adverse events developed in 26 of the 195 GKS-treated patients (13.3%), including 1 (0.5%) major event requiring microsurgery due to severe edema after GKS. Peritumoral edema was related to the development of adverse events (p = 0.004). **CONCLUSIONS:** Asymptomatic meningioma is a benign disease; however, nearly two-thirds of patients experience tumor growth and one-third of untreated patients eventually require neurosurgical interventions during watchful waiting. GKS can control tumors clinically and radiologically with high probability. Although the risk of transient adverse events exists, proactive GKS may be a reasonable treatment option when there are no comorbidities limiting life expectancy.

[28] Single-Fractionated Stereotactic Radiosurgery for Intracranial Meningioma in Elderly Patients: 25-Year Experience at a Single Institution.

Operative neurosurgery (Hagerstown, Md.). 2018;14(4):341-350

Hasegawa H, Hanakita S, Shin M, Koga T, Takahashi W, Nomoto AK, Sakuramachi M, Saito N

PMID: 29554374 DOI: 10.1093/ons/opx109

BACKGROUND: Stereotactic radiosurgery (SRS) has been accepted as a therapeutic option for intracranial meningiomas; however, the detailed data on outcomes in elderly patients remain unclear. **OBJECTIVE:** To delineate the efficacy of SRS for meningiomas in elderly patients. **METHODS:** The outcomes of 67 patients aged >/=65 yr who underwent SRS for benign intracranial meningioma (World Health Organization grade I) between 1990 and 2014 at our institution were retrospectively analyzed. The median age was 71 yr (range, 65-83 yr), and the mean and median follow-up were 62 and 52 mo (range, 7-195 mo), respectively. Tumor margins were irradiated with a median dose of 16 Gy, and the median tumor volume was 4.9 cm3 (range, 0.7-22.9 cm3). **RESULTS:** Actuarial local tumor control rates at 3, 5, and 10 yr after SRS were 92%, 86%, and 72%, respectively. Previous surgery and parasagittal/falcine location were statistically significant predictive factors for failed tumor control. Mild or moderate adverse events were noted in 9 patients. No severe adverse event was observed. A higher margin dose was significantly associated with adverse events by univariate analysis. **CONCLUSION:** SRS is one of the standard therapies for meningiomas in elderly patients, providing both favorable tumor control and a low risk of adverse events under minimum invasiveness.

[29] Stereotactic radiosurgery in the treatment of parasellar meningiomas: long-term volumetric evaluation.

Journal of neurosurgery. 2018;128(2):362-372

Cohen-Inbar O, Tata A, Moosa S, Lee CC, Sheehan JP

PMID: 28338439 DOI: 10.3171/2016.11.JNS161402

OBJECTIVE: Parasellar meningiomas tend to invade the suprasellar, cavernous sinus, and petroclival regions, encroaching on adjacent neurovascular structures. As such, they prove difficult to safely and completely resect. Stereotactic radiosurgery (SRS) has played a central role in the treatment of parasellar meningiomas. Evaluation of tumor control rates at this location using simplified single-dimension measurements may prove misleading. The authors report the influence of SRS treatment parameters and the timing and volumetric changes of benign WHO Grade I parasellar meningiomas after SRS on long-term outcome. **METHODS:** Patients with WHO Grade I parasellar meningiomas treated with single-session SRS and a minimum of 6 months of follow-up were selected. A total of 189 patients (22.2% males, n = 42) form the cohort. The median patient age was 54 years (range 19-88 years). SRS was performed as a primary upfront treatment for 44.4% (n = 84) of patients. Most (41.8%, n = 79) patients had undergone 1 resection prior to SRS. The median tumor volume at the time of SRS was 5.6 cm(3) (0.2-54.8 cm(3)). The median margin dose was 14 Gy (range 5-35 Gy). The volumes of the parasellar meningioma were determined on follow-up scans, computed by segmenting the meningioma on a slice-by-slice basis with numerical integration using the trapezoidal rule. **RESULTS:** The median follow-up was 71 months (range 6-298 months). Tumor volume control was achieved in 91.5% (n = 173). Tumor progression was documented in 8.5% (n = 16), equally divided among infield recurrences (4.2%, n = 8) and out-of-field recurrences (4.2%, n = 8). Post-SRS, new or worsening CN deficits were observed in 54 instances, of which 19 involved trigeminal nerve dysfunction and were 18 related to optic nerve dysfunction. Of these, 90.7% (n = 49) were due to tumor progression and only 9.3% (n = 5) were attributable to SRS. Overall, this translates to a 2.64% (n = 5/189) incidence of direct SRS-related complications. These patients were treated with repeat SRS (6.3%, n = 12), repeat resection (2.1%, n = 4), or both (3.2%, n = 6). For patients treated with a margin dose >/= 16 Gy, the 2-, 4-, 6-, 8-, 10-, 12-, and 15-year actuarial progression-free survival rates are 100%, 100%, 95.7%, 95.7%, 95.7%, 95.7%, and 95.7%, respectively. Patients treated with a margin dose < 16 Gy, had 2-, 4-, 6-, 8-, 10-, 12-, and 15-year actuarial progression-free survival rates of 99.4%, 97.7%, 95.1%, 88.1%, 82.1%, 79.4%, and 79.4%, respectively. This difference was deemed statistically significant (p = 0.043). Reviewing the volumetric patient-specific measurements, the early follow-up volumetric measurements (at the 3-year follow-up) reliably predicted long-term volume changes and tumor volume control (at the 10-year follow-up) (p = 0.029). **CONCLUSIONS:** SRS is a durable and minimally invasive treatment modality for benign parasellar meningiomas. SRS offers high rates of growth control with a low incidence of neurological deficits compared with other treatment modalities for meningiomas in this region. Volumetric regression or stability during short-term follow-up of 3 years after SRS was shown to be predictive of long-term tumor control.

[30] World Health Organization Grade II Meningiomas: The Role of Adjuvant/Salvage Gamma Knife Surgery After Initial Surgery and Prognostic Factor Assessment.

World neurosurgery. 2018;109:e352-e362

Liu X, Shan B, Wang M, Xu J

PMID: 28987849 DOI: 10.1016/j.wneu.2017.09.178

OBJECTIVE: This study was performed to evaluate the efficiency of Gamma Knife surgery (GKS) on reducing recurrence of World Health Organization (WHO) grade II meningiomas after surgery and to define the risk factors associated with tumor recurrence/progression and patient's death. **METHODS:** This retrospective study included 75 patients who were diagnosed with WHO grade II meningiomas after initial surgery. The Kaplan-Meier method with a log-rank test was used to calculate the survival curves. Univariate and multivariate Cox proportional hazards model were used to identify the risk factors associated with tumor recurrence/progression and patient's death. **RESULTS:** The median follow-up period was 70 months. The overall survival (OS) was 97.2% at 2 years and 89.8% at 5 years. The progression-free survival (PFS) at 1, 3, and 5 years was 89.3%, 72.6%, and 59.3%, respectively. Comparing the effects on PFS and OS between different groups, there were no statistically significant differences between the surgery-alone group and the surgery with adjuvant/salvage GKS group (P = 0.512; P = 0.949). In multivariate Cox proportional hazards model analysis, extent of resection (P = 0.001) and tumor location (P = 0.015) were associated with tumor recurrence; only histologic subtypes (P = 0.005) were associated with patient's death. **CONCLUSIONS:** There was no significant PFS or OS benefit for patients with WHO grade II meningiomas treated with adjuvant/salvage GKS postoperatively. Convexity meningiomas with gross total resection tended to benefit PFS. We suggest trying to achieve maximum safe gross total resection for patients with WHO grade II meningiomas, then following up closely.

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[31] Stereotactic Radiosurgery of Central Skull Base Meningiomas-Volumetric Evaluation and Long-Term Outcomes.

World neurosurgery. 2017;108:176-184

Patibandla MR, Lee CC, Sheehan J

PMID: 28882711 DOI: 10.1016/j.wneu.2017.08.166

BACKGROUND AND OBJECTIVE: Complete resection of a central skull base meningioma (CSM) is possible, but it is often associated with high morbidity. Stereotactic radiosurgery (SRS) plays an appreciable role in the management of skull base meningiomas. This study aims to apply volumetric methods to assess the CSM response after SRS and correlate it with clinical outcomes. **MATERIALS AND METHODS:** The cohort consisted of 219 patients, of whom 73.9% were female (n = 162), with a median age of 55 years (19-88). SRS was the primary treatment for 45.7% (n = 100), while 37.9% (n = 83) underwent treatment for residual tumors, 14.2% (n = 31) for recurrence, and in 5 with others reasons. The median tumor volume was 4.9 cm(3) (0.3-105 cm(3)) to a median margin dose of 14 Gy (5-35 Gy). Volumetric analysis of CSM was performed on the SRS scan and each available magnetic resonance image thereafter. **RESULTS:** The median clinical and imaging follow-ups of the cohort were 72 (24-298) and 66 (18-298) months, respectively. The overall tumor control rate was 83.4% (n = 183) at last follow-up with tumor regression 72.1% (n = 158). Neurologic symptoms were improved after SRS in 6.8% (n = 15), stable in 72.6% (n = 159), and worsened in 20.5% (n = 45). The clinical deterioration usually occurred in the patients with tumor progression ($P < 0.001$). Following SRS, the volumetric analysis confirmed that tumor response at 3 years reliably projected volumetric change and tumor control at 5 years ($R(2) = 0.694$) with $P < 0.001$ and 10 years ($R(2) = 0.571$) with $P = 0.001$. **CONCLUSION:** SRS affords effective tumor volumetric control and neurologic stability or improvement in the majority of patients with CSMs. The radiologic response of CSM as determined by volumetry at 3 years post-SRS is predictive of long-term tumor response at 5 and 10 years following SRS.

[32] Efficacy and outcomes of facial nerve-sparing treatment approach to cerebellopontine angle meningiomas.

Journal of neurosurgery. 2017;127(6):1231-1241

D'Amico RS, Banu MA, Petridis P, Bercow AS, Malone H, Praver M, Wang TJC, Isaacson SR, Sisti MB

PMID: 28186449 DOI: 10.3171/2016.10.JNS161982

OBJECTIVE: Advanced microsurgical techniques contribute to reduced morbidity and improved surgical management of meningiomas arising within the cerebellopontine angle (CPA). However, the goal of surgery has evolved to preserve the quality of the patient's life, even if it means leaving residual tumor. Concurrently, Gamma Knife radiosurgery (GKRS) has become an acceptable and effective treatment modality for newly diagnosed, recurrent, or progressive meningiomas of the CPA. The authors review their institutional experience with CPA meningiomas treated with GKRS, surgery, or a combination of surgery and GKRS. They specifically focus on rates of facial nerve preservation and characterize specific anatomical features of tumor location with respect to the internal auditory canal (IAC). **METHODS:** Medical records of 76 patients with radiographic evidence or a postoperative diagnosis of CPA meningioma, treated by a single surgeon between 1992 and 2016, were retrospectively reviewed. Patients with CPA meningiomas smaller than 2.5 cm in greatest dimension were treated with GKRS, while patients with tumors 2.5 cm or larger underwent facial nerve-sparing microsurgical resection where appropriate. Various patient, clinical, and tumor data were gathered. Anatomical features of the tumor origin as seen on preoperative imaging confirmed by intraoperative investigation were evaluated for prognostic significance. Facial nerve preservation rates were evaluated. **RESULTS:** According to our treatment paradigm, 51 (67.1%) patients underwent microsurgical resection and 25 (32.9%) patients underwent GKRS. Gross-total resection (GTR) was achieved in 34 (66.7%) patients, and subtotal resection (STR) in 17 (33.3%) patients. Tumors recurred in 12 (23.5%) patients initially treated surgically, requiring additional surgery and/or GKRS. Facial nerve function was unchanged or improved in 68 (89.5%) patients. Worsening facial nerve function occurred in 8 (10.5%) patients, all of whom had undergone microsurgical resection. Upfront treatment with GKRS for CPA meningiomas smaller than 2.5 cm was associated with preservation of facial nerve function in all patients over a median follow-up of 46 months, regardless of IAC invasion and tumor origin. Anatomical origin was associated with extent of resection but did not correlate with postoperative facial nerve function. Tumor size, extent of resection, and the presence of an arachnoid plane separating the tumor and the contents of the IAC were associated with postoperative facial nerve outcomes. **CONCLUSIONS:** CPA meningiomas remain challenging lesions to treat, given their proximity to critical neurovascular structures. GKRS is a safe and effective option for managing CPA meningiomas smaller than 2.5 cm without associated mass effect or acute neurological symptoms. Maximal safe resection with preservation of neurological function can be performed for tumors 2.5 cm or larger without significant risk of facial nerve dysfunction, and, when combined with GKRS for recurrence and/or progression, provides excellent disease control. Anatomical features of the tumor origin offer critical insights for optimizing facial nerve preservation in this cohort.

[33] Multimodal treatment of parasagittal meningiomas: a single-center experience.

Journal of neurosurgery. 2017;127(6):1249-1256

Gatterbauer B, Gevsek S, Hoftberger R, Lutgendorf-Caucig C, Ertl A, Mallouhi A, Kitz K, Knosp E, Frischer JM

PMID: 28156245 DOI: 10.3171/2016.9.JNS161859

OBJECTIVE: Treatment of parasagittal meningiomas is still considered a challenge in modern microsurgery. The use of microsurgical resection, radiosurgery, or a microsurgery-radiosurgery combination treatment strategy is often debated. The aim of this study was to evaluate the treatment of parasagittal meningioma and provide evidence that a multimodal approach reduces complication rates and achieves good tumor control rates. **METHODS:** The authors retrospectively reviewed long-term follow-up data on 117 patients who had been treated for parasagittal meningiomas at their institution between 1993 and 2013. Treatment included microsurgery, Gamma Knife radiosurgery (GKRS), and radiotherapy. **RESULTS:** The median tumor volume prior to the first microsurgical resection was largest in the microsurgery-radiosurgery combination treatment group. Invasion of the superior sagittal sinus was significantly associated with a Simpson Grade IV resection and subsequent radiosurgery treatment. The Simpson resection grade did not influence time to progression or recurrence in benign meningioma cases. Complete sinus occlusion was followed by microsurgical resection of the occluded sinus, by tumor resection without resection of the sinus, or by GKRS. Histopathology revealed WHO Grade I tumors in most patients. However, a high percentage (33%) of atypical or malignant meningiomas were diagnosed after the last microsurgical resection. The time to recurrence or progression after microsurgery was significantly longer in patients with WHO Grade I meningiomas than in those with Grade II or III meningiomas. At follow-up, tumor control rates after GKRS were 91% for presumed meningioma, 85% for benign meningioma, 71% for atypical meningioma, and 38% for malignant meningioma. **CONCLUSIONS:** A multimodal treatment approach to parasagittal meningiomas reduces the rate of complications. Thus, microsurgery, radiotherapy, and radiosurgery are complementary treatment options. Gamma Knife radiosurgery is safe and effective in patients with meningiomas invading the superior sagittal sinus. The procedure can be part of a multimodal treatment plan or administered as a single treatment in well-selected patients.

[34] Recurred Intracranial Meningioma: A Retrospective Analysis for Treatment Outcome and Prognostic Factor.

Brain tumor research and treatment. 2017;5(2):54-63

Ryu HS, Moon KS, Lee KH, Jang WY, Jung TY, Kim IY, Jung S

PMID: 29188205 DOI: 10.14791/btrt.2017.5.2.54
BACKGROUND: In this study, we aimed to compare repeated resection and radiation treatment, such as Gamma knife radiosurgery (GKRS) or conventional radiotherapy (RT), and investigate the factors influencing treatment outcome, including overall survival (OS), progression-free survival (PFS), and complication rates. **METHODS:** We retrospectively reviewed 67 cases of recurred intracranial meningiomas (repeated resection: 36 cases, radiation treatment: 31 cases) with 56 months of the median follow-up duration (range, 13-294 months). **RESULTS:** The incidence of death rate was 29.9% over follow-up period after treatment for recurred meningiomas (20/67). As independent predictable factors for OS, benign pathology [hazard ratio (HR) 0.132, 95% confidence interval (CI) 0.048-0.362, p<0.001] and tumor size <3 cm (HR 0.167, 95% CI 0.061-0.452, p<0.001) were significantly associated with a longer OS. The incidence of progression rate was 23.9% (16/67). Only treatment modality was important for PFS as an independent predictable factor (GKRS/RT vs. open resection; HR 0.117, 95% CI 0.027-0.518, p<0.005). The complication rate was 14.9% in our study (10/67). Larger tumor size (>/=3 cm, HR 0.060, 95% CI 0.007-0.509, p=0.010) was significant as an independent prognostic factor for development of complications. Although treatment modality was not included for multivariate analysis, it should be considered as a predictable factor for complications (p=0.001 in univariate analysis). **CONCLUSION:** The role of repeated resection is questionable for recurred intracranial meningiomas, considering high progression and complication rates. Frequent and regular imaging follow-up is required to detect recurred tumor sized as small as possible, and radiation treatment can be a preferred treatment.

