LEKSELL
GAMMA KNIFE
SOCIETY

BIBLIOGRAPHY

Leksell Gamma Knife® Radiosurgery Bibliography

Trigeminal Neuralgia

2012–2020

≥ 30 patient cohorts

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

LEKSELL GAMMA KNIFE SOCIETY

2020

[1] Long-term pain outcomes in elderly patients with trigeminal neuralgia: comparison of first-time microvascular decompression and stereotactic radiosurgery.

Neurosurg Focus. 2020 Oct;49(4):E23.
Raygor KP, Lee AT, Nichols N, Wang DD, Ward MM, Barbaro NM, Chang EF
PMID: 33002871 DOI: 10.3171/2020.7.FOCUS20446

OBJECTIVE: Common surgical treatments for trigeminal neuralgia (TN) include microvascular decompression (MVD) and stereotactic radiosurgery (SRS). The use of MVD in elderly patients has been described but has yet to be prospectively compared to SRS, which is well-tolerated and noninvasive. The authors aimed to directly compare long-term pain control and adverse event rates for first-time surgical treatments for idiopathic TN in the elderly. **METHODS:** A prospectively collected database was reviewed for TN patients who had undergone treatment between 1997 and 2017 at a single institution. Standardized collection of preoperative demographics, surgical procedure, and postoperative outcomes was performed. Data analysis was limited to patients over the age of 65 years who had undergone a first-time procedure for the treatment of idiopathic TN with at least 1 year of follow-up. **RESULTS:** One hundred ninety-three patients meeting the study inclusion criteria underwent surgical procedures for TN during the study period (54 MVD, 24 MVD+Rhiz, 115 SRS). In patients in whom an artery was not compressing the trigeminal nerve during MVD, a partial sensory rhizotomy (MVD+Rhiz) was performed. Patients in the SRS cohort were older than those in the MVD and MVD+Rhiz cohorts (mean +/- SD, 79.2 +/- 7.8 vs 72.9 +/- 5.7 and 70.9 +/- 4.8 years, respectively; $p < 0.0001$) and had a higher mean Charlson Comorbidity Index (3.8 +/- 1.1 vs 3.0 +/- 0.9 and 2.9 +/- 1.0, respectively; $p < 0.0001$). Immediate or short-term postoperative pain-free rates (Barrow Neurological Institute [BNI] pain intensity score I) were 98.1% for MVD, 95.8% for MVD+Rhiz, and 78.3% for SRS ($p = 0.0008$). At the last follow-up, 72.2% of MVD patients had a favorable outcome (BNI score I-IIIa) compared to 54.2% and 49.6% of MVD+Rhiz and SRS patients, respectively ($p = 0.02$). In total, 0 (0%) SRS, 5 (9.3%) MVD, and 1 (4.2%) MVD+Rhiz patients developed any adverse event. Multivariate Cox proportional hazards analysis demonstrated that procedure type ($p = 0.001$) and postprocedure sensory change ($p = 0.003$) were statistically significantly associated with pain control. **CONCLUSIONS:** In this study cohort, patients who had undergone MVD had a statistically significantly longer duration of pain freedom than those who had undergone MVD+Rhiz or SRS as their first procedure. Fewer adverse events were seen after SRS, though the MVD-associated complication rate was comparable to published rates in younger patients. Overall, the results suggest that both MVD and SRS are effective options for the elderly, despite their advanced age. Treatment choice can be tailored to a patient's unique condition and wishes.

[2] Trigeminal Neuralgia Secondary to Meningiomas and Vestibular Schwannoma Is Improved after Stereotactic Radiosurgery: A Systematic Review and Meta-Analysis.

Stereotact Funct Neurosurg. 2020 Sep 9:1-11.
Peciu-Florianu I, Regis J, Levivier M, Dedeciusova M, Reyns N, Tuleasca C
PMID: 32906130 DOI: 10.1159/000509842

INTRODUCTION: Trigeminal neuralgia (TN) secondary to tumors is encountered in up to 6% of patients with facial pain syndromes and is considered to be associated with tumors affecting the trigeminal nerve pathways. The most frequent are meningiomas and vestibular schwannomas (VS). Stereotactic radiosurgery (SRS) has emerged as a valuable treatment, with heterogeneity of clinical results. We sought to review the medical literature on TN treated with SRS for meningiomas and VS and investigate the rates of improvement of TN symptoms. **METHODS:** We reviewed articles published between January 1990 and December 2019 in PubMed. Pain relief after SRS, the maintenance of pain relief, and TN recurrence and complications were evaluated with separate meta-analyses, taking into account the data on individual patients. **RESULTS:** Pain relief after SRS was reported as Barrow Neurological Institute (BNI) pain intensity scores of BNI I in 50.5% (range 36-65.1%) of patients and BNI I-IIIb in 83.8% (range 77.8-89.8%). There was no significant difference in series discussing outcomes for tumor targeting versus tumor and nerve targeting. Recurrences were described in 34.7% (range 21.7-47.6; tumor targeting). Maintenance of BNI I was reported in 36.4% (range 20.1-52.7) and BNI I-IIIb in 41.2% (range 29.8-52.7; tumor targeting series). When both the nerve and the tumor were targeted, only 1 series reported 86.7% with BNI I-IIIb at last follow-up. Complications were encountered in 12.6% (range 6.3-18.8; tumor targeting series) of patients; however, they were much higher, as high as 26.7%, in the only study reporting them after targeting both the nerve and the tumor. The most common complication was facial numbness. **CONCLUSION:** SRS for TNB secondary to benign tumors, such as meningiomas and VS, is associated with favorable clinical course, but less favorable than in idiopathic TN. There was, however, heterogeneity among reports and targeting approaches. Although targeting both the nerve and the tumor seemed to achieve better long-term results, the rate of complications was much higher and the number of patients treated was limited. Future clinical studies should focus on the standard reporting of clinical outcomes and randomization of targeting methods.

2019

[3] Effectiveness of Gamma Knife Radiosurgery in the Treatment of Refractory Trigeminal Neuralgia: A Case Series.

Operative neurosurgery (Hagerstown, Md.). 2019;18(6):571-576
Tavakol S, Jackanich A, Strickland BA, Marietta M, Ravina K, Yu C, Chang EL, Giannotta S, Zada G
PMID: 31620790 DOI: 10.1093/ons/opz311

BACKGROUND: Medical management is the first line of treatment for trigeminal neuralgia (TN). Patients with medically refractory TN may undergo a variety of invasive surgical interventions with varying success rates. Management of TN refractory to both medical and surgical intervention remains somewhat controversial. **OBJECTIVE:** To assess the effectiveness of Gamma Knife radiosurgery (GKRS; Elekta Instruments AB) for medically refractory TN. **METHODS:** A retrospective review was conducted for 57 cases (47 patients) who underwent GKRS for refractory TN at our institution between 2005 and 2018. TN pain outcomes were evaluated using the Barrow Neurological Institute (BNI) Pain Scale. A good outcome was defined by post-GKRS BNI score of I-III, whereas treatment failure was defined BNI score IV-V. **RESULTS:** Of the total 57 GKRS procedures, 47 (82.5%) had good outcomes. A total of 22 patients (46.8%) experienced complete pain relief off medications (BNI I). The average time to pain relief was 30 d (range 1-120 d). Prior invasive surgical treatment for TN was not found to have a significant impact on GKRS outcomes ($P = .32$). Target and treatment volumes were not found to correlate significantly with GKRS outcomes (.47 and .47, respectively). Complications included 2 cases (4.2%) of facial numbness. A total of 37 patients (78.7%) did not have any additional invasive surgical interventions following GKRS treatment. **CONCLUSION:** GKRS is a safe and effective treatment modality for both medically and surgically refractory TN. Complete symptom relief was possible in patients with prior surgical or GKRS treatments. Recurrent symptoms following surgery or GKRS should not exclude a patient from future GKRS consideration.

[4] Establishment of a Therapeutic Ratio for Gamma Knife Radiosurgery of Trigeminal Neuralgia: The Critical Importance of Biologically Effective Dose Versus Physical Dose.

World neurosurgery. 2019;134:e204-e213
Tuleasca C, Paddick I, Hopewell JW, Jones B, Millar WT, Hamdi H, Porcheron D, Levivier M, Regis J
PMID: 31606504 DOI: 10.1016/j.wneu.2019.10.021

OBJECTIVE: How variations of treatment time affect the safety and efficacy of Gamma Knife (GK) radiosurgery is a matter of considerable debate. With

the relative simplicity of treatment planning for trigeminal neuralgia (TN), this question has been addressed in a group of these patients. Using the concept of the biologically effective dose (BED), the effect of the two key variables, dose and treatment time, were considered. **METHODS:** A retrospective analysis was performed of 408 TN cases treated from 1997 to 2010. Treatment involved the use of a single 4 mm isocenter. If conditions allowed, the isocenter was placed at a median distance of 7.5 mm from the emergence of the trigeminal nerve from the brain stem. The effects were assessed in terms of the incidence of the complication, hypoesthesia, and in terms of efficacy using the incidence of pain free after 30 days and 1 and 2 years. These responses were evaluated with respect to both the physical dose and the BED, the latter using a bi-exponential repair model. **RESULTS:** RE-evaluation showed that the prescription doses, at the 100% isodose, varied from 75 to 97.9 Gy, delivered in 25-135 minutes. The relationship between the physical dose and the incidence of hypoesthesia was not significant; the overall incidence was approximately 20%. However, a clear relationship was found between the BED and the incidence of hypoesthesia, with the incidence increasing from <5% after a BED of approximately 1800 Gy2.47 to 42% after approximately 2600 Gy2.47. Efficacy, in terms of freedom from pain, was approximately 90%, irrespective of the BED (1550-2600 Gy2.47) at 1 and 2 years. The data suggested that "pain free" status developed more slowly at lower BED values. **CONCLUSIONS:** These results strongly suggest that safety and efficacy might be better achieved by prescribing a specific BED instead of a physical dose. A dose and time to BED conversion table has been prepared to enable iso-BED prescriptions. This finding could dramatically change dose-planning strategies in the future. However, this concept requires validation for other indications for which more complex dose planning is required.

[5] Characteristics and treatment of Multiple Sclerosis-related trigeminal neuralgia: An Italian multi-centre study.

Multiple sclerosis and related disorders. 2019;37:101461

Ferraro D, Annovazzi P, Moccia M, Lanzillo R, De Luca G, Nociti V, Fantozzi R, Paolicelli D, Ragonese P, Gajofatto A, Boffa L, Cavalla P, Lo Fermo S, Buscarinu MC, Lorefice L, Cordioli C, Calabrese M, Gallo A, Pinardi F, Tortorella C, Di Filippo M, Camera V, Maniscalco GT, Radaelli M, Buttari F, Tomassini V, Cocco E, Gasperini C, Solaro C

PMID: 31678859 DOI: 10.1016/j.msard.2019.101461

BACKGROUND: The prevalence of trigeminal neuralgia (TN) in Multiple Sclerosis (MS) patients is higher than in the general population and its management can be particularly challenging. Our aim is to describe the characteristics, treatment and prognostic factors of MS-related TN in a retrospective multicentre study. **METHODS:** Neurologists members of the RIREMS group (Rising Researchers in MS) enrolled MS patients with a TN diagnosis and filled out a spreadsheet comprising their clinical data. **RESULTS:** Population consisted of 298 patients. First-choice preventive treatments were carbamazepine and oxcarbazepine. A surgical procedure was performed in 81 (30%) patients, most commonly gamma knife stereotactic radiosurgery (37%), followed by microvascular decompression (22%) and radiofrequency thermocoagulation (21%); one third of patients underwent at least two procedures. Surgery was associated with higher disability, male sex and longer interval between MS and TN onset. Patients (77%) who stayed on at least one preventive medication at most recent follow-up, after a mean period of 8 years, had a higher disability compared to the untreated group. Furthermore, patients with higher disability at TN onset were less likely to discontinue their first preventive medication due to pain remission, had bilateral TN more frequently and underwent surgical interventions earlier. **CONCLUSION:** MS patients with a higher disability at TN onset and with a longer interval between MS and TN onset had differing clinical features and outcomes: pain was more frequently bilateral, surgery was more frequent and anticipated, and preventive medication discontinuation due to pain remission was less common.