[35] The Role of Adjuvant Treatment in Patients with High-Grade Meningioma.

Journal of Korean Neurosurgical Society. 2017;60(5):527-533
Cho M, Joo JD, Kim IA, Han JH, Oh CW, Kim CY
PMID: 28881115 DOI: 10.3340/jkns.2016.1111.009
OBJECTIVE: To investigate the efficacy of adjuvant treatment in patients with high-grade meningioma. **METHODS:** A retrospective analysis was performed for patients with high-grade meningioma, World Health Organization grade 2 or 3, in a single center between 2003 and 2014. The patients were reviewed according to age at diagnosis, sex, the location of meningioma, degree of tumor resection, histological features, and type of adjuvant treatment. These factors were analyzed by Firth logistic regression analyses. **RESULTS:** Fifty-three patients with high-grade meningioma were enrolled. Thirty-four patients received adjuvant treatment; conventional radiotherapy or radiosurgery. Clinical follow-up ranged from 13-113 months with a median follow-up of 35.5 months. Gross total removal (GTR), Simpson grade 1 or 2, was achieved in 29 patients and, among them, 13 patients received adjuvant treatment. In the other 24 patients with non-GTR, conventional adjuvant radiotherapy and radiosurgery were performed in 11 and 10 patients, respectively. The other 3 patients did not receive any adjuvant treatment. Radiation-related complications did not occur. Of the 53 patients, 19 patients had suffered from recurrence. The recurrence rate in the adjuvant treatment group was 23.5% (8 out of 34). On the other hand, the rate for the non-adjuvant treatment group was 57.9% (11 out of 19) (odds ratio [OR]=0.208, p=0.017). In the GTR group, the recurrence rate was 7.5% (1 out of 13) for patients with adjuvant treatment and 50% (8 out of 16) for patients without adjuvant treatment (OR=0.121, p=0.04). **CONCLUSION:** Adjuvant treatment appears to be safe and effective, and could lead to a lower recurrence rate in high-grade meningioma, regardless of the extent of removal. Our results might be used as a reference for making decisions when planning adjuvant treatments for patients with high-grade meningioma after surgery.

[36] Gamma Knife Stereotactic Radiosurgery for Grade 2 Meningiomas.

Journal of neurological surgery. Part B, Skull base. 2017;78(4):288-294
Refaat T, Gentile M, Sachdev S, Dalal P, Butala A, Gutiontov S, Helenowksi I, Lee P, Sathiaseelan V, Bloch O, Chandler J, Kalapurakal JA
PMID: 28725514 DOI: 10.1055/s-0036-1597834
PURPOSE: This study aims to report long-term clinical outcomes after Gamma Knife radiosurgery (GKRS) for intracranial grade 2 meningiomas. **METHODS:** In this Institutional Review Board approved study, we reviewed records of all patients with grade 2 meningiomas treated with GKRS between 1998 and 2014. **RESULTS:** A total of 97 postoperative histopathologically confirmed grade 2 meningiomas in 75 patients were treated and are included in this study. After a mean follow-up of 41 months, 28 meningiomas had local recurrence (29.79%). Median time to local recurrence was 89 months (mean: 69, range: 47-168). The 3- and 5-year actuarial local control (LC) rates were 68.9 and 55.7%, respectively. The 3- and 5-year overall survival rates were 88.6 and 81.1%, respectively. There was a trend toward worse LC with tumors treated with radiation doses </= 13 versus > 13 Gy. There was no radiation necrosis or second malignant tumors noted in our series. **CONCLUSIONS:** This report, one of the largest GKRS series for grade 2 meningiomas, demonstrates that GKRS is a safe and effective treatment modality for patients with grade 2 meningiomas with durable tumor control and minimal toxicity. Adjuvant GKRS could be considered as a reasonable treatment approach for patients with grade 2 meningiomas.

[37] Gamma Knife Radiosurgery for Cavernous Sinus Meningiomas: Analysis of Outcome in 166 Patients.

Stereotactic and functional neurosurgery. 2017;95(4):259-267
Azar M, Kazemi F, Jahanbakhshi A, Chanideh I, Jalessi M, Amini E, Geraily G, Farhadi M
PMID: 28797005 DOI: 10.1159/000478024
OBJECTIVES: The outcomes of Gamma Knife radiosurgery (GKRS) for cavernous sinus meningioma (CSM) are presented, and factors possibly affecting outcome are investigated. **METHODS:** The medical records and imaging and procedural reports of 166 patients with CSM were retrospectively reviewed. Demographic data, procedural data, symptomatic improvement, radiological regression, and progression-free survival (PFS) rates were evaluated. **RESULTS:** There were 124 women and 42 men; including 44 postoperative and 122 primary GKRS cases. Mean follow-up was 32.4 months. Mean marginal dose was 13 Gy. Symptomatic improvement was seen in 40.4%, while neurologic deterioration occurred in 9.6%; 50% remained symptomatically stable. Radiological regression was noted in 57.2%; the tumor remained stable in 35.5%, and 7.2% of the patients experienced tumor progression. The actuarial 5- and 10-year PFS rates were 90.1% (+/-3.3) and 75.8% (+/-8.8), respectively. History of previous surgery or radiotherapy were associated with lower symptomatic improvement. Higher tumor coverage and isodose lines were accompanied with better radiological prognosis. However, a history of conventional radiotherapy, presence of facial sensory deficits at presentation, a higher tumor volume, and tumor extension to the suprasellar compartment affected the radiologic outcome negatively. **CONCLUSION:** This study revealed a high efficacy and safety for GKRS in both postoperative and primary GKRS patients. Achievability of a good profile of tumor coverage and isodose lines at radiosurgical planning predict a better outcome.

[38] Gamma Knife Radiosurgery for Petroclival Meningioma: Long-Term Outcome and Failure Pattern.

Stereotactic and functional neurosurgery. 2017;95(4):209-215
Kim JW, Kim DG, Se YB, Kim SK, Chung HT, Paek SH, Jung HW
PMID: 28683438 DOI: 10.1159/000475763
Total removal of petroclival meningioma is difficult, and aggressive extirpation is often associated with significant surgical morbidity and mortality. The aim of this study was to evaluate the long-term outcome and failure pattern of treatment with Gamma Knife radiosurgery (GKRS) in patients with petroclival meningiomas. Eighty-nine consecutive patients with petroclival meningiomas underwent GKRS between 1998 and 2013. Fifty-eight patients received GKRS as a primary treatment and 31 patients underwent GKRS as a secondary treatment after microsurgery. The mean tumor volume was 6.7 cm3 (range, 0.5-46.3 cm3) and the mean marginal dose was 13.2 Gy (range, 8-17 Gy). At the last radiological follow-up, tumor volume was decreased in 50 patients (56.2%), stationary in 34 patients (38.2%), and

increased in 5 patients (5.6%). The actuarial progression-free survival after GKRS was 94.7% at 5 years and 88.9% at 10 years. Favorable cranial nerve outcomes were found in 81 patients (91%). A regrowth pattern was present in all 4 patients of the primary treatment group, whereas cyst formation (3 patients) and regrowth (1 patient) were observed in the secondary treatment group. GKRS is an effective and reasonable option as a primary or secondary treatment for petroclival meningioma. Further studies of failure patterns after GKRS for petroclival meningioma are mandatory.

[39] Direct Comparison of Gamma Knife Radiosurgery and Microsurgery for Small Size Meningiomas.

World neurosurgery. 2017;101:170-179
Bir SC, Patra DP, Maiti TK, Bollam P, Minagar A, Nanda A
PMID: 28185974 DOI: 10.1016/j.wneu.2017.01.105

BACKGROUND: Patients with small (<3 cm) intracranial meningiomas can be either observed or treated. Treatment can be either radiosurgery or microsurgery if and when tumor progression occurs. We compared local tumor growth control and recurrence-free survival (RFS) of microsurgical resection and radiosurgery in small intracranial meningiomas and identified predictors of unfavorable outcome. **METHODS:** A retrospective review (2005-2016) was performed of 90 consecutive patients with intracranial meningiomas who underwent either microsurgery (n = 31) or Gamma Knife radiosurgery (GKRS) (n = 59). The study population was evaluated clinically and radiographically after treatment. **RESULTS:** GKRS in meningiomas showed a significantly higher percentage of local control of tumor growth compared with microsurgery (P = 0.02) 5 and 10 years (P = 0.003) after treatment. The median RFS was also significantly higher in the GKRS group compared with the microsurgery group (P = 0.04). There was no difference in RFS between Simpson grade I resection and GKRS (P = 0.69). In univariate analysis, RFS after procedures was significantly affected by tumor involvement of cranial nerves, presence of comorbidities, and preoperative Karnofsky performance scale score </=70. In multivariate analysis, only preoperative Karnofsky performance scale score </=70 was a predictor of unfavorable outcome. **CONCLUSIONS:** GKRS offers a high rate of tumor control and longer RFS that is comparable to Simpson grade I resection. Subtotal resection is not a good choice for small meningiomas. The treatment procedure should be tailored according to the presence of comorbidities and the maximum benefit for the patient.

[40] Is Fractionated Gamma Knife Radiosurgery a Safe and Effective Treatment Approach for Large-Volume (>10 cm(3)) Intracranial Meningiomas?

World neurosurgery. 2017;99:477-483
Han MS, Jang WY, Moon KS, Lim SH, Kim IY, Jung TY, Jung S
PMID: 28017757 DOI: 10.1016/j.wneu.2016.12.056

BACKGROUND: Even with great advances in surgery and improved clinical outcome, morbidity and mortality are still high for large-volume intracranial meningiomas (MNGs). Recently, Gamma Knife radiosurgery (GKS) has proven to be a safe and effective treatment for many patients with intracranial MNGs. However, single-session GKS may increase the risk of radiation-induced toxicity for large MNGs. Recently, fractionated GKS (FGKS) has been performed for an increasing number of patients with surgically high-risk and large intracranial tumors. In this study, we report our results on the efficacy and safety of FGKS for large MNGs. **METHODS:** The authors performed a retrospective review of 70 patients who underwent GKS for large-volume (>10 cm(3)) intracranial MNGs between 2004 and 2015, with a minimum follow-up of 12 months. The authors classified these patients into 2 groups of single-session GKS, FGKS. The patients were followed by clinical examination and serial imaging with magnetic resonance imaging. **RESULTS:** In the single-session GKS group (42 patients), the median tumor volume was 15.2 cm(3) (range 10.3-48.3 cm(3)); the median prescription dose was 12 Gy (range 8-14 Gy), and the median follow-up duration was 57.8 months (range 14.5-128.4 months). In the FGKS group (28 patients), the median tumor volume was 21 cm(3) (range 10.2-54.7 cm(3)), and the median prescription was 7.5 Gy in 2 fractions (range 5-8 Gy), 6 Gy in 3 fractions (range 5-6.5 Gy), and 4.5 Gy in 4 fractions. The median follow-up duration for the FGKS group was 50 months (range 12.5-90.6 months). The overall 5-year tumor control rate was 92.9% in the FGKS group and 88.1% in the single-session GKS group. Fourteen (33.3%) symptomatic complications after single-session GKS were noted, including 5 cases of hemiparesis, 4 of seizure, 3 of peritumoral edema, and 2 of hydrocephalus. Two (7.1%) symptomatic complications after FGKS were noted, including 2 cases of hemiparesis. The FGKS group had higher progression-free survival (PFS) rate at 5 years (92.9% vs. 88.1%), but the differences did not reach statistical significance (P = 0.389). The patients in the FGKS group, however, experienced a lower complication rate compared with patients with a single-session GKS group (P = 0.017, hazard ratio, 5.7:1). **CONCLUSION:** When the large-volume (>10 cm(3)) intracranial MNGs are expected to have high morbidity after microsurgery and for patients that have a poor medical status for surgery, FGKS can be considered an alternative with good tumor control and lower complications rates compared with single-session GKS (P = 0.017).

[41] Analysis the causes of radiosurgical failure in intracranial meningiomas treated with radiosurgery.

Clinical neurology and neurosurgery. 2017;154:51-58
Kim M, Cho YH, Kim JH, Kim CJ, Kwon DH
PMID: 28129632 DOI: 10.1016/j.clineuro.2017.01.013

OBJECTIVES: Surgical resection is a primary indication for intracranial meningioma. Radiosurgery is also an excellent treatment modality for postoperative residual tumors, or tumors in high-risk locations, such as the skull base. Despite multimodality treatments, there are some cases in which radiosurgery fails and surgical resection or re-radiosurgery is required. However, there has not been a comprehensive study focusing on the causes of secondary treatment for local recurrence or a new mass that develops outside the target area after radiosurgery. Hence, we analyzed the causes of radiosurgical failure in patients with meningioma. **METHODS:** From 2000 to 2015, we retrospectively reviewed 1086 patients who underwent gamma knife radiosurgery (GKRS) for intracranial meningioma at the Asan Medical Center. Multiple meningiomas or tumors with a volume greater than 7000mm(3) were excluded. All patients had a minimum follow-up of 12 months. Finally, 771 patients were enrolled in this study. Clinical symptoms and brain MRI findings were assessed by neurosurgeons. When the tumor size increased and was accompanied by newly developed neurological symptoms, further management was considered (e.g. microsurgical resection and stereotactic radiosurgery). Histological analyses of the resected tumors were performed by neuropathologists. **RESULTS:** Among the 771 patients, tumor growth was observed in 60 patients (7.78%). Seven patients showed transient tumor growth after GKRS. These patients have been under close observation without any further treatment. Thirty patients (3.89%) underwent re-radiosurgery for tumor control. Another 23 patients underwent procedures other than re-radiosurgery; 8 underwent microsurgical resection, 3 underwent cyber knife radiosurgery (CKRS), 1 underwent radiation therapy, and 8 were closely followed-up. Three patients visited other clinics or were lost to follow-up. Of the remaining 30 patients, 22 (group 1) underwent microsurgical resection prior to their initial course of GKRS and the other 8 (group 2) were treated only with re-radiosurgery. In group 1, recurrence rates after radiosurgery were 2.47% (n=19) and 0.39% (n=3) for local and distant recurrence, respectively. In group 2, recurrence rates after radiosurgery were 0.52% (n=4) and 0.52% (n=4) for local and distant recurrence, respectively. An analysis was performed to determine the factors that may result in differences between the two groups. Of the many variables, local recurrence (p=0.0331, Fisher's exact test) was the only significant factor. **CONCLUSION:** We analyzed the causes of radiosurgical failure in meningioma patients and observed that microsurgery before radiosurgery was significantly associated with a high local recurrence rate compared with primary radiosurgery. Furthermore, the percentage of local recurrence cases that required secondary radiosurgery was as low as 2.98%. This result is comparable with that of microsurgical resection, which is the mainstay of treatment for meningioma.

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[42] Analysis of the results of recurrent intracranial meningiomas treated with re-radiosurgery.

Clinical neurology and neurosurgery. 2017;153:93-101

Kim M, Lee DH, Kim Rn HJ, Cho YH, Kim JH, Kwon DH

PMID: 28081463 DOI: 10.1016/j.clineuro.2016.12.014

OBJECTS: Meningioma is the most common intracranial neoplasm, comprising approximately 30% of all primary intracranial tumors (Claus et al., 2005) [1]. Treatment options include observation, microsurgical resection, stereotactic radiosurgery (SRS), and whole brain radiation therapy (WBRT). Gamma knife radiosurgery (GKRS) is a very effective treatment for intracranial meningiomas; previous studies showed the tumor control rate at 5-10 years of follow-up as 84.3%-100% in all cases (Feigl et al., 2005; Linskey et al., 2005; Malik et al., 2005; Aichholzer et al., 2000; Hakim et al., 1998; Chang and Adler 1997; Lunsford, 1994; Ganz et al., 1993) [2-9]. Many studies have discussed issues like optimal dose, conformal configurations, and adverse effects to improve the treatment result with GKRS (Malik et al., 2005; Kenai et al., 2005; Rowe et al., 2004; Shrieve et al., 2004) [4,10-12]. There are some cases in which the radiosurgery result is unfavorable and perhaps further treatment is needed. In these cases, re-radiosurgery can be an option. However, there have not been comprehensive studies discussing the issues of re-radiosurgery. Therefore, we analyzed the result of re-radiosurgery for recurrent meningiomas and their impact on clinical outcomes. **METHODS:** From 1995 to 2015, we retrospectively reviewed 1163 patients who underwent GKRS for intracranial meningioma at the Asan Medical Center. Patients with multiple meningiomas or a follow-up with a period of less than a year were excluded from this study. Finally, 865 patients were enrolled in this study. Clinical symptoms and brain magnetic resonance imaging (MRI) scans were assessed by neurosurgeons. When tumor size increased together with newly developed neurologic symptoms, further management, such as microsurgical resection or SRS, was considered. Histologic analysis of the resected tumors was performed by neuropathologists. Clinical data, including patient's sex, age, and tumor locations were recorded. Treatment data included tumor volume, tumor grade, radiation dose, and presence of edema. Final outcome data including follow-up period, time to progression, interval between first and second radiosurgery courses and interval between microsurgery and radiosurgery were obtained. **RESULTS:** Among 865 patients, tumor recurrence was found in 63 patients (7.28%). Seven patients showed transient tumor growth after GKRS. These patients have been under close observation without any further treatments. Fifty-six patients (6.47%) showed permanent tumor growth on follow-up MRI. Thirty-three patients from this group underwent repeated radiosurgery owing to tumor growth, resulting in a re-irradiation rate of 3.82% at our radiosurgery center. The other 23 patients were treated using methods other than re-radiosurgery. Among the 33 patients, 25 underwent microsurgical resection prior to their initial course of GKRS, and the other 8 were treated with re-radiosurgery only. An analysis was performed to determine factors that may have a role in treatment results. Of the many variables, tumor grade (p=0.004, Fisher's exact test) was the only significant factor for progression-free survival (PFS). Thirteen patients with unbiopsied or benign meningioma showed stable tumor size, while there was tumor growth in 8 patients. Among high-grade meningioma patients, 3 and 9 showed stable disease and tumor growth, respectively. As a result of re-radiosurgery, 11 out of 17 patients showed tumor growth and needed further treatments; this involved a third GKRS for 4 patients, microsurgical resection for 6 patients, and cyber knife radiosurgery (CKRS) for 1 patient. Four patients from this group were also treated with WBRT. **CONCLUSION:** We analyzed the results of re-radiosurgery for recurrent meningiomas and observed that World Health Organization (WHO) grade II and III was significantly associated with a lower PFS rate compared with low-grade meningiomas (p=0.004). Conversely, patients with benign meningioma or unbiopsied tumors had much better results. Hence, re-radiosurgery is recommended for patients with unknown or benign meningiomas if their first GKRS result is unsatisfactory. However, re-radiosurgery should be considered carefully for recurrent high-grade tumors. Owing to the small number of recurrent meningioma patients treated with re-radiosurgery, further studies are required to delineate the role of this treatment.