[6] Repeat gamma knife stereotactic radiosurgery in the treatment of trigeminal neuralgia: A single-center experience and focused review of the literature.

Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia. 2019;70:102-107

Omar NB, Amburgy JW, Self DM, Christen AM, Larios EA, Ditty BJ, Jacob R, Fiveash J, Spencer S, Markert JM, Guthrie BL, Fisher WS, Chambers MR

PMID: 31447361 DOI: 10.1016/j.jocn.2019.08.061

OBJECTIVES: Repeat Gamma Knife stereotactic radiosurgery (GKSR) for refractory trigeminal neuralgia (TGN) is an increasingly common practice. Prior studies have reported varying success rates and incidence of trigeminal nerve dysfunction following repeated GKSR. We report treatment outcomes and toxicity in patients following repeat GKSR for TGN at the University of Alabama at Birmingham (UAB) with a focused review of the literature. **METHODS:** We retrospectively reviewed medical records of 55 TGN patients re-treated with radiosurgery using the Leksell Gamma Knife(R) at the University of Alabama at Birmingham between 1996 and 2012. Outcomes were defined using the Modified Marseille Scale. Demographics, prior treatments and symptom duration were correlated with outcomes. **RESULTS:** Eighteen patients (33%) achieved Marseille Class I or II, 14 (25%) Class III or IV, and 23 (42%) Class V at a mean follow-up of 14.4months. Twenty-five patients (45%) developed new trigeminal nerve dysfunction after re-treatment. Of these, four (16%) did not develop dysfunction until subsequent microvascular decompression (MVD) for inadequate symptom relief. **CONCLUSIONS:** Although more than half of the patients undergoing repeat GKSR for refractory TGN maintained excellent or good outcomes (Marseille classes I-IV) at an average follow-up of 14.4months, neither age, gender, nor pre-treatment duration of symptoms or interval between treatments had a statistically significant effect on outcomes. Following repeat GKSR, patients have increased risk for new-onset trigeminal nerve dysfunction and those undergoing MVD after repeat GKSR may have an increased risk for new-onset trigeminal nerve dysfunction.

[7] Changes in the muscles of mastication before and after primary stereotactic radiosurgery in patients with idiopathic trigeminal neuralgia.

Journal of neurosurgery. 2019;:1-8

Mohammed N, Hung YC, Eluvathingal Muttikkal TJ, Bliley RC, Xu Z, Sheehan JP

PMID: 31703194 DOI: 10.3171/2019.8.JNS191455

OBJECTIVE: The motor root of the trigeminal nerve runs close to the sensory root and receives considerable radiation during Gamma Knife radiosurgery (GKRS) for trigeminal neuralgia (TN). The object of this study was to evaluate via MRI the changes in the muscles of mastication before and after upfront GKRS in patients with idiopathic TN. **METHODS:** In this single-institution retrospective cohort study, all patients with idiopathic unilateral TN treated with primary GKRS at the University of Virginia in the period from 2007 to 2017 were included provided that they had pre- and post-GKRS MRI data. The thicknesses of the temporalis, pterygoid, and masseter muscles were measured on both pre- and post-GKRS MRI in a blinded fashion. Changes in the muscles like fatty infiltration, MRI signal, or atrophy were noted. **RESULTS:** Among the 68 patients eligible for inclusion in the study, 136 temporalis muscles, 136 medial pterygoid muscles, 136 lateral pterygoid muscles, and 136 masseter muscles were assessed. A subset of patients was found to have muscle atrophy even prior to GKRS. Pre-GKRS atrophy of the masseter, medial pterygoid, lateral pterygoid, and temporalis muscles was seen in 18 (26%), 16 (24%), 9 (13%), and 16 (24%) patients, respectively. Logistic regression analysis showed that distribution of pain in the V3 territory ($p = 0.01$, OR 5.43, 95% CI 1.46-20.12) and significant pain on chewing ($p = 0.02$, OR 5.32, 95% CI 1.25-22.48) were predictive of pre-GKRS atrophy. Reversal of atrophy of these muscles occurred after GKRS in a majority of the patients. The incidence of new-onset permanent post-GKRS muscle atrophy was 1.5%. The median follow-up was 39 months (range 6-108 months). **CONCLUSIONS:** A subset of patients with TN with significant pain on chewing have pre-GKRS disuse atrophy of the muscles of mastication. A reversal of the atrophy occurs in a majority of the patients following GKRS. New-onset motor neuropathy post-GKRS was rare.

LEKSELL GAMMA KNIFE SOCIETY

[8] Gamma Knife Radiosurgery for Multiple Sclerosis-Associated Trigeminal Neuralgia.