2016

[43] Grade II meningiomas and Gamma Knife radiosurgery: analysis of success and failure to improve treatment paradigm.

Journal of neurosurgery. 2016;125(Suppl 1):89-96

Valery CA, Faillot M, Lamproglou I, Golmard JL, Jenny C, Peyre M, Mokhtari K, Mazeron JJ, Cornu P, Kalamarides M

PMID: 27903189 DOI: 10.3171/2016.7.GKS161521

OBJECTIVE: Grade II meningiomas, which currently account for 25% of all meningiomas, are subject to multiple recurrences throughout the course of the disease and represent a challenge for the neurosurgeon. Radiosurgery is increasingly performed for the treatment of Grade II meningiomas and is quite efficient in controlling relapses locally at the site of the lesion, but it cannot prevent margin relapses. The aim of this retrospective study was to analyze the technical parameters involved in producing marginal relapses and to optimize loco-marginal control to improve therapeutic strategy. **METHODS:** Eighteen patients presenting 58 lesions were treated by Gamma Knife radiosurgery (GKRS) between 2010 and 2015 in Hopital de la Pitie-Salpetriere. The median patient age was 68 years (25%-75% interval: 61-72 years), and the sex ratio (M/F) was 13:5. The median delay between surgery and first GKRS was 3 years. Patients were classified as having Grade II meningioma using World Health Organization (WHO) 2007 criteria. The tumor growth rate was computed by comparing 2 volumetric measurements before treatment. After GKRS, iterative MRI, performed every 6 months, detected a relapse if tumor volume increased by more than 20%. Patterns of relapse were defined as being local, marginal, or distal. Survival curves were estimated using the Kaplan-Meier method, and the relationship between criterion and potential risk factors was tested by the log-rank test and univariable Cox model. **RESULTS:** The median follow-up was 36 months (range 8-57 months). During this period, 3 patients presented with a local relapse, 5 patients with a marginal relapse, and 7 patients with a distal relapse. Crude local control was 84.5%. The local control actuarial rate was 89% at 1 year and 71% at 3 years. The marginal control actuarial rate was 81% at 1 year and 74% at 2 years. The distal control actuarial rate was 100% at 1 year, 81% at 2 years, and 53% at 3 years. Median distal control was 38 months. Progression-free survival (PFS) was 71% at 1 year, 36% at 2 years, and 23% at 3 years. Median PFS was 18 months. Lesions treated with a minimum radiation dose of </= 12 Gy had significantly more local relapses than those treated with a dose > 12 Gy (p = 0.04) in univariate analysis. Marginal control was significantly influenced by tumor growth rate, with a lower growth rate being highly associated with improved marginal control (p = 0.002). There was a trend toward a relationship between dose and marginal control, but it was not significant (p = 0.09). PFS was significantly associated with delay between first surgery and GKRS (p = 0.03). The authors noticed few complications with no sequelae. **CONCLUSIONS:** In order to optimize loco-marginal control, radiosurgical treatment should require a minimum dose of > 12 Gy and an extended target volume along the dural insertion. Ideally, these parameters should correspond to the aggressiveness of the lesion, based on genetic features of the tumor.

[44] Long-term Outcomes After Gamma Knife Radiosurgery for Meningiomas.

American journal of clinical oncology. 2016;39(5):453-7

Kondziolka D, Patel AD, Kano H, Flickinger JC, Lunsford LD

PMID: 24755664 DOI: 10.1097/COC.0000000000000080

BACKGROUND: Gamma knife stereotactic radiosurgery (SRS) has become an important management strategy for patients with meningiomas. Although prior reports have studied early tumor control, neurological response, and associated morbidity, our purpose was to use clinical and imaging studies to determine whether long-term outcomes remain stable over time. **MATERIALS AND METHODS:** We studied 290 consecutive patients (92 men and 198 women) who underwent gamma knife SRS for a meningioma between 1987 and 1997.

The median tumor margin dose was 15 Gy and the median tumor volume was 5.5 mL. Target definition was performed using contrast enhanced computed tomography in 72 patients and magnetic resonance imaging in 218 patients. The median patient age at radiosurgery was 61 years. Twenty patients had a history of fractionated radiation therapy, 136 patients had undergone a subtotal resection, and 22 patients had recurrences after initial gross total resection. **RESULTS:** The overall tumor control rate was 91%. Twenty-six patients (9%) had evidence of delayed local tumor growth and 44 (15%) had regional tumor progression, which occurred at a median of 38 months. The 10- and 20-year actuarial rates of freedom from tumor progression of the targeted tumor were 87.7%+/-2.5% and 87.2%+/-4.2%. Of 234 patients who had symptoms before SRS (n=62, 26%) improved, 126 (54%) had no change in symptoms and 46 (20%) gradually worsened. Thirty-two of 34 (94%) asymptomatic patients remained asymptomatic. We found no difference in long-term tumor control rates between patients who had undergone craniotomy before radiosurgery (89%) and patients who underwent primary radiosurgery (93.1%). Adverse radiation effects were detected in 3.1% of patients. Factors associated with worse progression-free survival included prior radiation therapy (P<0.0001) and higher grade meningioma (P<0.0001). At a median of 8.7 years after SRS, 137 patients were dead at a median age of 77 years. **CONCLUSIONS:** We found that gamma knife SRS provided durable tumor control with low morbidity in meningioma patients.

[45] Gamma Knife Radiosurgery in Sphenopetroclival Meningiomas: Preliminary Experience at the Iran Gamma Knife Center.

World neurosurgery. 2016;93:39-43
Azar M, Kazemi F, Chanideh I, Amirjamshidi A, Amini E, Ghanavati P
PMID: 27262654 DOI: 10.1016/j.wneu.2016.05.071
OBJECTIVE: The aims of this study were to characterize the epidemiologic, histologic, and radiologic aspects of sphenopetroclival meningiomas (SpPCMs) and to evaluate the outcome of Gamma Knife radiosurgery (GKRS) either as an adjunct to microsurgery or as a primary SpPCM treatment modality. **METHODS:** In this retrospective study, medical records of patients with SpPCM who underwent GKRS at the Iran Gamma Knife Center between April 2003 and March 2012 were analyzed. **RESULTS:** We assessed 122 patients with SpPCMs, including 101 women and 21 men, aged 24-94 years. The mean tumor volume was 12.24 +/- 9.30 mL. Patients received 22.32 +/- 3.29 Gy and 13.18 +/- 1.02 Gy maximal and average marginal dose of GKRS, respectively. The most common complaint was visual impairment, followed by facial sensory impairment and headache. The most frequently involved cranial nerves were III, IV, and VI in 72.1% of patients, followed by II in 52.9%, and V in 35.5%. After radiosurgery, headaches improved in 90.0%, diplopia in 75.0%, and ptosis in 63.0% of patients. On magnetic resonance imaging, tumor size was reduced, unchanged, or increased in 77, 44, and 1 patient, respectively. Progression-free survival at the 5-year follow-up was 56.6%. Younger age (hazard ratio = 0.972, P = 0.011) and lower tumor volume (hazard ratio = 0.959, P = 0.009) were the main prognostic factors for progression-free survival. **CONCLUSION:** GKRS can be an effective alternative treatment for controlling the progression of SpPCM tumors, producing appropriate clinical outcomes and few complications.

[46] Microsurgical resectability, outcomes, and tumor control in meningiomas occupying the cavernous sinus.

Journal of neurosurgery. 2016;125(2):378-92
Nanda A, Thakur JD, Sonig A, Missios S
PMID: 26745483 DOI: 10.3171/2015.3.JNS142494
OBJECTIVE: Cavernous sinus meningiomas (CSMs) represent a cohort of challenging skull base tumors. Proper management requires achieving a balance between optimal resection, restoration of cranial nerve (CN) function, and maintaining or improving quality of life. The objective of this study was to assess the pre-, intra-, and postoperative factors related to clinical and neurological outcomes, morbidity, mortality, and tumor control in patients with CSM. **METHODS:** A retrospective review of a single surgeon's experience with microsurgical removal of CSM in 65 patients between January 1996 and August 2013 was done. Sekhar's classification, modified Kobayashi grading, and the Karnofsky Performance Scale were used to define tumor extension, tumor removal, and clinical outcomes, respectively. **RESULTS:** Preoperative CN dysfunction was evident in 64.6% of patients. CN II deficits were most common. The greatest improvement was seen for CN V deficits, whereas CN II and CN IV deficits showed the smallest degree of recovery. Complete resection was achieved in 41.5% of cases and was not significantly associated with functional CN recovery. Internal carotid artery encasement significantly limited the complete microscopic resection of CSM (p < 0.0001). Overall, 18.5% of patients showed symptomatic recurrence after their initial surgery (mean follow-up 60.8 months [range 3-199 months]). The use of adjuvant stereotactic radiosurgery (SRS) after microsurgery independently decreased the recurrence rate (p = 0.009; OR 0.036; 95% CI 0.003-0.430). **CONCLUSIONS:** Modified Kobayashi tumor resection (Grades I-IIIB) was possible in 41.5% of patients. CN recovery and tumor control were independent of extent of tumor removal. The combination of resection and adjuvant SRS can achieve excellent tumor control. Furthermore, the use of adjuvant SRS independently decreases the recurrence rates of CSM.

[47] Long-Term Results of Stereotactic Radiosurgery for Skull Base Meningiomas.

Neurosurgery. 2016 Jul;79(1):58-68.
Cohen-Inbar O, Lee CC, Schlesinger D, Xu Z, Sheehan JP
PMID: 26421592 DOI: 10.1227/NEU.0000000000001045
BACKGROUND: Gamma knife radiosurgery (GKRS) is well established in the management of inaccessible, recurrent, or residual benign skull base meningiomas. Most series report clinical outcome parameters and complications in the short intermediate period after radiosurgery. Reports of long-term tumor control and neurological status are still lacking. **OBJECTIVE:** To report the presentation, treatment, and long-term outcome of skull base meningiomas after GKRS. **METHODS:** From a prospectively collected institutional review board-approved database, we selected patients with a World Health Organization grade I skull base meningioma treated with a single-session GKRS and a minimum of 60 months follow-up. One hundred thirty-five patients, 54.1% males (n = 73), form the cohort. Median age was 54 years (19-80). Median tumor volume was 4.7 cm (0.5-23). Median margin dose was 15 Gy (7.5-36). Median follow-up was 102.5 months (60.1-235.4). Patient and tumor characteristics were assessed to determine the predictors of neurological function and tumor progression. **RESULTS:** At last follow-up, tumor volume control was achieved in 88.1% (n = 119). Post-GKRS clinical improvement or stability was reported in 61.5%. The 5-, 10-, and 15-year actuarial progression-free survival rates were 100%, 95.4%, and 68.8%, respectively. Favorable outcome (both tumor control and clinical preservation/improvement) was attained in 60.8% (n = 79). Pre-GKRS performance status (Karnofsky Performance Scale) was shown to influence tumor progression (P = .001) and post-GKRS clinical improvement/preservation (P = .003). **CONCLUSION:** GKRS offers a highly durable rate of tumor control for World Health Organization grade I skull base meningiomas, with an acceptably low incidence of neurological deficits. The Karnofsky Performance Scale at the time of radiosurgery serves as a reliable long-term predictor of overall outcome. ABBREVIATIONS: ARE, adverse radiation effectGKRS, Gamma knife radiosurgeryKPS, Karnofsky Performance ScaleWHO, World Health Organization.

[48] Parameters influencing local control of meningiomas treated with radiosurgery.

Journal of neuro-oncology. 2016;128(2):357-64
Kaprealian T, Raleigh DR, Sneed PK, Nabavizadeh N, Nakamura JL, McDermott MW
PMID: 27131883 DOI: 10.1007/s11060-016-2121-1
To identify parameters that influence local control after stereotactic radiosurgery (SRS) for meningiomas we retrospectively analyzed all meningiomas treated with Gamma Knife SRS at our institution from 1991 to 2007. Endpoints were measured

from the date of SRS and estimated using the Kaplan-Meier method; subgroups were compared with log-rank tests. Sex, performance status, age, SRS setting, radiation dose, grade, volume and location were evaluated with univariate and multivariate Cox proportional hazards analyses. Of 280 patients with 438 tumors, 264 patients with clinical follow-up and 406 tumors with imaging follow-up were analyzed (median follow-up: 75.9 months). Thirty-seven percent of the tumors had no tissue diagnosis, 32 % were benign (grade I), 12 % atypical (grade II), and 19 % malignant (grade III). Five-year freedom from progression (FFP) was 97 % for presumed meningiomas, 87 % for grade I tumors, 56 % for grade II tumors, and 47 % for grade III tumors ($p < 0.0001$). Five-year FFP probabilities for upfront SRS versus SRS at recurrence after surgery versus SRS at recurrence after RT were 97, 86, and 38 %, respectively ($p < 0.0001$). Univariate analysis revealed that higher grade, larger target volume (median diameter: 2.4 cm) and SRS setting were associated with poorer FFP. Only target volume and SRS setting remained significant on multivariate analysis. Local control of presumed and grade I meningiomas is excellent with Gamma Knife SRS, but is suboptimal with high-grade tumors as well as for those treated at recurrence after RT or of large volume.

[49] Adjuvant Stereotactic Radiosurgery Reduces Need for Retreatments in Patients with Meningioma Residuals.
World neurosurgery. 2016;88:475-482
Frostell A, Hakim R, Dodoo E, Sinclair G, Ohlsson M, Forander P, Milovac B, Brundin L, Svensson M
PMID: 26546994 DOI: 10.1016/j.wneu.2015.10.062
BACKGROUND: Radical surgical resection of cerebral meningiomas involving the dura mater of venous sinuses is challenging, and tumor residuals are frequently left after surgery. This study sought to evaluate the effect of adjuvant stereotactic radiosurgery (aSRS) on the time to significant growth of meningioma residuals requiring retreatment. **METHODS:** A total of 119 consecutive patients (2004-2013) receiving primary surgical treatment for a meningioma in proximity to a venous structure were included. The patients were assessed retrospectively, with a focus on retreatments and mortality. Radicality of initial tumor surgery was scored using postoperative magnetic resonance imaging. Three subgroups were identified: 1) radical total resection (RTR); 2) near-total resection (NTR), followed by aSRS (NTR + aSRS); and 3) NTR but no aSRS (NTR - aSRS). In the NTR - aSRS group, intervention was initiated after radiologic (magnetic resonance imaging) findings verified growth of residual tumor, in contrast to the NTR + aSRS group, which received aSRS before regrowth. Time to first retreatment, progression-free survival (PFS), and overall survival were analyzed with the log-rank test and multiple-events Cox regression. **RESULTS:** RTR was associated with the best prognosis. The patients in the NTR + aSRS group had significantly longer time to first retreatment compared with NTR - aSRS patients ($P < 0.001$). There was also a significant difference in mortality ($P < 0.05$) and a tendency to prolonged PFS ($P = 0.07$) in the NTR + aSRS group. The Cox regressions confirmed the positive effects of NTR + aSRS on time to retreatment (hazard ratio, 7.3; $P < 0.01$) and PFS (hazard ratio, 3.69; $P = 0.055$). **CONCLUSIONS:** aSRS of meningioma residuals had a positive effect on tumor control and should be considered in patients with meningioma residuals.

[50] Gamma Knife Radiosurgery for Atypical and Anaplastic Meningiomas.
World neurosurgery. 2016;87:557-64
Wang WH, Lee CC, Yang HC, Liu KD, Wu HM, Shiau CY, Guo WY, Pan DH, Chung WY, Chen MT
PMID: 26485417 DOI: 10.1016/j.wneu.2015.10.021
BACKGROUND: Atypical and anaplastic meningiomas have much higher recurrence rates after surgical resection compared with benign meningiomas, but the role of adjuvant radiosurgery remains unclear. This study was undertaken to evaluate the outcomes of gamma knife radiosurgery for patients with atypical and anaplastic meningiomas. **METHODS:** In this retrospective analysis of a prospectively maintained database, 46 patients with histologically proven atypical or anaplastic meningiomas by current World Health Organization (WHO) criteria underwent postoperative Gamma Knife radiosurgery between 1993 and 2013. The median follow-up period was 32.6 months. The median tumor volume and margin dose were 11.7 mL (range, 2-53 mL) and 13.1 Gy (range, 12.0-16.5 Gy), respectively. **RESULTS:** Local control at 3 and 5 years was 50.6% and 32.1%, respectively. Gender ($P = 0.013$) and marginal dose less than or equal to 13 Gy ($P = 0.049$) were associated with the local control. The 3- and 5-year overall survival for patients with WHO grade II was 97.1% and 88.3%, respectively, compared with 66.7% and 66.7% for patients with WHO grade III meningiomas. Radiation therapy before Gamma Knife radiosurgery (GKRS; $P = 0.018$) and tumor grade ($P = 0.019$) were the factors associated with a worse overall survival rate. Fourteen patients (30.4%) developed adverse radiation effects after GKRS treatment, and all were Radiation Therapy Oncology Group grade I. **CONCLUSIONS:** Postoperative GKRS treatment for patients with atypical and anaplastic meningioma is challenging. More aggressive treatment, including of safely maximizing the extent of surgical resection and using a higher margin dose (>13Gy), should be applied to achieve better local control.

[51] The Geriatric Scoring System (GSS) for Risk Stratification in Meningioma Patients as a Predictor of Outcome in Patients Treated with Radiosurgery.
World neurosurgery. 2016;87:431-8
Cohen-Inbar O, Lee CC, Schlesinger D, Xu Z, Sheehan JP
PMID: 26548822 DOI: 10.1016/j.wneu.2015.10.081
INTRODUCTION: Meningiomas are the most common primary benign brain tumor. Radiosurgery (primary or adjuvant) allows excellent local control. The Geriatric Scoring System (GSS) for preoperative risk stratification and outcome prediction of patients with meningiomas has been reported previously. The GSS incorporates 8 tumor and patient parameters on admission. A GSS score greater than 16 was reported previously to be associated with a more favorable outcome. We assessed the validity of the GSS score and its influence on outcome in patients treated with Gamma-Knife radiosurgery (GKRS). **PATIENTS AND METHODS:** Patients treated with single-session GKRS for World Health Organization grade I meningioma during 1989-2013 at the University of Virginia were reviewed. The cohort comprised 323 patients, 50.2% (n = 162) male. Median age was 56 years (29-84 years), and median follow-up was 53.6 months (6-235 months). Median tumor volume was 4.5 cm(3) (0.2-23). Median margin and maximal doses were 15 Gy (8-36) and 32.3 Gy (20-65), respectively. **RESULTS:** Tumor volume control was achieved in 87% (n = 281), and post-GKRS clinical neurologic improvement was reported in 66.3% (n = 214). The median change in KPS was +10 (range -30 to +40). The most common complication was intermittent headaches (34.1%, n = 110) and cranial nerve deficits (14.2%, n = 46). The GSS (calculated and grouped as GSS > 16 and GSS </= 16) was found to correlate with different post-GKRS functional status ($P < 0.0001$) and tumor control ($P = 0.028$). **CONCLUSION:** The GSS, used for risk stratification and outcome prediction in patients with meningiomas, seems valid for patients undergoing single-session GRKS. A GSS score greater than 16 is associated with a better long-term functional status and tumor control.

[52] Long-term outcomes following Gamma Knife radiosurgery for small, newly diagnosed meningiomas.
Clinical neurology and neurosurgery. 2016;142:1-7
Lee S, Kwon DH, Kim CJ, Kim JH
PMID: 26795493 DOI: 10.1016/j.clineuro.2016.01.009
OBJECTIVE: Although stereotactic radiosurgery were established as an effective treatment modality for intracranial meningiomas, there have been no comprehensive studies focused on long-term outcomes and histologic results for purely small-sized meningiomas after radiosurgery. Therefore, we investigated long-term outcomes and histology of small-sized meningiomas after radiosurgery. **METHODS:** The authors reviewed the data retrospectively of a total of 920 patients treated with single-session Gamma Knife radiosurgery with intracranial meningioma (Radiosurgery center, Asan Medical Center). After

stratifying meningiomas by size, it was defined as small-sized meningiomas less than 1000 mm(3) in tumor volume. The patients with newly diagnosed small-sized meningiomas were enrolled in this study (113 patients). All patients had a minimum follow up of 12 months (12-120 months), clinical symptoms and brain MRI were checked by neurosurgeons. When the tumors grew readily with newly developed neurologic symptoms, microsurgical resection was performed. Histologic analysis was done with resected tumors by neuropathologists. **RESULTS:** Among 113 patients, 9 patients (7.9%) showed the increased tumors with clinical symptoms after radiosurgery, followed by microsurgical resection in 4 patients (3.5%). The other 5 (4.4%) patients showed that the size of tumor slightly increased after GKRS that is transient. Interestingly, the histologic results of resected meningiomas due to increased volume after radiosurgery were all revealed as WHO grade II meningiomas (1 clear cell type and 3 atypical meningiomas). Although the histologic confirmation was performed only in 4 patients underwent surgery, it is interesting that all tumors readily grew after radiosurgery were high grade meningiomas. **CONCLUSION:** In this study, we revealed the long-term outcomes of small meningiomas following stereotactic radiosurgery in the aspect of tumor control. The tumor control rate of radiosurgery in small meningiomas reached to 92.1% and there were perilesional edema in 6.1%. The 7.9% of tumors grew readily and 3.5% were finally underwent microsurgical resection. The histologic results were all WHO grade II meningiomas (1 clear cell and 3 atypical meningiomas).

[53] Quantitative tumor volumetric responses after Gamma Knife radiosurgery for meningiomas.
Journal of neurosurgery. 2016;124(1):146-54
Harrison G, Kano H, Lunsford LD, Flickinger JC, Kondziolka D
PMID: 26162039 DOI: 10.3171/2014.12.JNS141341
OBJECTIVE: The reported tumor control rates for meningiomas after stereotactic radiosurgery (SRS) are high; however, early imaging assessment of tumor volumes may not accurately predict the eventual tumor response. The objective in this study was to quantitatively evaluate the volumetric responses of meningiomas after SRS and to determine whether early volume responses are predictive of longer-term tumor control. **METHODS:** The authors performed a retrospective review of 252 patients (median age 56 years, range 14-87 years) who underwent Gamma Knife radiosurgery between 2002 and 2010. All patients had evaluable pre- and postoperative T1-weighted contrast-enhanced MRIs. The median baseline tumor volume was 3.5 cm(3) (range 0.2-33.8 cm(3)) and the median follow-up was 19.5 months (range 0.1-104.6 months). Follow-up tumor volumes were compared with baseline volumes. Tumor volume percent change and the tumor volume rate of change were compared at 3-month intervals. Eventual tumor responses were classified as progressed for > 15% volume change, regressed for </= 15% change, and stable for +/- 15% of baseline volume at time of last follow-up. Volumetric data were compared with the final tumor status by using univariable and multivariable logistic regression. **RESULTS:** Tumor volume regression (median decrease of -40.2%) was demonstrated in 168 (67%) patients, tumor stabilization (median change of -2.7%) in 67 (26%) patients, and delayed tumor progression (median increase of 104%) in 17 (7%) patients ($p < 0.001$). Tumors that eventually regressed had an average volume reduction of -18.2% at 3 months. Tumors that eventually progressed all demonstrated volume increase by 6 months. Transient progression was observed in 15 tumors before eventual decrease, and transient regression was noted in 6 tumors before eventual volume increase. **CONCLUSIONS:** The volume response of meningiomas after SRS is dynamic, and early imaging estimations of the tumor volume may not correlate with the final tumor response. However, tumors that ultimately regressed tended to respond in the first 3 months, whereas tumors that ultimately progressed showed progression within 6 months.

2015

[54] Dose-Response Relationships for Meningioma Radiosurgery.
American journal of clinical oncology. 2015;38(6):600-4
Sethi RA, Rush SC, Liu S, Sethi SA, Parker E, Donahue B, Narayana A, Silverman J, Kondziolka D, Golfinos JG
PMID: 26595685 DOI: 10.1097/COC.0000000000000008
OBJECTIVE: Dose-response relationships for meningioma radiosurgery are poorly characterized. We evaluated determinants of local recurrence for meningiomas treated with Gamma Knife radiosurgery (GKRS), to guide future treatment approaches to optimize tumor control. **MATERIALS AND METHODS:** A total of 101 consecutive patients (108 tumors) who underwent GKRS for benign, atypical, or malignant meningiomas between 1998 and 2011 were studied. Local recurrence was assessed. Cox proportional hazards and logistic regression analyses were used to determine the association of patient-related, tumor-related, and treatment-related characteristics with local recurrence. Acute and late toxicity was evaluated. **RESULTS:** World Health Organization (2007 classification) tumor grade was I (82%), II (11%), or III (7%). Median dose was 14 Gy (range, 10 to 18 Gy) for grade I tumors and 16 Gy (range, 12 to 20 Gy) for grade II and III tumors. Median follow-up was 25 months (maximum, 17 y). Two- /5-year actuarial local control rates were 100%/98% for grade I tumors and 76%/56% for grade II/III tumors. Higher tumor grade and lower GKRS dose were associated with local failure. In this cohort, there was a 42% relative reduction in local recurrence for each 1 Gy of dose escalation. **CONCLUSIONS:** Treatment was well tolerated with no moderate or severe toxicity. Tumor control was excellent in benign tumors and suboptimal in higher grade tumors. Because the main determinant of local recurrence was GKRS dose, we recommend dose escalation for atypical or malignant tumors to doses between 16 and 20 Gy where critical structures allow.

[55] Predictors of response to Gamma Knife radiosurgery for intracranial meningiomas.
Journal of neurosurgery. 2015;123(5):1294-300
Mansouri A, Larjani S, Klironomos G, Laperriere N, Cusimano M, Gentili F, Schwartz M, Zadeh G
PMID: 26140488 DOI: 10.3171/2014.12.JNS141687
OBJECTIVE: In this paper, the authors' aim was to determine short-term volumetric and diametric tumor growth and identify clinical, radiological, and dosimetric predictors of adverse radiation events (AREs) following stereotactic radiosurgery (SRS) for intracranial WHO Grade I meningiomas. **METHODS:** This is a retrospective review of all WHO Grade I meningiomas that were treated with SRS (primary or adjuvant) between December 2005 and June 2012 at the University Health Network. Seventy-five patients had at least 24 months of both clinical and radiological follow-up and were, therefore, included in this study. Tumor growth was defined as any volumetric or diametric change greater than 10% per year. Any variation less than +10% was considered growth stability. Volumetric measurements were made using T1-weighted gadolinium-enhanced 3-T MRI scans and ITK-SNAP software. Tumor growth rates were calculated using the specific growth rate (SGR). Univariate statistics were used to identify predictors of post-SRS AREs. All statistical analyses were performed using IBM SPSS. **RESULTS:** Women accounted for 69.3% of patients, and the mean treatment age was 58.6 years. Median follow-up was 36.2 months. Twenty-one (28%) patients had undergone prior resection. Two (3%) patients required salvage surgical intervention following SRS. The majority of the lesions (56%) were skull base tumors. Median tumor volume and diameter were 5.2 cm3 and 27.5 mm, respectively. The absence of tumor growth was observed in 39 cases (52%) based on the volumetric measurements, while the absence of tumor growth was observed in 69 cases (92%) based on the diametric measurements. Twenty-six patients (34.6%) experienced new-onset AREs, including headache (17.3%), cranial neuropathy (10.6%), speech impairment (2.7%), tremors (2.7%), and ataxia

(1.3%). Fourteen patients (18.7%) experienced new-onset edema, and 4 of these patients were symptomatic. A lower conformity index (1.24 vs 1.4) was significantly associated with the development of edema (p<0.001 power>0.8). Patients with meningiomas that had growth rates of more than 10% per year were more likely to experience long-term headaches after SRS (p=0.022). **CONCLUSIONS:** Volume-based reporting of SRS outcomes for meningiomas may be a more accurate method given the complex morphology of some lesions. The conformity index was identified as a predictor of edema following radiosurgery.

[56] Edema following Gamma Knife radiosurgery for parasagittal and parafalcine meningiomas.

Journal of neurosurgery. 2015;123(5):1287-93
Sheehan JP, Lee CC, Xu Z, Przybylowski CJ, Melmer PD, Schlesinger D
PMID: 26115473 DOI: 10.3171/2014.12.JNS142159
OBJECTIVE: Stereotactic radiosurgery (SRS) has been shown to offer a high probability of tumor control for Grade I meningiomas. However, SRS can sometimes incite edema or exacerbate preexisting edema around the targeted meningioma. The current study evaluates the incidence, timing, and degree of edema around parasagittal or parafalcine meningiomas following SRS. **METHODS:** A retrospective review was undertaken of a prospectively maintained database of patients treated with Gamma Knife radiosurgery at the University of Virginia Health System. All patients with WHO Grade I parafalcine or parasagittal meningiomas with at least 6 months of clinical follow-up were identified, resulting in 61 patients included in the study. The median radiographic follow-up was 28 months (range 6-158 months). Rates of new or worsening edema were quantitatively assessed using volumetric analysis; edema indices were computed as a function of time following radiosurgery. Statistical methods were used to identify favorable and unfavorable prognostic factors for new or worsening edema. **RESULTS:** Progression-free survival at 2 and 5 years was 98% and 90%, respectively, according to Kaplan-Meier analysis. After SRS, new peritumoral edema occurred or preexisting edema worsened in 40% of treated meningiomas. The median time to onset of peak edema was 36 months post-SRS. Persistent and progressive edema was associated with 11 tumors, and resection was undertaken for these lesions. However, 20 patients showed initial edema progression followed by regression at a median of 18 months after radiosurgery (range 6-24 months). Initial tumor volume greater than 10 cm3, absence of prior resection, and higher margin dose were significantly (p<0.05) associated with increased risk of new or progressive edema after SRS. **CONCLUSIONS:** Stereotactic radiosurgery offers a high rate of tumor control in patients with parasagittal or parafalcine meningiomas. However, it can lead to worsening peritumoral edema in a minority of patients. Following radiosurgery, transient edema occurs earlier than persistent and progressive edema. Longitudinal follow-up of meningioma patients after SRS is required to detect and appropriately treat transient as well as progressive edema.

[57] Post-radiosurgical edema associated with parasagittal and parafalcine meningiomas: a multicenter study.

Journal of neuro-oncology. 2015;125(2):317-24
Sheehan JP, Cohen-Inbar O, Ruangkanchanasetr R, Bulent Omay S, Hess J, Chiang V, Iorio-Morin C, Alonso-Basanta M, Mathieu D, Grills IS, Lee JY, Lee CC, Dade Lunsford L
PMID: 26329323 DOI: 10.1007/s11060-015-1911-1
Stereotactic radiosurgery (SRS) offers a high degree of tumor control for benign meningiomas. However, radiosurgery can occasionally incite edema or exacerbate pre-existing peri-tumoral edema. The current study investigates the incidence, timing, and extent of edema around parasagittal or parafalcine meningiomas following SRS. A retrospective multicenter review was undertaken through participating centers in the International Gamma Knife Research Foundation (previously the North American Gamma Knife Consortium or NAGKC). All included patients had a parafalcine or parasagittal meningioma and a minimum of 6 months follow up. The median follow up was 19.6 months (6-158 months). Extent of new or worsening edema was quantitatively analyzed using volumetric analysis; edema indices were longitudinally computed following radiosurgery. Analysis was performed to identify prognostic factors for new or worsening edema. A cohort of 212 patients comprised of 51.9 % (n = 110) females, 40.1 % upfront SRS and 59.9 % underwent adjuvant SRS for post-surgical residual tumor. The median tumor volume at SRS was 5.2 ml. Venous sinus compression or invasion was demonstrated in 25 % (n = 53). The median marginal dose was 14 Gy (8-20 Gy). Tumor volume control was determined in 77.4 % (n = 164 out of 212 patients). Tumor edema progressed and then regressed in 33 % (n = 70), was stable or regressed in 52.8 % (n = 112), and progressively worsened in 5.2 % (n = 11). Tumor location, tumor volume, venous sinus invasion, margin, and maximal dose were found to be significantly related to post-SRS edema in multivariate analysis. SRS affords a high degree of tumor control for patients with parasagittal or parafalcine meningiomas. Nevertheless, SRS can lead to worsening peritumoral edema in a subset of patients such as those with larger tumors (>10 cc) and venous sinus invasion/compression. Long-term follow up is required to detect and appropriately manage post-SRS edema.