Neurosurgery. 2019;85(5):E933-E939
Helis CA, McTyre E, Munley MT, Bourland JD, Lucas JT, Cramer CK, Tatter SB, Laxton AW, Chan MD
PMID: 31173108 DOI: 10.1093/neuros/nyz182

BACKGROUND: Trigeminal neuralgia in the setting of multiple sclerosis (MS-TN) is a challenging condition to manage that is commonly treated with Gamma Knife radiosurgery (GKRS; Elekta AB). However, data regarding the efficacy of this treatment are somewhat limited, particularly for repeat GKRS. **OBJECTIVE:** To report outcomes of GKRS for MS-TN from a cohort study. **METHODS:** Retrospective review of our GKRS database identified 77 cases of unilateral MS-TN (UMSTN) in 74 patients treated with GKRS between 2001 and 2016, with 37 cases undergoing repeat GKRS. Background medical history, treatment outcomes and complications, and dosimetric data were obtained by retrospective chart reviews and telephone interviews. **RESULTS:** Eighty-two percent of UMSTN cases achieved Barrow Neurological Institute (BNI) IIIb or better pain relief following initial GKRS for a median duration of 1.1 yr. Estimated rates of pain relief at 1, 3, and 5 yr were 51, 39, and 29% respectively. Eighty-eight percent achieved BNI IIIb or better pain relief after repeat GKRS for a median duration of 4.0 yr. Estimated rates of pain relief at 1 and 3 yr were 70 and 54%, respectively. Median doses for initial and repeat GKRS were 85 and 80 Gy to the 100% isodose line, respectively. Those with MS-TN had a shorter duration of BNI IIIb or better pain relief after initial (4.6 vs 1.1 yr), but not repeat GKRS (3.8 vs 4.0 yr) compared to a historical cohort from our institution. **CONCLUSION:** GKRS is an effective, well-tolerated treatment for patients with MS-TN. More durable relief is often achieved with repeat GKRS.

[9] Temporal disconnection between pain relief and trigeminal nerve microstructural changes after Gamma Knife radiosurgery for trigeminal neuralgia.

Journal of neurosurgery. 2019;:1-9
Hung PS, Tohyama S, Zhang JY, Hodaie M
PMID: 31299654 DOI: 10.3171/2019.4.JNS19380

OBJECTIVE: Gamma Knife radiosurgery (GKRS) is a noninvasive surgical treatment option for patients with medically refractive classic trigeminal neuralgia (TN). The long-term microstructural consequences of radiosurgery and their association with pain relief remain unclear. To better understand this topic, the authors used diffusion tensor imaging (DTI) to characterize the effects of GKRS on trigeminal nerve microstructure over multiple posttreatment time points. **METHODS:** Ninety-two sets of 3-T anatomical and diffusion-weighted MR images from 55 patients with TN treated by GKRS were divided within 6-, 12-, and 24-month posttreatment time points into responder and nonresponder subgroups (>/= 75% and < 75% reduction in posttreatment pain intensity, respectively). Within each subgroup, posttreatment pain intensity was then assessed against pretreatment levels and followed by DTI metric analyses, contrasting treated and contralateral control nerves to identify specific biomarkers of successful pain relief. **RESULTS:** GKRS resulted in successful pain relief that was accompanied by asynchronous reductions in fractional anisotropy (FA), which maximized 24 months after treatment. While GKRS responders demonstrated significantly reduced FA within the radiosurgery target 12 and 24 months posttreatment ($p < 0.05$ and $p < 0.01$, respectively), nonresponders had statistically indistinguishable DTI metrics between nerve types at each time point. **CONCLUSIONS:** Ultimately, this study serves as the first step toward an improved understanding of the long-term microstructural effect of radiosurgery on TN. Given that FA reductions remained specific to responders and were absent in nonresponders up to 24 months posttreatment, FA changes have the potential of serving as temporally consistent biomarkers of optimal pain relief following radiosurgical treatment for classic TN.

[10] Gamma knife radiosurgery on the trigeminal ganglion for idiopathic trigeminal neuralgia: Results and review of the literature.

Surgical neurology international. 2019;10:89
Somaza S, Montilla EM, Mora MC
PMID: 31528427 DOI: 10.25259/SNI-134-2019

BACKGROUND: In the present study, we evaluate the results of gamma knife surgery (GKS) for the treatment of trigeminal neuralgia (TN) using the trigeminal ganglion (TG') and the adjacent fibers of trigeminal nerve as a target. **METHODS:** From February 2013 to July 2017, we treated 30 cases of TN with GKS. In this group, all patients had an idiopathic typical TN. The radiosurgical target was conformed through two isocenters, 8 and 4 mm at the cavum de Meckel. The maximum dose was 86 Gy using the isodose line of 50%. The median age of the patients was 58.5 (range 28-94) years old, and the median time from diagnosis to GKS was 94 months (range 13-480 months). The median follow-up was 28.5 (range 12-49) months. Clinical outcomes were analyzed. Univariate and multivariate analyses were performed to evaluate factors that correlated with a favorable, pain-free outcome. **RESULTS:** The mean time to relief of pain was 7 (range 1-40) days. The percentage of patients with significant pain relief was 93.3%. Relapse in pain was noted in four patients at 3, 16, 19, and 36 months. Nine patients were treated in acute status. Fourteen patients had intense pain between 1 and 7 days before the procedure. Among those with the recurrence of their symptoms, one patient had a microvascular decompression. Multivariate regression adjusted for age and sex suggests that, by 40 months, 70% of the patients treated with radiosurgery will remain pain free. At the last follow-up, GKS resulted in pain relief in 86.6% of patients. Our analysis suggests that, using this technique, we can expect that approximately 70% of patients with TN will have some degree of pain improvement at 3 years' post radiosurgery. **CONCLUSIONS:** GKS on TG appears to be a reasonable treatment option with short latency period, minor collateral effects, and high percentage of pain control. The mechanism of action of radiosurgery could be related to the inactivation of the satellite glial cells in the TG.

[11] Gamma Knife Radiosurgery for Trigeminal Neuralgia: A Comparison of Dose Protocols.

Brain sciences. 2019;9(6)
Boling W, Song M, Shih W, Karlsson B
PMID: 31185646 DOI: 10.3390/brainsci9060134

PURPOSE: A variety of treatment plans including an array of prescription doses have been used in radiosurgery treatment of trigeminal neuralgia (TN). However, despite a considerable experience in the radiosurgical treatment of TN, an ideal prescription dose that balances facial dysesthesia risk with pain relief durability has not been determined. **METHODS AND MATERIALS:** This retrospective study of patients treated with radiosurgery for typical TN evaluates two treatment doses in relation to outcomes of pain freedom, bothersome facial numbness, and patient satisfaction with treatment. All patients were treated with radiosurgery for intractable and disabling TN. A treatment dose protocol change from 80 to 85 Gy provided an opportunity to compare two prescription doses. The variables evaluated were pain relief, treatment side-effect profile, and patient satisfaction. **RESULTS:** Typical TN was treated with 80 Gy in 26 patients, and 85 Gy in 37 patients. A new face sensory disturbance was reported after 80 Gy in 16% and after 85 Gy in 27% ($p = 0.4$). Thirteen failed an 80 Gy dose whereas seven failed an 85 Gy dose. Kaplan-Meier analysis found that at 29 months 50% failed an 80 Gy treatment compared with 79% who had durable pain relief after 85 Gy treatment ($p = 0.04$). **CONCLUSION:** The 85 Gy dose for TN provided a more durable pain relief compared to the 80 Gy one without a significantly elevated occurrence of facial sensory disturbance.

[12] Trigeminal Nerve Atrophy Predicts Pain Recurrence After Gamma Knife Stereotactic Radiosurgery for Classical Trigeminal Neuralgia.

Neurosurgery. 2019;84(4):927-934
Hu YS, Lee CC, Guo WY, Lin CJ, Yang HC, Wu HM, Liu KD, Chung WY

PMID: 29660047 DOI: 10.1093/neuros/nyy122
BACKGROUND: Trigeminal nerve atrophy and neurovascular compression (NVC) are frequently observed in classical trigeminal neuralgia (CTN). **OBJECTIVE:** To determine whether nerve characteristics contribute to Gamma Knife (Elekta AB, Stockholm, Sweden) surgery (GKS) outcomes in unilateral CTN without previous surgery. **METHODS:** From 2006 to 2012, 67 patients with unilateral CTN without previous surgery received GKS with a maximal dose of 90 Gy delivered to the trigeminal nerve juxta brainstem. Two evaluators, blinded to the side of pain, analyzed the magnetic resonance images before GKS to obtain the parameters, including nerve cross-sectional area (CSA), vessel type of NVC, and site of NVC along the nerve. Correlations of the parameters with pain relief (Barrow Neurological Institute [BNI] grades I-IIIb) and recurrence (BNI grades VI-V) were made by using Cox regression and Kaplan-Meier analyses. **RESULTS:** The median CSA of the symptomatic nerves was significantly smaller than that of the asymptomatic nerves (4.95 vs 5.9 mm2, P < .001). After adjustment for age and sex, larger nerve CSA was associated with lower initial pain relief (hazard ratio 0.81, P = .03) and lower pain recurrence after initial response (hazard ratio 0.58, P = .02). Patients with nerve atrophy (CSA of </= 4.4 mm2 after receiver operating characteristic curve analysis) had a lower 5-yr probability of maintaining pain relief after initial response than those without nerve atrophy (65% vs 86%, P = .04). **CONCLUSION:** Trigeminal nerve atrophy may predict pain recurrence in patients with initial post-GKS relief of CTN. Arterial and proximal NVC are not predictive of GKS outcomes. Future studies are required to determine optimal treatments for long-term pain relief in patients with CTN and trigeminal nerve atrophy.

[13] Application of an artificial neural network model for early outcome prediction of gamma knife radiosurgery in patients with trigeminal neuralgia and determining the relative importance of risk factors.

Clinical neurology and neurosurgery. 2019;179:47-52
Ertiaei A, Ataeinezhad Z, Bitaraf M, Sheikhrezaei A, Saberi H
PMID: 30825722 DOI: 10.1016/j.clineuro.2018.11.007
OBJECTIVES: Stereotactic radiosurgery (SRS) is a minimally invasive modality for the treatment of trigeminal neuralgia (TN). Outcome prediction of this modality is very important for proper case selection. The aim of this study was to create artificial neural networks (ANN) to predict the clinical outcomes after gamma knife radiosurgery (GKRS) in patients with TN, based on preoperative clinical factors. **PATIENTS AND METHODS:** We used the clinical findings of 155 patients who were underwent GKRS (from March 2000 to march 2015) at Iran Gamma Knife center, Teheran, Iran. Univariate analysis was performed for a long list of risk factors, and those with P-Value < 0.2 were used to create back-propagation ANN models to predict pain reduction and hypoesthesia after GKRS. Pain reduction was defined as BNI score 3a or lower and hypoesthesia was defined as BNI score 3 or 4. **RESULTS:** Typical trigeminal neuralgia (TTN) (P-Value = 0.018) and age>65 (P-Value = 0.040) were significantly associated with successful pain reduction and three other variables including radiation dosage >85 (P-Value = 0.098), negative history of diabetes mellitus (P-Value = 0.133) and depression (P-Value = 0.190). On the other hand, radio dosage>85 (P-Value = 0.008) was significantly associated with hypoesthesia, other related risk factors (with p-Value<0.2), were history of multiple sclerosis (P-Value = 0.106), pain duration more than 10 years before GKRS (P-Value = 0.115), history of depression (P-Value = 0.139), history of percutaneous ablative procedures (P-Value = 0.148) and history of diabetes mellitus (P-Value = 0.169).ANN models could predict pain reduction and hypoesthesia with the accuracy of 84.5% and 91.5% respectively. By mutual elimination of each factor in this model we could also evaluate the contribution of each factor in the predictive performance of ANN. **CONCLUSIONS:** The findings show that artificial neural networks can predict post operative outcomes in patients who underwent GKRS with a high level of accuracy. Also the contribution of each factor in the prediction of outcomes can be determined using the trained network.