[58] Long-Term Results of Gamma Knife Radiosurgery for Intracranial Meningioma.

Brain tumor research and treatment. 2015;3(2):103-7
Jang CK, Jung HH, Chang JH, Chang JW, Park YG, Chang WS
PMID: 26605265 DOI: 10.14791/btrt.2015.3.2.103
BACKGROUND: The predominant treatment modality for meningioma is surgical resection. However, gamma knife radiosurgery is also an important treatment modality for meningioma that is small or cannot be completely removed because of its location. In this study, we evaluated the effectiveness and long-term results of radiosurgical treatment for meningioma in our institution. **METHODS:** We studied 628 patients (130 men and 498 women) who underwent gamma knife radiosurgery for intracranial meningioma, which is radiologically diagnosed, from Jan 2008 to Nov 2012. We included patients with single lesion meningioma, and followed up after 6 months with imaging, and then at 24 months with a clinical examination. Patients with high-grade meningioma or multiple meningiomas were excluded. We analyzed each of the factors associated with progression free survival. The median patient's age was 56.8 years. Maximal dosage was 27.8 Gy and marginal dosage was 13.9 Gy. **RESULTS:** The overall tumor control rate was 95%. Twenty-eight patients (4.4%) showed evidence of tumor recurrence. Ninety-eight patients (15%) developed peritumoral edema (PTE) after gamma-knife surgery; two of them (2%) underwent surgical resections due to PTE. Nine patients had craniotomy and tumor removal after gamma knife surgery. **CONCLUSION:** Gamma knife surgery for intracranial meningioma has proven to be a safe and effective treatment tool with successful long-term outcomes. Gamma knife radiosurgery can be especially effective in cases of remnant meningioma after surgical resection or where PTE is not present.

[59] Peritumoral Brain Edema after Stereotactic Radiosurgery for Asymptomatic Intracranial Meningiomas: Risks and Pattern of Evolution.

Journal of Korean Neurosurgical Society. 2015;58(4):379-84
Hoe Y, Choi YJ, Kim JH, Kwon DH, Kim CJ, Cho YH
PMID: 26587194 DOI: 10.3340/jkns.2015.58.4.379
OBJECTIVE: To investigate the risks and pattern of evolution of peritumoral brain edema (PTE) after stereotactic radiosurgery (SRS) for asymptomatic intracranial meningiomas. **METHODS:** A retrospective study was conducted on 320 patients (median age 56 years, range 24-87 years) who underwent primary Gamma Knife radiosurgery for asymptomatic meningiomas between 1998 and 2012. The median tumor volume was 2.7 cc (range 0.2-10.5 cc) and the median follow-up was 48 months (range 24-168 months). Volumetric data sets for tumors and PTE on serial MRIs were analyzed. The edema index (EI) was defined as the ratio of the volume of PTE including tumor to the tumor volume, and the relative edema indices (rEIs) were calculated from serial EIs normalized against the baseline EI. Risk factors for PTE were analyzed using logistic regression. **RESULTS:** Newly developed or

increased PTE was noted in 49 patients (15.3%), among whom it was symptomatic in 28 patients (8.8%). Tumor volume larger than 4.2 cc (p<0.001), hemispheric tumor location (p=0.005), and pre-treatment PTE (p<0.001) were associated with an increased risk of PTE. rEI reached its maximum value at 11 months after SRS and decreased thereafter, and symptoms resolved within 24 months in most patients (85.7%). **CONCLUSION:** Caution should be exercised in decision-making on SRS for asymptomatic meningiomas of large volume (>4.2 cc), of hemispheric location, or with pre-treatment PTE. PTE usually develops within months, reaches its maximum degree until a year, and resolves within 2 years after SRS.

[60] Stereotactic Gamma Knife surgery safety and efficacy in the management of symptomatic benign confined cavernous sinus meningioma.

Acta neurochirurgica. 2015;157(9):1559-64
Hafez RF, Morgan MS, Fahmy OM
PMID: 26231629 DOI: 10.1007/s00701-015-2509-2

BACKGROUND: Considering the proximity to cranial nerves from II to VI and the internal carotid artery microsurgery for cavernous sinus meningioma (CSM) has its limits of complete resection, with high potential tumor recurrences, cranial nerve and vascular morbidity. Gamma Knife surgery (GKS) is an advanced modality as primary treatment for patients harboring symptomatic benign confined CSM as well as adjuvant therapy to postoperative residual tumor giving a high rate of tumor control, stabilizing or even improving clinical condition with low morbidity. **MATERIALS AND METHODS:** The aim of this study is to evaluate the safety and efficacy of GKS used in the management of 62 patients with symptomatic benign confined CSM < 3 cm in maximum diameters treated at the International Medical Centre (IMC), Cairo, Egypt, from 2005 to end of 2012, with mean follow-up period of 36 months (range, 24-96 months) by reviewing their clinical and radiological data. For 51 patients GKS was performed as a primary treatment. The diagnosis was based on typical clinical and imaging findings and in 11 patients GKS was used as adjuvant to post-operative tumor residual with histological confirmation. **RESULTS:** There were 43 females and 19 males. The median age at the time of treatment was 48 years. The mean tumor volume was 5.7 cc, the mean tumor marginal radiation dose was 14.4 Gy, the mean isodose line was 38 %, and the mean tumor coverage was 94.4 %. The optic pathway received < 8 Gy and the brain stem < 10 Gy. At most recent follow-up, 57 patients (92 %) had stable or improved cranial nerve deficits. Post-GKS cranial nerve complications were detected in five patients (8 %). Tumor volume was controlled in 60 patients (96 %) at most recent follow-up MRI; 12 patients had a reduction in tumor size and 42 had stable tumor size, while tumor size progression was detected in two patients. The tumor progression-free survival at 3 and 5 years in 40 patients who completed at least 5 years of follow-up was 95 %. **CONCLUSIONS:** Gamma Knife surgery is a safe and effective option for the treatment of cavernous sinus meningioma not only as an adjuvant to surgery but also as an alternative to surgical removal in tumors confined mainly to the cavernous sinus.

[61] Gamma Knife radiosurgery for posterior fossa meningiomas: a multicenter study.

Journal of neurosurgery. 2015;122(6):1479-89
Sheehan JP, Starke RM, Kano H, Barnett GH, Mathieu D, Chiang V, Yu JB, Hess J, McBride HL, Honea N, Nakaji P, Lee JY, Rahmathulla G, Evanoff WA, Alonso-Basanta M, Lunsford LD
PMID: 25859812 DOI: 10.3171/2014.10.JNS14139

OBJECTIVE: Posterior fossa meningiomas represent a common yet challenging clinical entity. They are often associated with neurovascular structures and adjacent to the brainstem. Resection can be undertaken for posterior fossa meningiomas, but residual or recurrent tumor is frequent. Stereotactic radiosurgery (SRS) has been used to treat meningiomas, and this study evaluates the outcome of this approach for those located in the posterior fossa. **METHODS:** At 7 medical centers participating in the North American Gamma Knife Consortium, 675 patients undergoing SRS for a posterior fossa meningioma were identified, and clinical and radiological data were obtained for these cases. Females outnumbered males at a ratio of 3.8 to 1, and the median patient age was 57.6 years (range 12-89 years). Prior resection was performed in 43.3% of the patient sample. The mean tumor volume was 6.5 cm(3), and a median margin dose of 13.6 Gy (range 8-40 Gy) was delivered to the tumor. **RESULTS:** At a mean follow-up of 60.1 months, tumor control was achieved in 91.2% of cases. Actuarial tumor control was 95%, 92%, and 81% at 3, 5, and 10 years after radiosurgery. Factors predictive of tumor progression included age greater than 65 years (hazard ratio [HR] 2.36, 95% CI 1.30-4.29, p = 0.005), prior history of radiotherapy (HR 5.19, 95% CI 1.69-15.94, p = 0.004), and increasing tumor volume (HR 1.05, 95% CI 1.01-1.08, p = 0.005). Clinical stability or improvement was achieved in 92.3% of patients. Increasing tumor volume (odds ratio [OR] 1.06, 95% CI 1.01-1.10, p = 0.009) and clival, petrous, or cerebellopontine angle location as compared with petroclival, tentorial, and foramen magnum location (OR 1.95, 95% CI 1.05-3.65, p = 0.036) were predictive of neurological decline after radiosurgery. After radiosurgery, ventriculoperitoneal shunt placement, resection, and radiation therapy were performed in 1.6%, 3.6%, and 1.5%, respectively. **CONCLUSIONS:** Stereotactic radiosurgery affords a high rate of tumor control and neurological preservation for patients with posterior fossa meningiomas. Those with a smaller tumor volume and no prior radiation therapy were more likely to have a favorable response after radiosurgery. Rarely, additional procedures may be required for hydrocephalus or tumor progression.

[62] Gamma Knife radiosurgery of large skull base meningiomas.

Journal of neurosurgery. 2014;122(2):363-72
Starke RM, Przybylowski CJ, Sugoto M, Fezeu F, Awad AJ, Ding D, et al.
PMID: 25479122 DOI: 10.3171/2014.10.JNS14198

OBJECTIVE: Stereotactic radiosurgery (SRS) has become a common treatment modality for intracranial meningiomas. Skull base meningiomas greater than 8 cm3 in volume have been found to have worse outcomes following SRS. When symptomatic, patients with these tumors are often initially treated with resection. For tumors located in close proximity to eloquent structures or in patients unwilling or unable to undergo a resection, SRS may be an acceptable therapeutic approach. In this study, the authors review the SRS outcomes of skull base meningiomas greater than 8 cm3 in volume, which corresponds to a lesion with an approximate diameter of 2.5 cm. **METHODS:** The authors reviewed the data in a prospectively compiled database documenting the outcomes of 469 patients with skull base meningiomas treated with single-session Gamma Knife radiosurgery (GKRS). Seventy-five patients had tumors greater than 8 cm3 in volume, which was defined as a large tumor. All patients had a minimum follow-up of 6 months, but patients were included if they had a complication at any time point. Thirty patients were treated with upfront GKRS, and 45 were treated following microsurgery. Patient and tumor characteristics were assessed to determine predictors of new or worsening neurological function and tumor progression following GKRS. **RESULTS:** After a mean follow-up of 6.5 years (range 0.5-21 years), the tumor volume was unchanged in 37 patients (49%), decreased in 26 patients (35%), and increased in 12 patients (16%). Actuarial rates of progression-free survival at 3, 5, and 10 years were 90.3%, 88.6%, and 77.2%, respectively. Four patients had new or worsened edema following GKRS, but preexisting edema decreased in 3 patients. In Cox multivariable analysis, covariates associated with tumor progression were 1) presentation with any cranial nerve (CN) deficit from III to VI (hazard ratio [HR] 3.78, 95% CI 1.91-7.45; p<0.001), history of radiotherapy (HR 12.06, 95% CI 2.04-71.27; p=0.006), and tumor volume greater than 14 cm3 (HR 6.86, 95% CI 0.88-53.36; p=0.066). In those patients with detailed clinical follow-up (n=64), neurological function was unchanged in 37 patients (58%), improved in 16 patients (25%), and deteriorated in 11 patients (17%). In multivariate analysis, the factors predictive of new or worsening neurological function were history of surgery (OR 3.00, 95% CI 1.13-7.95; p=0.027), presentation with any CN deficit from III to VI (OR 3.94, 95% CI 1.49-10.24; p=0.007), and decreasing maximal dose (OR 0.76, 95% CI 0.63-0.93; p=0.007). Tumor progression was present in 64% of patients with new or worsening neurological decline. **CONCLUSIONS:** Stereotactic radiosurgery affords a reasonable rate of tumor control for large skull base meningiomas and

does so with a low incidence of neurological deficits. Those with a tumor less than 14 cm3 in volume and without presenting CN deficit from III to VI were more likely to have effective tumor control.

[63] Stereotactic radiosurgery of meningiomas following resection: predictors of progression.
Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia. 2015;22(1):161-5
Przybylowski CJ, Raper DM, Starke RM, Xu Z, Liu KC, Sheehan JP
PMID: 25439747 DOI: 10.1016/j.jocn.2014.07.028
Residual or recurrent meningiomas after initial surgical resection are commonly treated with stereotactic radiosurgery (SRS), but progression of these tumors following radiosurgery is difficult to predict. We performed a retrospective review of 60 consecutive patients who underwent resection and subsequent Gamma Knife (Elekta AB, Stockholm, Sweden) radiosurgery for residual or recurrent meningiomas at our institution from 2001-2012. Patients were subdivided by Simpson resection grade and World Health Organization (WHO) grade. Cox multivariate regression and Kaplan-Meier analyses were performed to assess risk of tumor progression. There were 45 men (75%) and 15 women (25%) with a median age of 56.8 years (range 26.5-82 years). The median follow-up period was 34.9 months (range 6-108.4 months). Simpson grade 1-3 resection was achieved in 17 patients (28.3%) and grade 4 resection in 43 patients (71.7%). Thirty-four tumors (56.7%) were WHO grade 1, and 22 (36.7%) were WHO grade 2-3. Time from resection to SRS was significantly shorter in patients with Simpson grade 4 resection compared to grade 1-3 resection (p<0.01), but did not differ by WHO grade (p=0.17). Post-SRS complications occurred in five patients (8.3%). Overall, 19 patients (31.7%) experienced progression at a median of 15.3 months (range 1.2-61.4 months). Maximum tumor diameter >2.5 cm at the time of SRS (p=0.02) and increasing WHO grade (p<0.01) were predictive of progression in multivariate analysis. Simpson resection grade did not affect progression-free survival (p=0.90). The mortality rate over the study period was 8.3%. SRS offers effective tumor control for residual or recurrent meningiomas following resection, especially for small benign tumors.

2014

[64] Outcomes and complications of gamma knife radiosurgery for skull base meningiomas.
Journal of neurological surgery. Part B, Skull base. 2014;75(6):397-401
Bir SC, Ambekar S, Ward T, Nanda A
PMID: 25452897 DOI: 10.1055/s-0034-1376422
OBJECTIVE: To review the outcomes and complications of meningiomas treated with gamma knife radiosurgery (GKRS) as a primary treatment as well as an adjunct therapy. **MATERIALS AND METHODS:** We performed a retrospective review (2000-2013) of 136 patients with meningiomas who received GKRS. Of 136 patients, 68 patients had recurrent or residual tumors after microsurgical resection, and the other 68 patients received GKRS alone. The study population was evaluated clinically and radiographically after GKRS treatment. **RESULTS:** GKRS in meningiomas showed significant variations in tumor growth control (decreased in 69 patients [50.7%], arrested growth in 47 patients [34.6%], and increased tumor size in 20 patients [14.7%]). Progression-free survival rates after GKRS at 3, 5, and 10 years were 98%, 95% and 85%, respectively. Overall improvement of signs and symptoms after GKRS was 30% (71% versus 41%) compared with pretreated sign and symptoms (p = 0.0001). The Karnofsky performance scale was significantly improved after GKRS compared with the pretreated status (92 versus 80). Twenty patients (14.7%) required resection after initial GKRS. **CONCLUSIONS:** These study findings revealed that GKRS offers a high rate of tumor control, preservation of multiple nerve functions, and a good quality of life in both new and recurrent patients with meningiomas.

[65] Is there a tumor volume threshold for postradiosurgical symptoms? A single-institution analysis.
Neurosurgery. 2014;75(5):536-45; discussion 544-5; quiz 545
Kuhn EN, Taksler GB, Dayton O, Loganathan A, Bourland D, Tatter SB, Laxton AW, Chan MD
PMID: 25171304 DOI: 10.1227/NEU.0000000000000519
BACKGROUND: Single-fraction radiosurgery may carry a higher risk of symptomatic peritumoral edema than conventionally fractionated radiotherapy, with a reported incidence of 2.5% to 37%. Previous research has shown that larger tumor volume and margin dose >14 Gy are associated with increased risk of toxicity. Parasagittal location has been associated with toxicity in some studies, but not in others. **OBJECTIVE:** To determine risk factors for and patterns of postradiosurgical symptoms (PRS). **METHODS:** This single-institution retrospective chart review included 282 stereotactic radiosurgery procedures for an intracranial meningioma from January 1999 to March 2011. PRS were assessed by using the Common Terminology Criteria for Adverse Events (Version 4.0). Statistical analyses were conducted by using the 194 procedures for which treatment plans were available. **RESULTS:** PRS were observed after 65 procedures (23%); 35 (12%) were grade 2 or higher. Posttreatment edema occurred in 21% of grade I PRS, 68% of grade II PRS, and 71% of grade III PRS. Tumor volume >/=7.1 cc (adjusted hazards ratio = 4.9, P = .02), prior external beam radiotherapy (adjusted hazards ratio = 2.6, P = .03), and histological grade (P = .005) predicted PRS. On multivariate analysis, parasagittal location was not predictive of PRS, although skull base location predicted a lower risk of symptomatic posttreatment edema (adjusted hazards ratio = 0.133, P = .02). **CONCLUSION:** In our series, prior external beam radiotherapy, tumor volume, and tumor grade are risk factors for PRS, while pretreatment edema approached statistical significance. Peritumoral edema is the predominant mechanism of significant PRS, and skull base tumors have a lower risk of posttreatment edema.

[66] Gamma knife radiosurgery for cerebellopontine angle meningiomas: a multicenter study.
Neurosurgery. 2014;75(4):398-408; quiz 408
Ding D, Starke RM, Kano H, Nakaji P, Barnett GH, Mathieu D, Chiang V, Omay SB, Hess J, McBride HL, Honea N, Lee JY, Rahmathulla G, Evanoff WA, Alonso-Basanta M, Lunsford LD, Sheehan JP
PMID: 24991710 DOI: 10.1227/NEU.0000000000000480
BACKGROUND: Resection of cerebellopontine angle (CPA) meningiomas may result in significant neurological morbidity. Radiosurgery offers a minimally invasive alternative to surgery. **OBJECTIVE:** To evaluate, in a multicenter cohort study, the outcomes of patients harboring CPA meningiomas who underwent Gamma Knife radiosurgery (GKRS). **METHODS:** From 7 institutions participating in the North American Gamma Knife Consortium, 177 patients with benign CPA meningiomas treated with GKRS and at least 6 months radiologic follow-up were included for analysis. The mean age was 59 years and 84% were female. Dizziness or imbalance (48%) and cranial nerve (CN) VIII dysfunction (45%) were the most common presenting symptoms. The median tumor volume and prescription dose were 3.6 cc and 13 Gy, respectively. The mean radiologic and clinical follow-up durations were 47 and 46 months, respectively. Multivariate regression analyses were performed to identify the predictors of tumor progression and neurological deterioration. **RESULTS:** The actuarial rates of progression-free survival at 5 and 10 years were 93% and 77%, respectively. Male sex (P = .014), prior fractionated radiation therapy (P = .010), and ataxia at presentation (P = .002) were independent predictors of tumor progression. Symptomatic adverse radiation effects and permanent neurological deterioration were observed in 1.1% and 9% of patients, respectively. Facial spasms at presentation (P = .007) and lower maximal dose (P = .011) were independently associated with neurological deterioration. **CONCLUSION:** GKRS is an effective therapy for CPA meningiomas. Depending on the patient and tumor characteristics, radiosurgery can be an adjuvant treatment to initial surgical resection or a standalone procedure that obviates the need for resection in most patients.

LEKSELL GAMMA KNIFE SOCIETY

[67] Stereotactic radiosurgery of petroclival meningiomas: a multicenter study.
Journal of neuro-oncology. 2014;119(1):169-76
Starke R, Kano H, Ding D, Nakaji P, Barnett GH, Mathieu D, Chiang V, Yu JB, Hess J, McBride HL, Honea N, Lee JY, Rahmathulla G, Evanoff WA, Alonso-Basanta M, Lunsford LD, Sheehan JP
PMID: 24821284 DOI: 10.1007/s11060-014-1470-x
Petroclival meningiomas are difficult to treat due to their intimate location with critical structures, and complete microsurgical resection is often associated with significant morbidity. In this study, we evaluate the outcomes of petroclival meningiomas treated with Gamma Knife radiosurgery (GKRS) as an adjunct to microsurgery or a primary treatment modality. A multicenter study of 254 patients with a benign petroclival meningioma was conducted through the North American Gamma Knife Consortium. One hundred and forty patients were treated with upfront radiosurgery, and 114 following surgery. Multivariate analysis was used to determine predictors of favorable defined as no tumor progression following radiosurgery and the absence of any new or worsening neurological function. At mean follow up of 71 months (range 6-252), tumor volumes increased in 9 % of tumors, remained stable in 52 %, and decreased in 39 %. Kaplan-Meier actuarial progression free survival rates at 3, 5, 8, 10, and 12 years were 97, 93, 87, 84, and 80 % respectively. At last clinical follow-up, 93.6 % of patients demonstrated no change or improvement in their neurological condition whereas 6.4 % of patients experienced progression of symptoms. Favorable outcome was achieved in 87 % of patients and multivariate predictors of favorable outcome included smaller tumor volume (OR = 0.92; 95 % CI 0.87-0.97, p = 0.003), female gender (OR 0.37; 95 % CI 0.15-0.89, p = 0.027), no prior radiotherapy (OR 0.03; 95 % CI 0.01-0.36, p = 0.006), and decreasing maximal dose (OR 0.92; 95 % CI 0.96-0.98, p = 0.010). GKRS of petroclival meningiomas achieves neurological preservation in most patients and with a high rate of tumor control.

[68] Gamma Knife radiosurgery for intracranial meningiomas: Do we need to treat the dural tail? A single-center retrospective analysis and an overview of the literature.
Surgical neurology international. 2014;5(Suppl 8):S391-5
Bulthuis VJ, Hanssens PE, Lie ST, van Overbeeke JJ
PMID: 25289168 DOI: 10.4103/2152-7806.140192
BACKGROUND: The dural tail (DT) has been described as a common feature in meningiomas. There is a great variation of tumor invasion and extent of tumor cells in the DT. Therefore, the necessity to include the whole DT in Gamma Knife radiosurgery is not clear, since inclusion increases the target volume and therefore increases the risk of complications. In this analysis, we evaluated whether the complete tail should be included as part of the target in Gamma Knife radiosurgery for meningiomas. **METHODS:** Between June 2002 and December 2010, Gamma Knife radiosurgery was performed in 160 patients with 203 meningiomas with a DT. In 105 tumors, the diagnosis was based on magnetic resonance imaging (MRI) characteristics, and in 98 tumors, the diagnosis was confirmed by histopathologic examination after surgery. The median volume of the tumors was 3.55 cc. All tumors were treated with Gamma Knife radiosurgery with a median prescribed dose of 13 Gy (range 11-15), resulting in a median marginal dose of 11 Gy (range 10-15). Only the part of the DT closely related to the tumor mass was included in the target. The median follow-up period was 41 months (range 12-123). **RESULTS:** In image-based meningiomas, the overall local control rate was 96.2% with 2- and 5-year control rates of 98.0% and 95.1%, respectively. In WHO grade I tumors, the overall local control rate was 85.9% with 2- and 5-year control rates of 94.5% and 88.0%, respectively. The overall local control rate in World Health Organization (WHO) grade II tumors was 70.6% with control rates of 83.4% and 64.4% after 2 and 5 years, respectively. The growth of all new tumors was found in the radiation target area. No tumor growth was observed in the part of the DT that had been excluded from the target volume. **CONCLUSION:** We found in this study that routinely excluding the DT from the target does not lead to out-of-field tumor progression. Given the possibility that the DT is infiltrated with tumor cells, regular follow-up is needed.

[69] Gamma Knife radiosurgery for sellar and parasellar meningiomas: a multicenter study.
Journal of neurosurgery. 2014;120(6):1268-77
Sheehan JP, Starke RM, Kano H, Kaufmann AM, Mathieu D, Zeiler FA, West M, Chao ST, Varma G, Chiang VL, Yu JB, McBride HL, Nakaji P, Youssef E, Honea N, Rush S, Kondziolka D, Lee JY, Bailey RL, Kunwar S, Petti P, Lunsford LD
PMID: 24678777 DOI: 10.3171/2014.2.JNS13139
OBJECTIVE: Parasellar and sellar meningiomas are challenging tumors owing in part to their proximity to important neurovascular and endocrine structures. Complete resection can be associated with significant morbidity, and incomplete resections are common. In this study, the authors evaluated the outcomes of parasellar and sellar meningiomas managed with Gamma Knife radiosurgery (GKRS) both as an adjunct to microsurgical removal or conventional radiation therapy and as a primary treatment modality. **METHODS:** A multicenter study of patients with benign sellar and parasellar meningiomas was conducted through the North American Gamma Knife Consortium. For the period spanning 1988 to 2011 at 10 centers, the authors identified all patients with sellar and/or parasellar meningiomas treated with GKRS. Patients were also required to have a minimum of 6 months of imaging and clinical follow-up after GKRS. Factors predictive of new neurological deficits following GKRS were assessed via univariate and multivariate analyses. Kaplan-Meier analysis and Cox multivariate regression analysis were used to assess factors predictive of tumor progression. **RESULTS:** The authors identified 763 patients with sellar and/or parasellar meningiomas treated with GKRS. Patients were assessed clinically and with neuroimaging at routine intervals following GKRS. There were 567 females (74.3%) and 196 males (25.7%) with a median age of 56 years (range 8-90 years). Three hundred fifty-five patients (50.7%) had undergone at least one resection before GKRS, and 3.8% had undergone prior radiation therapy. The median follow-up after GKRS was 66.7 months (range 6-216 months). At the last follow-up, tumor volumes remained stable or decreased in 90.2% of patients. Actuarial progression-free survival rates at 3, 5, 8, and 10 years were 98%, 95%, 88%, and 82%, respectively. More than one prior surgery, prior radiation therapy, or a tumor margin dose < 13 Gy significantly increased the likelihood of tumor progression after GKRS. At the last clinical follow-up, 86.2% of patients demonstrated no change or improvement in their neurological condition, whereas 13.8% of patients experienced symptom progression. New or worsening cranial nerve deficits were seen in 9.6% of patients, with cranial nerve (CN) V being the most adversely affected nerve. Functional improvements in CNs, especially in CNs V and VI, were observed in 34% of patients with preexisting deficits. New or worsened endocrinopathies were demonstrated in 1.6% of patients; hypothyroidism was the most frequent deficiency. Unfavorable outcome with tumor growth and accompanying neurological decline was statistically more likely in patients with larger tumor volumes (p = 0.022) and more than 1 prior surgery (p = 0.021). **CONCLUSIONS:** Gamma Knife radiosurgery provides a high rate of tumor control for patients with parasellar or sellar meningiomas, and tumor control is accompanied by neurological preservation or improvement in most patients.

[70] Surgical Experience of Infratentorial Meningiomas : Clinical Series at a Single Institution during the 20-Year Period.
Journal of Korean Neurosurgical Society. 2014;55(6):321-30
Jung MH, Moon KS, Lee KH, Jang WY, Jung TY, Jung S
PMID: 25237427 DOI: 10.3340/jkns.2014.55.6.321
OBJECTIVE: Based on surgical outcomes of patients with infratentorial meningiomas surgically treated at our institution, we analyzed the predictors for surgical resection, recurrence, complication, and survival. **METHODS:** Of surgically treated 782 patients with intracranial meningioma, 158 (20.2%) consecutive cases of infratentorial location operated on between April 1993 and May 2013 at out institute were reviewed retrospectively. The patients had a median age of 57.1 years (range, 16--77 years), a female predominance of 79.7%, and a mean follow-up duration of 48.4 months (range, 0.8--242.2 months). **RESULTS:** Gross total resection (Simpson's grade I & II) was achieved in 81.6%

(129/158) of patients. Non-skull base location was an independent factor for complete resection. The recurrence rate was 13.3% (21/158) and the 5-, 10-, and 15-year recurrence rates were 8.2%, 12.0%, and 13.3%, respectively. Benign pathology, postoperative KPS over than 90, low peritumoral edema, and complete resection were significantly associated with longer recurrence-free survival rate. The 5-, 10-, and 15-year survival rates were 96.2%, 94.9%, and 94.9%, respectively. Benign pathology, postoperative KPS over than 90 and complete resection were significantly associated with a longer survival rate. The permanent complication rate was 13% (21/158). Skull base location and postoperative KPS less than 90 were independent factors for the occurrence of permanent complication. **CONCLUSION:** Our experience shows that infratentorial meningiomas represent a continuing challenge for contemporary neurosurgeons. Various factors are related with resection degree, complications, recurrence and survival.

[71] Stereotactic radiosurgery for cerebellopontine angle meningiomas.
Journal of neurosurgery. 2014;120(3):708-15
Park SH, Kano H, Niranjan A, Flickinger JC, Lunsford LD
PMID: 24329019 DOI: 10.3171/2013.11.JNS131607
OBJECTIVE: To assess the long-term outcomes of stereotactic radiosurgery (SRS) for cerebellopontine angle (CPA) meningiomas, the authors retrospectively reviewed data from a 20-year experience. They evaluated progression-free survival as well as improvement, stabilization, or deterioration in clinical symptoms. **METHODS:** Seventy-four patients with CPA meningiomas underwent SRS involving various Gamma Knife technologies between 1990 and 2010. The most common presenting symptoms were dizziness or disequilibrium, hearing loss, facial sensory dysfunction, and headache. The median tumor volume was 3.0 cm(3) (range 0.3-17.1 cm(3)), and the median radiation dose to the tumor margin was 13 Gy (range 11-16 Gy). The median follow-up period was 40 months (range 4-147 months). **RESULTS:** At last imaging follow-up, the tumor volume had decreased in 46 patients (62%), remained stable in 26 patients (35%), and increased in 2 patients (3%). The progression-free survival after SRS was 98% at 1 year, 98% at 3 years, and 95% at 5 years. At the last clinical follow-up, 23 patients (31%) showed neurological improvement, 43 patients (58%) showed no change in symptoms or signs, and 8 patients (11%) had worsening symptoms or signs. The neurological improvement rate after SRS was 16% at 1 year, 31% at 3 years, and 40% at 5 years. The post-SRS deterioration rate was 5% at 1 year, 10% at 3 years, and 16% at 5 years. A multivariate analysis demonstrated that trigeminal neuralgia was the symptom most likely to worsen after SRS (HR 0.08, 95% CI 0.02-0.31; p = 0.001). Asymptomatic peritumoral edema occurred in 4 patients (5%) after SRS, and symptomatic adverse radiation effects developed in 7 patients (9%). **CONCLUSIONS:** Stereotactic radiosurgery for CPA meningiomas provided a high tumor control rate and relatively low risk of ARE. Tumor compression of the trigeminal nerve by a CPA meningioma resulted in an increased rate of facial pain worsening in this patient experience.

[72] Gamma Knife radiosurgery of olfactory groove meningiomas provides a method to preserve subjective olfactory function.
Journal of neuro-oncology. 2014;116(3):577-83
Gande A, Kano H, Bowden G, Mousavi SH, Niranjan A, Flickinger JC, Lunsford LD
PMID: 24398616 DOI: 10.1007/s11060-013-1335-8
Anosmia is a common outcome after resection of olfactory groove meningioma(s) (OGM) and for some patients represents a significant disability. To evaluate long term tumor control rates and preservation of subjective olfaction after Gamma Knife (GK) stereotactic radiosurgery (SRS) of OGM. We performed a retrospective chart review and telephone assessments of 41 patients who underwent GK SRS between 1987 and 2008. Clinical outcomes were stratified by full, partial or no subjective olfaction, whereas tumor control was assessed by changes in volume greater or lesser than 25%. The median clinical and imaging follow-up were 76 and 65 months, respectively. Prior to SRS, 19 (46%) patients had surgical resections and two (5%) had received fractionated radiation therapy. Twenty four patients (59%) reported a normal sense of smell, 12 (29%) reported a reduced sense of smell and five (12%) had complete anosmia. The median tumor volume was 8.5 cm(3) (range 0.6-56.1), the mean radiation dose at the tumor margin was 13 Gy (range 10-20) and the median estimated dose to the olfactory nerve was 5.1 Gy (range 1.1-18.1). At follow-up, 27 patients (66%) reported intact olfaction (three (7%) described return to a normal sense of smell), nine (22%) described partial anosmia, and five (12%) had complete anosmia. No patient reported deterioration in olfaction after SRS. Thirteen patients (32%) showed significant tumor regression, 26 (63%) had no further growth and two (5%) had progressed. The progression free tumor control rates were 97% at 1 year and 95% at 2, 10 and 20 years. Symptomatic adverse radiation effects occurred in three (7%) patients. Stereotactic radiosurgery provided both long term tumor control and preservation of olfaction.

[73] Simpson grade: an opportunity to reassess the need for complete resection of meningiomas.
Acta neurochirurgica. 2014;156(2):383-8
Heald JB, Carroll TA, Mair RJ
PMID: 24193889 DOI: 10.1007/s00701-013-1923-6
BACKGROUND: The relevance of the Simpson grading system as a predictor of meningioma progression or recurrence in modern neurosurgical practice has recently been called into question. The aim of our study was to compare the risk of progression/recurrence of tumours that had been treated with different Simpson grade resections in a contemporary population of benign (WHO grade I) meningioma patients. **METHOD:** One hundred eighty-three patients with histologically confirmed WHO grade I meningioma were retrospectively analysed. All patients underwent first-time craniotomy as their initial therapy between 2004 and 2012. Univariate analysis was performed using log-rank testing and Kaplan-Meier analysis for progression/recurrence-free survival. Multivariate analysis was performed using Cox proportional hazards regression modelling. **RESULTS:** The three-year progression/recurrence-free survival rates for patients receiving Simpson grade 1, 2 or 4 resections were 95 %, 87 % and 67 %, respectively. Simpson grade 4 resections progressed/recurred at a significantly greater rate than Simpson grade 1 resections (hazard ratio [HR] = 3.26, P = 0.04), whereas Simpson grade 2 resections did not progress/recur at a significantly greater rate than Simpson grade 1 resections (HR = 1.78, P = 0.29). Subtotal resections progressed/recurred at a significantly greater rate than gross-total resections (HR = 2.47, P = 0.03). **CONCLUSIONS:** Tumours that undergo subtotal resection are at a significantly greater risk of progression/recurrence than tumours that undergo gross-total resection. Gross-total resection should therefore be the aim of surgery. However, given modern access to follow-up imaging and stereotactic radiosurgery, these results should not be used to justify overly 'heroic' tumour resection.