[14] Stereotactic Radiosurgery for Trigeminal Neuralgia in Patients With Multiple Sclerosis: A Multicenter Study.

Neurosurgery. 2019;84(2):499-505
Xu Z, Mathieu D, Heroux F, Abbassy M, Barnett G, Mohammadi AM, Kano H, Caruso J, Shih HH, Grills IS, Lee K, Krishnan S, Kaufmann AM, Lee JYK, Alonso-Basanta M, Kerr M, Pierce J, Kondziolka D, Hess JA, Gerrard J, Chiang V, Lunsford LD, Sheehan JP
PMID: 29688562 DOI: 10.1093/neuros/nyy142
BACKGROUND: Facial pain response (PR) to various surgical interventions in patients with multiple sclerosis (MS)-related trigeminal neuralgia (TN) is much less optimal. No large patient series regarding stereotactic radiosurgery (SRS) has been published. **OBJECTIVE:** To evaluate the clinical outcomes of MS-related TN treated with SRS. **METHODS:** This is a retrospective cohort study. A total of 263 patients contributed by 9 member tertiary referral Gamma Knife centers (2 in Canada and 7 in USA) of the International Gamma Knife Research Consortium (IGKRF) constituted this study. **RESULTS:** The median latency period of PR after SRS was 1 mo. Reasonable pain control (Barrow Neurological Institute [BNI] Pain Scores I-IIIb) was achieved in 232 patients (88.2%). The median maintenance period from SRS was 14.1 months (range, 10 days to 10 years). The actuarial reasonable pain control maintenance rates at 1 yr, 2 yr, and 4 yr were 54%, 35%, and 24%, respectively. There was a correlation between the status of achieving BNI-I and the maintenance of facial pain recurrence-free rate. The median recurrence-free rate was 36 mo and 12.2 mo in patients achieving BNI-I and BNI > I, respectively (P = .046). Among 210 patients with known status of post-SRS complications, the new-onset of facial numbness (BNI-I or II) after SRS occurred in 21 patients (10%). **CONCLUSION:** In this largest series SRS offers a reasonable benefit to risk profile for patients who have exhausted medical management. More favorable initial response to SRS may predict a long-lasting pain control.

[15] Study on the Therapeutic Effects of Trigeminal Neuralgia With Microvascular Decompression and Stereotactic Gamma Knife Surgery in the Elderly.

The Journal of craniofacial surgery. 2019;30(1):e77-e80
Yu R, Wang C, Qu C, Jiang J, Meng Q, Wang J, Wei S
PMID: 30507874 DOI: 10.1097/SCS.0000000000004999
OBJECTIVE: The aim of the study was to evaluate the efficacy of microvascular decompression (MVD) and stereotactic gamma knife surgery (GKS) in the treatment of trigeminal neuralgia (TN) in the elderly. **PATIENTS AND METHODS:** Retrospective analysis of 137 elderly cases with TN underwent MVD, partial sensory rhizotomy (PR) treatment from August 2007 to March 2017 and 56 cases underwent GKS treatment from May 2014 to February 2017 was made, compared the efficacy of MVD and GKS in different age groups. **RESULTS:** In 125 patients of MVD alone, the responsible vessels included 60 cases of superior cerebellar artery, 55 cases of anterior inferior cerebellar artery, 4 cases of venous vascular compression, 13 cases of mixed arteriovenous compression and 3 cases of vertebral artery, and 2 cases of no responsible vessel. **METHODS:** MVD 125 cases, MVD + PR 10 cases, PR 1 cases, simple exploration in 1 case. Results of MVD surgery: Among 125 patients of MVD alone, 95 cases were cured, 15 cases improved, and 15 cases were ineffective. Among 10 cases of MVD + PR, cured in 9 cases and improved in 1 case. PR and simple exploration in 2 cases got pain disappeared. Postoperative complications of MVD: No deaths, CSF leakage in 2 cases, intracranial infection in 3 cases, ipsilateral hearing loss in 1 case, and ipsilateral facial paralysis in 1 case, delayed intracranial hematoma in 2 cases. After GKS treatment, the shortest onset time was from 9 days up to 6 months, an average of 2.2 months. Among 56 patients, 30 cases were cured, accounting for 53.6%, 20 cases improved, accounting for 35.7%, 6 cases were ineffective, accounting for 10.7%. Postoperative complications were facial numbness and dysesthesia, 7 cases, the incidence was 12.5%. In the group of 60 to 70 years old and the group of 70 to 80 years old, the treatment effect of MVD was better than that of GKS (chi test, P < 0.05); there was no significant difference between MVD and GKS in >80 years old group (chi test, P > 0.05). There was no significant

difference in the therapeutic effect of TN underwent GKS among all age groups (chi test, P > 0.05). **CONCLUSION:** Microvascular decompression should be performed more prudently in elderly patients (>80 years old), and the indications for PR should be relatively relaxed. MVD + PR could improve the curative effect in patients with trigeminal neuralgia >80 years. Gamma knife treatment of trigeminal neuralgia had high safety, less complications, and positive curative effect, especially suitable for patients >80 years.

2018

[16] Radiosurgery for multiple sclerosis-related trigeminal neuralgia: retrospective review of long-term outcomes.