[74] A retrospective analysis of survival and prognostic factors after stereotactic radiosurgery for aggressive meningiomas.
Radiation oncology (London, England). 2014;9:38
Ferraro DJ, Funk RK, Blackett JW, Ju MR, DeWees TA, Chicoine MR, Dowling JL, Rich KM, Drzymala RE, Zoberi I, Simpson JR, Jaboin JJ
PMID: 24467972 DOI: 10.1186/1748-717X-9-38
BACKGROUND: While most meningiomas are benign, aggressive meningiomas are associated with high levels of recurrence and mortality. A single institution's Gamma Knife radiosurgical experience with atypical and malignant meningiomas is presented, stratified by the most recent WHO classification. **METHODS:** Thirty-one patients with atypical and 4 patients with malignant meningiomas treated with Gamma Knife radiosurgery between July 2000 and July 2011 were retrospectively reviewed. All patients underwent prior surgical resection. Overall survival was the primary endpoint and rate of disease recurrence in the brain was a secondary endpoint. Patients who had previous radiotherapy or prior surgical resection were included. Kaplan-Meier and Cox proportional hazards models were used to estimate survival and identify factors predictive of recurrence and survival. **RESULTS:** Post-Gamma Knife recurrence was identified in 11 patients (31.4%)

with a median overall survival of 36 months and progression-free survival of 25.8 months. Nine patients (25.7%) had died. Three-year overall survival (OS) and progression-free survival (PFS) rates were 78.0% and 65.0%, respectively. WHO grade II 3-year OS and PFS were 83.4% and 70.1%, while WHO grade III 3-year OS and PFS were 33.3% and 0%. Recurrence rate was significantly higher in patients with a prior history of benign meningioma, nuclear atypia, high mitotic rate, spontaneous necrosis, and WHO grade III diagnosis on univariate analysis; only WHO grade III diagnosis was significant on multivariate analysis. Overall survival was adversely affected in patients with WHO grade III diagnosis, prior history of benign meningioma, prior fractionated radiotherapy, larger tumor volume, and higher isocenter number on univariate analysis; WHO grade III diagnosis and larger treated tumor volume were significant on multivariate analysis. **CONCLUSION:** Atypical and anaplastic meningiomas remain difficult tumors to treat. WHO grade III diagnosis and treated tumor volume were significantly predictive of recurrence and survival on multivariate analysis in aggressive meningioma patients treated with radiosurgery. Larger tumor size predicts poor survival, while nuclear atypia, necrosis, and increased mitotic rate are risk factors for recurrence. Clinical and pathologic predictors may help identify patients that are at higher risk for recurrence.

[75] Meningiomas engaging major venous sinuses.
World neurosurgery. 2014;81(1):116-24
Mathiesen T, Pettersson-Segerlind J, Kihlstrom L, Ulfarsson E
PMID: 23376533 DOI: 10.1016/j.wneu.2013.01.095
BACKGROUND: Meningiomas with growth onto or into the major venous sinuses, that is, venous meningiomas, provide management problems regarding their radical removal and preservation of venous drainage. The relationship to venous structures often precludes radical surgery; the risk of recurrence and aggressive histology is greater for parasagittal meningiomas than in other locations. Older series reflect the conflict between radical surgery and subtotal removal followed by the "wait-and-scan" approach for the residual. This review summarizes our experience of a more contemporary series of venous meningiomas, after to the introduction of gamma-knife radiosurgery, for residual tumors and a long follow-up of 10 years. **METHODS:** Treatment, histopathology, and follow-up data of 100 consecutive patients undergoing surgery for venous meningiomas were prospectively collected. Gamma-knife surgery was considered as a direct postsurgical adjunct or as an adjunct after a period of radiological follow-up. The proliferation marker MIB-1 was prospectively analyzed. Two patients were lost to follow-up after 5 years, and 98 were followed until their death or a minimum of 10 years. **RESULTS:** The 6-month outcome was good-to-excellent in 94 patients; one patient died. Eighteen patients died within 10 years. Ten had aggressive or anaplastic meningiomas. In 10 years, tumor recurrence or progression was noted in 23 patients. One important reason was that only 42% of patients undergoing Simpson grade 1 removal had free resection margins at microscopic examination. Patients with Simpson grade 1 surgery had a recurrence rate of 10%. Patients with deliberate nonradical surgery (Simpson grade IV) had a tumor recurrence rate of 72%, whereas a combined treatment of direct gamma-knife radiosurgery after a tailored microsurgical resection (Simpson IV gamma) allowed return to a low recurrence rate of 10%. The tumor proliferation indices (MIB-1/Ki-67) were prognostically relevant for recurrence after either microsurgery or gamma-knife radiosurgery. **CONCLUSION:** Surgical microscopic radicality was unexpectedly difficult to achieve. Gamma-knife radiosurgery was a useful adjunct but only in patients with tumors of low proliferative index. It should probably be used as part of the initial surgical management. As expected, treatment results for these patients seem to have improved during the last decades but recurrence and malignancy remained a problem, which is not always solved by repeated radiosurgery.

2013

[76] Patterns of recurrence after stereotactic radiosurgery for treatment of meningiomas.
Neurosurgical focus. 2013;35(6):E14
Kuhn EN, Taksler GB, Dayton O, Loganathan AG, Vern-Gross TZ, Bourland JD, Laxton AW, Chan MD, Tatter SB
PMID: 24289122 DOI: 10.3171/2013.8.FOCUS13283
OBJECTIVE: The purpose of this study was to evaluate patterns of failure after stereotactic radiosurgery (SRS) for meningiomas and factors that may influence these outcomes. **METHODS:** Based on a retrospective chart review, 279 patients were treated with SRS for meningiomas between January 1999 and March 2011 at Wake Forest Baptist Health. Disease progression was determined using serial imaging, with a minimum follow-up of 6 months (median 34.2 months). **RESULTS:** The median margin dose was 12.0 Gy (range 8.8-20 Gy). Local control rates for WHO Grade I tumors were 96.6%, 84.4%, and 75.7% at 1, 3, and 5 years, respectively. WHO Grade II and III tumors had local control rates of 72.3%, 57.7%, and 52.9% at 1, 3, and 5 years, respectively. Tumors without pathological grading had local control rates of 98.7%, 97.6%, and 94.2% at 1, 3, and 5 years, respectively. Of the local recurrences, 63.1% were classified as marginal (within 2 cm of treatment field). The 1-, 3-, and 5-year rates of distant failure were 6.5%, 10.3%, and 16.6%, respectively, for Grade I tumors and 11.4%, 17.2%, and 22.4%, respectively, for Grade II/III tumors. Tumors without pathological grading had distant failure rates of 0.7%, 3.2%, and 6.5% at 1, 3, and 5 years, respectively. Wilcoxon analysis revealed that multifocal disease ($p < 0.001$) and high-grade histology (WHO Grade II or III; $p < 0.001$) were significant predictors of local recurrence. Additionally, male sex was a significant predictor of distant recurrence ($p = 0.04$). Multivariate analysis also showed that doses greater than or equal to 12 Gy were associated with improved local control ($p = 0.015$). **CONCLUSIONS:** In this patient series, 12 Gy was the minimum sufficient margin dose for the treatment of meningiomas. Male sex is a risk factor for distant failure, whereas high-grade histology and multifocal disease are risk factors for local failure.

[77] Radiosurgery for parasagittal and parafalcine meningiomas.
Journal of neurosurgery. 2013;119(4):871-7
Ding D, Xu Z, McNeill IT, Yen CP, Sheehan JP
PMID: 23930861 DOI: 10.3171/2013.6.JNS13110
OBJECTIVE: Parasagittal and parafalcine (PSPF) meningiomas represent the second most common location for intracranial meningiomas. Involvement of the superior sagittal sinus or deep draining veins may prevent gross-total resection of these tumors without significant morbidity. The authors review their results for treatment of PSPF meningiomas with radiosurgery. **METHODS:** The authors retrospectively reviewed the institutional review board-approved University of Virginia Gamma Knife database and identified 65 patients with 90 WHO Grade I parasagittal (59%) and parafalcine (41%) meningiomas who had a mean MRI follow-up of 56.6 months. The patients' mean age was 57 years, the median preradiosurgery Karnofsky Performance Status score was 80, and the median initial tumor and treatment volumes were 3 and 3.7 cm(3), respectively. The median prescription dose was 15 Gy, isodose line was 40%, and the number of isocenters was 5. Kaplan-Meier analysis was used to determine progression-free survival (PFS). Univariate and multivariate Cox regression analyses were used to identify factors associated with PFS. **RESULTS:** The median overall PFS was 75.6 months. The actuarial tumor control rate was 85% at 3 years and 70% at 5 years. Parasagittal location, no prior resection, and younger age were found to be independent predictors of tumor PFS. For the 49 patients with clinical follow-up (mean 70.8 months), the median postradiosurgery Karnofsky Performance Status score was 90. Symptomatic postradiosurgery peritumoral edema was observed in 4 patients (8.2%); this group comprised 3 patients (6.1%) with temporary and 1 patient (2%) with permanent clinical sequelae. Two patients (4.1%) died of tumor

progression. **CONCLUSIONS:** Radiosurgery offers a minimally invasive treatment option for PSPF meningiomas, with a good tumor control rate and an acceptable complication rate comparable to most surgical series.

[78] Stereotactic radiosurgery for trigeminal pain secondary to benign skull base tumors.

World neurosurgery. 2013;80(3-4):371-7
Tanaka S, Pollock BE, Stafford SL, Link MJ
PMID: 22381855 DOI: 10.1016/j.wneu.2012.01.057
OBJECTIVE: To assess the outcome of stereotactic radiosurgery (SRS) for patients with benign skull base tumors and trigeminal-related facial pain. **METHODS:** We undertook a retrospective review of 31 consecutive patients (25 women, 6 men) with benign skull base tumors and trigeminal pain who underwent SRS between 1991 and 2008. The tumors included 17 posterior fossa meningiomas, 9 cavernous sinus meningiomas, and 5 trigeminal schwannomas. The median patient age was 62 years (range, 17-81 years). In all cases the tumor was the primary target for SRS. The median follow-up after SRS was 50 months (range, 12-184 months). **RESULTS:** The actuarial tumor control rate after SRS was 95% at both 3 years and 5 years. Eighteen patients (58%) initially achieved complete resolution of trigeminal pain. Higher maximum dose was associated with initial complete pain resolution on a multivariate analysis. However, 7 patients had recurrent pain during follow-up. At last follow-up, only 7 patients (23%) remained pain-free off medications. Further treatment in addition to medical therapy was required for 6 patients (19%). **CONCLUSION:** Although SRS offers excellent radiographic tumor control for benign skull base tumors, durable relief of tumor-related trigeminal pain without medication was noted in only one-fourth of patients at last follow-up.

[79] Does prior microsurgery improve or worsen the outcomes of stereotactic radiosurgery for cavernous sinus meningiomas?

Neurosurgery. 2013;73(3):401-10
Kano H, Park KJ, Kondziolka D, Iyer A, Liu X, Tonetti D, Flickinger JC, Lunsford LD
PMID: 23719052 DOI: 10.1227/01.neu.0000431471.64289.3d
BACKGROUND: Stereotactic radiosurgery (SRS) is an important option for patients with cavernous sinus meningiomas. **OBJECTIVE:** To evaluate cranial nerve outcomes in patients who underwent SRS for cavernous sinus meningiomas with or without prior microsurgery. **METHODS:** During a 23-year interval, 272 patients underwent Gamma Knife SRS for cavernous sinus meningiomas (70 men, 202 women; median age, 54 years). In this series, 99 patients underwent prior microsurgical resection. The median tumor volume was 7.9 cm and median marginal dose was 13 Gy. The median follow-up period was 62 months (range, 6-209 months). **RESULTS:** The progression-free survival after SRS was 96% at 3 years, 94% at 5 years, and 86% at 10 years. After SRS, 13 of 91 patients (14%) who underwent prior microsurgery had improvement of preexisting cranial nerve symptoms or signs. In comparison, 54 of 145 patients (37%) without prior microsurgery had improvement of preexisting cranial nerve symptoms or signs. The improvement rate of cranial nerve deficits after SRS in patients without prior microsurgery was 20% at 1 year, 34% at 2 years, 36% at 3 years, and 39% at 5 years. Patients who had not undergone prior microsurgery had significantly higher improvement rates of preexisting cranial nerve symptoms and signs (P = .001). After SRS, 29 patients (11%) developed new or worsened cranial nerve function. **CONCLUSION:** SRS provided long-term effective tumor control and a low risk of new cranial nerve deficits. Improvement in preexisting cranial neuropathies was detected in significantly more patients who had not undergone prior microsurgical procedures.

[80] Single-fraction radiosurgery of benign cavernous sinus meningiomas.

Journal of neurosurgery. 2013;119(3):675-82
Pollock BE, Stafford SL, Link MJ, Garces YI, Foote RL
PMID: 23808540 DOI: 10.3171/2013.5.JNS13206
OBJECTIVE: Stereotactic radiosurgery (SRS) is an important treatment option for patients with cavernous sinus meningiomas (CSM). To analyze factors associated with local tumor control and complications after single-fraction SRS, the authors reviewed cases involving patients treated with Gamma Knife SRS between 1990 and 2008. **METHODS:** Excluded were patients with WHO Grade II or III tumors, radiation-induced tumors, multiple meningiomas, neurofibromatosis Type 2, and prior or concurrent radiotherapy. Five patients were lost to follow-up and 3 patients refused research authorization. The remaining 115 patients (29 men, 86 women) had either histologically confirmed WHO Grade I (n = 46, 40%) or presumed (n = 69, 60%) CSM. The median treatment volume was 9.3 cm(3) (range 1.3-42.2 cm(3)). The median margin dose was 16 Gy (range 12-20 Gy). The median follow-up after SRS was 89 months (range 12-251 months). Thirty-nine patients (34%) had 10 or more years of follow-up after SRS. **RESULTS:** Six patients (5%) had tumor progression (in field, n = 3; marginal, n = 3) at a median of 74 months (range 42-145 months) after SRS. The local tumor control rate was 99% at 5 years and 93% at 10 years after SRS. No analyzed factor was associated with local control after SRS. Fourteen patients (12%) had permanent complications at a median onset of 23 months (range 2-146 months) including trigeminal dysfunction (n = 9), diplopia (n = 2), ischemic stroke (n = 2), and hypopituitarism (n = 1). The 2-year, 5-year, and 10-year rates of complications were 7%, 10%, and 15%, respectively. Multivariate analysis found larger treatment volume (HR 1.1, 95% CI 1.02-1.2, p = 0.01) to be associated with complications after SRS. The complication rate for patients with a treatment volume of 9.3 cm(3) or less was 3% (2 of 58 cases) compared with 21% (12 of 57 cases) for patients with a treatment volume greater than 9.4 cm(3). **CONCLUSIONS:** Single-fraction SRS at the radiation doses used in this series provided durable tumor control for patients with benign CSM. Larger tumor volume remains the primary factor associated with complications after single-fraction SRS of benign CSM despite advancements in SRS technique.

[81] Gamma Knife surgery for the treatment of patients with asymptomatic meningiomas.

Journal of neurosurgery. 2013;119(2):487-93
Salvetti DJ, Nagaraja TG, Levy C, Xu Z, Sheehan J
PMID: 23706054 DOI: 10.3171/2013.4.JNS121746
OBJECTIVE: Increasingly, meningiomas are detected incidentally, prior to symptom development. While these lesions are traditionally managed conservatively until symptoms develop or lesion growth occurs, it is conceivable that patients at high risk for symptom development may benefit from earlier intervention prior to the appearance of symptoms. However, little research has been performed to determine whether Gamma Knife surgery (GKS) can alter the rate of symptom development in such patients. **METHODS:** A retrospective case study was performed by screening the University of Virginia GKS database for patients treated for asymptomatic meningiomas. From the patient's medical records, pertinent demographic and treatment information was obtained. Yearly follow-up MRI had been performed to assess tumor control and detect signs of radiation-induced injury. Clinical follow-up via neurological examination had been performed to assess symptom development. **RESULTS:** Forty-two patients, 33 females (78.6%) and 9 males (21.4%), with 42 asymptomatic meningiomas were included in the analysis. The median age at GKS was 53 years. The most common lesion location was the cerebral convexities (10 lesions [23.8%]), and the median lesion size was 4.0 ml. The median duration of imaging and clinical follow-ups was 59 and 76 months, respectively. During the follow-up period, 1 tumor (2.4%) increased in size, 2 patients (4.8%) demonstrated symptoms, and 1 patient (2.4%) exhibited possible signs of radiation-induced injury. Thus, actuarial tumor control rates were 100%, 95.7%, and 95.7% for 2, 5, and 10 years, respectively. Actuarial symptom control at 5 and 10 years was 97% and 93.1%, respectively. Overall progression-free survival was 91.1% and 77.8% at 5 and 10 years, respectively. **CONCLUSIONS:** Compared with published rates of symptom development in patients with untreated meningiomas, results in this study indicated that patients with asymptomatic lesions may benefit from prophylactic radiosurgery prior to the appearance of symptoms. Additionally, GKS is a treatment option that offers low morbidity.

LEKSELL GAMMA KNIFE SOCIETY

[82] The impact of adjuvant stereotactic radiosurgery on atypical meningioma recurrence following aggressive microsurgical resection.

Journal of neurosurgery. 2013;119(2):475-81

Hardesty DA, Wolf AB, Brachman DG, McBride HL, Youssef E, Nakaji P, Porter RW, Smith KA, Spetzler RF, Sanai N

PMID: 23394332 DOI: 10.3171/2012.12.JNS12414

OBJECTIVE: Patients with atypical meningioma often undergo gross-total resection (GTR) at initial presentation, but the role of adjuvant radiation therapy remains unclear. The increasing prevalence of stereotactic radiosurgery (SRS) in the modern neurosurgical era has led to the use of routine postoperative radiation therapy in the absence of evidence-based guidelines. This study sought to define the long-term recurrence rate of atypical meningiomas and identify the value of SRS in affecting outcome. **METHODS:** The authors identified 228 patients with microsurgically treated atypical meningiomas who underwent a total of 257 resections at the Barrow Neurological Institute over the last 20 years. Atypical meningiomas were diagnosed according to current WHO criteria. Clinical and radiographic data were collected retrospectively. **RESULTS:** Median clinical and radiographic follow-up was 52 months. Gross-total resection, defined as Simpson Grade I or II resection, was achieved in 149 patients (58%). The median proliferative index was 6.9% (range 0.4%-20.6%). Overall 51 patients (22%) demonstrated tumor recurrence at a median of 20.2 months postoperatively. Seventy-one patients (31%) underwent adjuvant radiation postoperatively, with 32 patients (14%) receiving adjuvant SRS and 39 patients (17%) receiving adjuvant intensity modulated radiation therapy (IMRT). The recurrence rate for patients receiving SRS was 25% (8/32) and for IMRT was 18% (7/39), which was not significantly different from the overall group. Gross-total resection was predictive of progression-free survival (PFS; relative risk 0.255, $p < 0.0001$), but postoperative SRS was not associated with improved PFS in all patients or in only those with subtotal resections. **CONCLUSIONS:** Atypical meningiomas are increasingly irradiated, even after complete or near-complete microsurgical resection. This analysis of the largest patient series to date suggests that close observation remains reasonable in the setting of aggressive microsurgical resection. Although postoperative adjuvant SRS did not significantly affect tumor recurrence rates in this experience, a larger cohort study with longer follow-up may reveal a therapeutic benefit in the future.

[83] Gamma knife stereotactic radiosurgery for atypical and malignant meningiomas.

Acta neurochirurgica. Supplement. 2013;116:85-9

Mori Y, Tsugawa T, Hashizume C, Kobayashi T, Shibamoto Y

PMID: 23417463 DOI: 10.1007/978-3-7091-1376-9_13

BACKGROUND: Non-benign meningioma has a known trend to recur repeatedly. The results of Gamma Knife stereotactic radiosurgery (GKS) for recurrent or residual atypical and malignant meningiomas are reported. **METHODS:** Thirty patients (13 men, 17 women) with World Health Organization (WHO) grade II (24 cases) or grade III (6 cases) intracranial meningiomas underwent GKS. Their age varied from 30 to 86 years (mean 64 years). Before GKS, the tumor was surgically resected in all patients, and 11 of them also underwent conventional external beam radiation therapy, LINAC-based stereotactic radiotherapy (SRT), or intensity-modulated radiation therapy. FINDINGS: Of the 30 patients, 23 were followed after the initial GKS for a median period of 28 months (range 2-135 months). Local tumor control after treatment was 74 % at 1 year, 52 % at 2 years, and 34 % at 3 years. A total of 15 patients underwent repeat GKS (one to nine times) because of local or distant intracranial tumor progression, seven were subjected to surgical re-resection of the neoplasm, and four had additional SRT. At the time of the last follow-up, 21 patients were alive, and 2 had died. One of the latter expired because of brain tumor progression at 91 months after the initial GKS, and the other patient died from lung cancer. **CONCLUSIONS:** Although atypical and malignant meningiomas have a trend to recur repeatedly, aggressive tumor management with repeat GKS at the time of progression can provide long survival in these patients.

[84] Management of spheno-orbital en plaque meningiomas: clinical outcome in a consecutive series of 40 patients.

British journal of neurosurgery. 2013;27(1):84-90

Boari N, Gagliardi F, Spina A, Bailo M, Franzin A, Mortini P

PMID: 22905887 DOI: 10.3109/02688697.2012.709557

OBJECTIVE: The clinical results of combined surgical-radiosurgical treatment of the spheno-orbital en plaque meningiomas in a consecutive series of 40 patients are presented. The clinical outcome is evaluated in terms of surgical morbidity, tumour control, visual function and cosmetic result. **METHODS:** Forty patients harbouring spheno-orbital en plaque meningiomas were treated. Forty-two surgical procedures were performed through a fronto-temporal craniotomy. The reconstruction of the orbital walls was performed using a titanium mesh. In case of sub-total resection, the patients underwent Gamma-Knife radiosurgery on residual tumour. Visual function was evaluated considering visual acuity tested with a Snellen chart, funduscopy and Goldmann perimetry for visual field defects. Proptosis was quantified on CT scans. **RESULTS:** Total or gross-total tumour resection was achieved in 56.1% of cases. Permanent morbidity was recorded in three patients after surgery. Visual acuity and visual field defect both improved in 66.7% of patients; improvement of proptosis was recorded in 92.7% of cases. Eighteen patients were treated with Gamma-Knife radiosurgery for residual tumour after surgery and four patients for tumour relapse at follow-up. The mean follow-up period was 72.6 months. **CONCLUSIONS:** Surgical treatment of spheno-orbital en plaque meningiomas is safe and effective: a low morbidity rate was recorded and visual function improved in about two-thirds of patients. Reconstruction of the orbital walls with titanium mesh provides for good functional and cosmetic results. In case of superior orbital fissure and cavernous sinus invasion, the combined surgical-radiosurgical treatment allows to minimise surgical morbidity and to achieve tumour control.

2012

[85] Radiosurgery for atypical and anaplastic meningiomas: histopathological predictors of local tumor control.

Stereotact Funct Neurosurg. 2012;90(5):316–324.

Kim JW, Kim DG, Paek SH, Chung HT, Myung JK, Park SH, Kim YH, Han JH, Yang SY, Park CK, Jung HW

PMID: 22797807 DOI: 10.1159/000338253

OBJECTIVE: We investigated the radiosurgical outcomes of patients with nonbenign meningiomas retrospectively and sought to identify prognostic factors for local tumor control after radiosurgery with an emphasis on histopathology. **METHOD:** Between 1998 and 2010, 35 patients with 49 atypical or anaplastic meningiomas were treated with radiosurgery. The mean tumor volume and marginal irradiation dose were 3.5 cm(3) (range 0.3–25.3) and 16 Gy (range 12–21), respectively. **RESULTS:** The actuarial local tumor control rates for patients with atypical meningiomas at 1, 2 and 3 years after radiosurgery were 78, 53 and 36%, respectively, whereas those for anaplastic meningiomas were 35% at 1 year and 10% at 2 years. Multivariate analysis revealed that the mitotic count t (</=8 per 10 high-power fields; HPF) and the MIB-1 proliferation marker labeling index (LI; </=8%) were significant favorable prognostic factors for the radiosurgical outcomes of patients with nonbenign meningiomas ($p = 0.014$ and$p = 0.012$, respectively). **CONCLUSIONS:** Radiosurgery could be a treatment option for patients with atypical meningiomas, but more aggressive treatments are needed for those with anaplastic meningiomas. Histopathological factors such as mitotic count and MIB-1 LI are significant prognostic factors for the radiosurgical outcomes of patients with nonbenign.

[86] Single-fraction radiosurgery of benign intracranial meningiomas.

Neurosurgery. 2012;71(3):604–612.

Pollock BE, Stafford SL, Link MJ, Brown PD, Garces YI, Foote RL

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BACKGROUND: Stereotactic radiosurgery (SRS) of benign intracranial meningiomas is an accepted management option for well selected patients. **OBJECTIVE:** To analyze patients who had single-fraction SRS for benign intracranial meningiomas to determine factors associated with tumor control and neurologic complications. **METHOD:** Retrospective review was performed of 416 patients (304 women/112 men) who had single-fraction SRS for imaging defined (n = 252) or confirmed World Health Organization grade I (n = 164) meningiomas from 1990 to 2008. Excluded were patients with radiation-induced tumors, multiple meningiomas, neurofibromatosis type 2, and previous or concurrent radiotherapy. The majority of tumors (n = 337; 81%) involved the cranial base or tentorium. The median tumor volume was 7.3 cm; the median tumor margin dose was 16 Gy. The median follow-up was 60 months. **RESULTS:** The disease-specific survival rate was 97% at 5 years and 94% at 10 years. The 5- and 10-year local tumor control rate was 96% and 89%, respectively. Male sex (hazard ratio [HR]: 2.5, P = .03), previous surgery (HR: 6.9, P = .002) and patients with tumors located in the parasagittal/ falx/convexity regions (HR: 2.8, P = .02) were negative risk factors for local tumor control. In 45 patients (11%) permanent radiation-related complications developed at a median of 9 months after SRS. The 1- and 5-year radiation related complication rate was 6% and 11%, respectively. Risk factors for permanent radiation-related complication rate were increasing tumor volume (HR: 1.05, P = .008) and patients with tumors of the parasagittal/falx/ convexity regions (HR: 3.0, P = .005). **CONCLUSIONS:** Single-fraction SRS at the studied dose range provided a high rate of tumor control for patients with benign intracranial meningiomas. Patients with small volume, nonoperated cranial base or tentorial meningiomas had the best outcomes after single-fraction SRS.

[87] Single-fraction radiosurgery for presumed intracranial meningiomas: efficacy and complications from a 22-year experience.

Int J Radiat Oncol Biol Phys. 2012;83(5):1414–1418.
Pollock BE, Stafford SL, Link MJ, Garces YI, Foote
PMID: 22209154 DOI: 10.1016/j.ijrobp.2011.10.033 RL
PURPOSE: To define the rate of tumor control and factors associated with radiation-related complications after single-fraction radiosurgery (SRS) for patients with imaging defined intracranial meningiomas. **MATERIALS AND METHODS:** Retrospective review of 251 patients (192 women, 59 men) having SRS for imaging-defined intracranial meningiomas between 1990 and 2008. Excluded were patients with radiation-induced tumors, meningiomatosis, or neurofibromatosis. The mean patient age was 58.6 +/- 13.4 years. The majority of tumors involved the skull base/ tentorium (n = 210, 83.7%). The mean treatment volume was 7.7 +/- 6.2 cm(3); the mean tumor margin dose was 15.8 +/- 2.0 Gy. Follow-up (mean, 62.9 +/- 43.9 months) was censored at last evaluation (n = 224), death (n = 22), or tumor resection (n = 5). **RESULTS:** No patient died from tumor progression or radiation-related complications. Tumor size decreased in 181 patients (72.1%) and was unchanged in 67 patients (26.7%). Three patients (1.2%) had in-field tumor progression noted at 28, 145, and 150 months, respectively. No patient had a marginal tumor progression. The 3- and 10-year local control rate was 99.4%. One patient had distant tumor progression at 105 months and underwent repeat SRS. Thirty-one patients (12.4%) had either temporary (n = 8, 3.2%) or permanent (n = 23, 9.2%) symptomatic radiation-related complications including cranial nerve deficits (n = 14), headaches (n = 5), hemiparesis (n = 5), new/ worsened seizure (n = 4), cyst-formation (n = 1), hemifacial spasm (n = 1), and stroke (n = 1). The 1- and 5-year complication rates were 8.3% and 11.5%, respectively. Radiation-related complications were associated with convexity/falx tumors (HR = 2.8, 95% CI 1.3–6.1, p = 0.009) and increasing tumor volume (HR = 1.05, 95% CI 1.0–1.1, p = 0.04) on multivariate analysis. No patient developed a radiation-induced tumor. **CONCLUSIONS:** Single-fraction SRS at the used dose range provides a high rate of tumor control for patients with imaging defined intracranial meningiomas. However, treatment failures were noted after 10 years emphasizing the need for long-term imaging follow-up after meningioma SRS.

[88] The Importance of the conformality, heterogeneity, and gradient indices in evaluating gamma knife radiosurgery treatment plans for intracranial meningiomas.

Int J Radiat Oncol Biol Phys. 2012; 83(5):1406–1416.
Balagamwala EH,1 Suh JH, Barnett GH, Khan MK, Neyman G, Cai RS, Vogelbaum MA, Novak E, Chao ST
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PURPOSE: To investigate the relationship between the conformality index (CIn), heterogeneity index (HIn), and gradient index (GIn) and the development of toxicity in patients treated with Gamma Knife radiosurgery (GKRS) for intracranial meningiomas. **MATERIALS AND METHODS:** Treatment records of patients treated from 1997 to 2009 with at least 6 months of follow-up were reviewed. The following parameters were collected: CIn, HIn, GIn (ratio of the volume receiving half the prescription isodose to the volume receiving the full prescription isodose), brainstem (BS) maximum dose (MD), BS volume receiving >/=12 Gy (V12), optic apparatus (OA) MD, OA V8 Gy, OA V10, number of isocenters, number of isocenters outside target volume, and the occurrence of six toxicities. Univariate and multivariate logistic regression modeling were used for analysis. **RESULTS:** This study included 145 patients (148 meningiomas) with a median follow-up time of 27 months (range, 6–113.9 months). The majority of meningiomas were located in the skull base (53%). The median prescription dose was 13 Gy (range, 10–24 Gy) to the 51.50% (range, 50–92%) isodose. A lower HIn was correlated with a higher GIn (p = 0.007). CIn was not associated with any toxicity. Higher HIn was associated with the development of dizziness (odds ratio [OR] 1.9; p = 0.02), whereas a lower GIn was associated with motor deficits (OR 0.38; p = 0.04) and auditory changes (OR 0.59; p = 0.04). The OA MD, V8, and V12 were not associated with visual changes, but visual changes were associated with a higher number of isocenters outside the target volume (OR 1.93; p = 0.07). BS V12 was correlated with the development of auditory changes (OR 1.05; p = 0.05), whereas patients with higher BS MD tended to have increased toxicity. **CONCLUSIONS:** Close attention must be paid to all three indices (CIn, HIn, GIn) when optimal treatment plans are determined. We recommend that the target CIn should be /=3.0 for intracranial meningiomas.

[89] Long-term tumor control of benign intracranial meningiomas after radiosurgery in a series of 4565 patients.

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Santacroce A, Walier M, Regis J, Liscak R, Motti E, Lindquist C, Kemeny A, Kitz K, Lippitz B, Alvarez RM, Pedersen PH, Yomo S, Lupidi F, Dominikus K, Blackburn P, Mindermann T, Bundschuh O, van Eck AT, Fimmers R, Horstmann GA
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BACKGROUND: Radiosurgery is the main alternative to microsurgical resection for benign meningiomas. **OBJECTIVE:** To assess the long-term efficacy and safety of radiosurgery for meningiomas with respect to tumor growth and prevention of associated neurological deterioration. Medium- to long-term outcomes have been widely reported, but no large multicenter series with long-term follow-up have been published. **METHOD:** From 15 participating centers, we performed a retrospective observational analysis of 4565 consecutive patients harboring 5300 benign meningiomas. All were treated with Gamma Knife radiosurgery at least 5 years before assessment for this study. Clinical and imaging data were retrieved from each center and uniformly entered into a database by 1 author (A.S.). **RESULTS:** Median tumor volume was 4.8 cm, and median dose to tumor margin was 14 Gy. All tumors with imaging follow-up <24 months were excluded. Detailed results from 3768 meningiomas (71%) were analyzed. Median imaging follow-up was 63 months. The volume of treated tumors decreased in 2187 lesions (58%), remained unchanged in 1300 lesions (34.5%), and increased in 281 lesions (7.5%), giving a control rate of 92.5%. Only 84 (2.2%) enlarging tumors required further treatment. Five- and 10-year progression-free survival rates were 95.2% and 88.6%, respectively. Tumor control was higher for imaging defined tumors vs grade I meningiomas (P <.001), for female vs male patients (P <.001), for sporadic vs multiple meningiomas (P <.001), and for skull base vs convexity tumors (P <.001). Permanent morbidity rate was 6.6% at the last follow-up. **CONCLUSIONS:** Radiosurgery is a safe and effective method for treating benign meningiomas even in the medium to long term.