Journal of neurosurgery. 2018;:1-8
Przybylowski CJ, Cole TS, Baranoski JF, Little AS, Smith KA, Shetter AG
PMID: 30544359 DOI: 10.3171/2018.5.JNS173194

OBJECTIVE: The objective of this study was to assess long-term outcomes of facial pain and numbness after radiosurgery for multiple sclerosis (MS)-related trigeminal neuralgia (MS-TN). **METHODS:** The authors conducted a retrospective review of their Gamma Knife radiosurgeries (GKRSs) to identify all patients treated for MS-TN (1998-2014) with at least 3 years of follow-up. Treatment and clinical data were obtained via chart review and mailed or telephone surveys. Pain control was defined as a facial pain score of I-IIIb on the Barrow Neurological Institute (BNI) Facial Pain Intensity Scale. Kaplan-Meier analysis was performed to determine the rates of pain control after index and first salvage GKRS procedures. Patients could have had more than 1 salvage procedure. Pain control rates were based on the number of patients at risk during follow-up. **RESULTS:** Of the 50 living patients who underwent GKRS, 42 responded to surveys (31 women [74%], median age 59 years, range 32-76 years). During the initial GKRS, the trigeminal nerve root entry zone was targeted with a single isocenter, using a 4-mm collimator with the 90% isodose line completely covering the trigeminal nerve and the 50% isodose line abutting the surface of the brainstem. The median maximum radiation dose was 85 Gy (range 50-85 Gy). The median follow-up period was 78 months (range 36-226 months). The rate of pain control after the index GKRS (n = 42) was 62%, 29%, 22%, and 13% at 1, 3, 5, and 7 years, respectively. Twenty-eight patients (67%) underwent salvage treatment, including 25 (60%) whose first salvage treatment was GKRS. The rate of pain control after the first salvage GKRS (n = 25) was 84%, 50%, 44%, and 17% at 1, 3, 5, and 7 years, respectively. The rate of pain control after the index GKRS with or without 1 salvage GKRS (n = 33) was 92%, 72%, 52%, 46%, and 17% at 1, 3, 5, 7, and 10 years, respectively. At last follow-up, 9 (21%) of the 42 patients had BNI grade I facial pain, 35 (83%) had achieved pain control, and 4 (10%) had BNI grade IV facial numbness (very bothersome in daily life). **CONCLUSIONS:** Index GKRS offers good short-term pain control for MS-TN, but long-term pain control is uncommon. If the index GKRS fails, salvage GKRS appears to offer beneficial pain control with low rates of bothersome facial numbness.

[17] Long-term pain outcomes for recurrent idiopathic trigeminal neuralgia after stereotactic radiosurgery: a prospective comparison of first-time microvascular decompression and repeat stereotactic radiosurgery.

Journal of neurosurgery. 2018;:1-9
Raygor KP, Wang DD, Ward MM, Barbaro NM, Chang EF
PMID: 30485183 DOI: 10.3171/2018.5.JNS172243

OBJECTIVE: Microvascular decompression (MVD) and stereotactic radiosurgery (SRS) are common surgical treatments for trigeminal neuralgia (TN). Many patients who receive SRS have pain recurrence; the ideal second intervention is unknown. The authors directly compared pain outcomes after MVD and repeat SRS in a population of patients in whom SRS failed as their first-line procedure for TN, and they identified predictors of pain control. **METHODS:** The authors reviewed a prospectively collected database of patients undergoing surgery for TN between 1997 and 2014 at the University of California, San Francisco (UCSF). Standardized data collection focused on preoperative clinical characteristics, surgical characteristics, and postoperative outcomes. Patients with typical type 1, idiopathic TN with >/= 1 year of follow-up were included. **RESULTS:** In total, 168 patients underwent SRS as their first procedure. Of these patients, 90 had residual or recurrent pain. Thirty of these patients underwent a second procedure at UCSF and had >/= 1 year of follow-up; 15 underwent first-time MVD and 15 underwent repeat SRS. Patients undergoing MVD were younger than those receiving repeat SRS and were more likely to receive >/= 80 Gy during the initial SRS. The average follow-up was 44.9 +/- 33.6 months for MVD and 48.3 +/- 45.3 months for SRS. All patients achieved complete pain freedom without medication at some point during their follow-up. At last follow-up, 80% of MVD-treated patients and 33.3% of SRS-treated patients had a favorable outcome, defined as Barrow Neurological Institute Pain Intensity scores of I-IIIa ($p < 0.05$). Percentages of patients with favorable outcome at 1 and 5 years were 86% and 75% for the MVD cohort and 73% and 27% for the SRS cohort, respectively ($p < 0.05$). Multivariate Cox proportional hazards analysis demonstrated that performing MVD was statistically significantly associated with favorable outcome (HR 0.12, 95% CI 0.02-0.60, $p < 0.01$). There were no statistically significant predictors of favorable outcome in the MVD cohort; however, the presence of sensory changes after repeat SRS was associated with pain relief ($p < 0.01$). **CONCLUSIONS:** Patients who received MVD after failed SRS had a longer duration of favorable outcome compared to those who received repeat SRS; however, both modalities are safe and effective. The presence of post-SRS sensory changes was predictive of a favorable pain outcome in the SRS cohort.

[18] Gamma knife radiosurgery for trigeminal schwannoma: a 20-year experience with long-term treatment outcome.

Journal of neuro-oncology. 2018;140(1):89-97
Ryu J, Lee SH, Choi SK, Lim YJ
PMID: 29931615 DOI: 10.1007/s11060-018-2934-1

PURPOSE: This study evaluated the long-term tumor control rate (TCR) and symptomatic outcomes of patients treated with gamma knife radiosurgery (GKRS) for trigeminal schwannomas (TSs). **METHODS:** Thirty-two patients with TS who underwent GKRS between January 1994 and January 2013 with at least 2 years of follow-up were enrolled in the study. Clinical charts and surgical records were retrospectively reviewed to evaluate factors affecting TCR and symptomatic outcomes. The median patient age was 57.5 years (max = 81, interquartile range [IQR] = 51-67), and the median tumor volume was 3.55 cm(3) (max = 25.2 cm(3), IQR = 2.0-6.2 cm(3)). The median marginal and maximum doses were 13.0 Gy (max = 18.0 Gy, IQR = 12.5-15 Gy) and 23.8 Gy (max = 35 Gy, IQR = 21.7-25.0 Gy), respectively. **RESULTS:** At a median follow-up of 90.5 months (max = 281 months, IQR = 49-139.75 months), the actuarial 3-, 5-, and 10-year TCR were 93.8, 86.2, and 80.8%, respectively. Our data and multivariate analysis indicated that the target volume was the only significant factor determining TCR and that larger tumors (> 5 cm(3)) were more likely to progress ($p = 0.011$). Cystic tumors had a higher incidence of transient enlargement and temporary symptom change compared to those in solid tumors. An unfavorable outcome of symptoms was observed in five patients (15.6%). Complications were observed in two patients (6.25%), including hydrocephalus and radio-induced trigeminal neuropathy, respectively. **CONCLUSIONS:** GKRS can be a safe and effective treatment modality for TS with long-term follow-up, especially for small tumors. An extended period of follow-up observation is required to conclude the clinical response to GKRS.

[19] Early postsurgical diffusivity metrics for prognostication of long-term pain relief after Gamma Knife radiosurgery for trigeminal neuralgia.

Journal of neurosurgery. 2018;131(2):539-548
Tohyama S, Hung PS, Zhong J, Hodaie M
PMID: 30117773 DOI: 10.3171/2018.3.JNS172936

OBJECTIVE: Gamma Knife radiosurgery (GKRS) is an important treatment modality for trigeminal neuralgia (TN). Current longitudinal assessment after

GKRS relies primarily on clinical diagnostic measures, which are highly limited in the prediction of long-term clinical benefit. An objective, noninvasive, predictive tool would be of great utility to advance the clinical management of patients. Using diffusion tensor imaging (DTI), the authors' aim was to determine whether early (6 months post-GKRS) target diffusivity metrics can be used to prognosticate long-term pain relief in patients with TN. **METHODS:** Thirty-seven patients with TN treated with GKRS underwent 3T MRI scans at 6 months posttreatment. Diffusivity metrics of fractional anisotropy, axial diffusivity, radial diffusivity, and mean diffusivity were extracted bilaterally from the radiosurgical target of the affected trigeminal nerve and its contralateral, unaffected nerve. Early (6 months post-GKRS) diffusivity metrics were compared with long-term clinical outcome. Patients were identified as long-term responders if they achieved at least 75% reduction in preoperative pain for 12 months or longer following GKRS. **RESULTS:** Trigeminal nerve diffusivity at 6 months post-GKRS was predictive of long-term clinical effectiveness, where long-term responders (n = 19) showed significantly lower fractional anisotropy at the radiosurgical target of their affected nerve compared to their contralateral, unaffected nerve and to nonresponders. Radial diffusivity and mean diffusivity, correlates of myelin alterations and inflammation, were also significantly higher in the affected nerve of long-term responders compared to their unaffected nerve. Nonresponders (n = 18) did not exhibit any characteristic diffusivity changes after GKRS. **CONCLUSIONS:** The authors demonstrate that early postsurgical target diffusivity metrics have a translational, clinical value and permit prediction of long-term pain relief in patients with TN treated with GKRS. Importantly, an association was found between the footprint of radiation and clinical effectiveness, where a sufficient level of microstructural change at the radiosurgical target is necessary for long-lasting pain relief. DTI can provide prognostic information that supplements clinical measures, and thus may better guide the postoperative assessment and clinical decision-making for patients with TN.

[20] Evaluation of Microvascular Decompression as Rescue Therapy for Trigeminal Neuralgia in Patients with Failed Gamma Knife Surgery.
World neurosurgery. 2018;116:e86-e91
Zhao H, Fan SQ, Wang XH, Zhang X, Tang YD, Zhu J, Zhou P, Li ST
PMID: 29807177 DOI: 10.1016/j.wneu.2018.04.063
OBJECTIVE: Owing to increasing use of Gamma Knife surgery (GKS) for trigeminal neuralgia (TN), physicians are challenged over the problem of choosing an appropriate treatment if GKS fails. The aim of this study was to determine whether microvascular decompression (MVD) is a safe and effective alternative therapy for trigeminal neuralgia in patients with failed GKS. **METHODS:** Between January 1, 2010, and January 1, 2012, data of 32 patients with trigeminal neuralgia who presented with persistent or recurrent pain after GKS and elected to undergo MVD were collected. Clinical characteristics, operative findings, outcomes of MVD, and complications were reviewed. **RESULTS:** Mean interval time between GKS and MVD was 16 +/- 5.64 months (range, 6-27 months). During MVD, the most common offending vessel was the superior cerebellar artery, followed by the anterior inferior cerebellar artery and vertebral artery. Immediately after MVD, 29 patients (90.63%) experienced complete pain relief without medication. At the end of the follow-up period, 25 patients were pain-free without medication. **CONCLUSIONS:** Our data confirm that MVD is an effective and safe alternative therapy after GKS, although the risk of facial numbness seems higher in patients with a history of GKS than in patients without a history of GKS.

[21] Efficacy and Safety of Microvascular Decompression and Gamma Knife Surgery Treatments for Patients with Primary Trigeminal Neuralgia: A Prospective Study.
World neurosurgery. 2018;116:e113-e117
Zeng YJ, Zhang H, Yu S, Zhang W, Sun XC
PMID: 29705231 DOI: 10.1016/j.wneu.2018.04.120
PURPOSE: To compare efficacy and safety of microvascular decompression (MVD) and Gamma Knife surgery (GKS) treatments for trigeminal neuralgia. **METHOD:** Patients with primary trigeminal neuralgia were randomly divided into 2 groups to undergo either MVD or GKS. All patients were followed for 2 years to evaluate efficacy, recurrence rates, and complications of treatment. **RESULTS:** Of 441 enrolled patients, 220 were in the MVD group, and 221 were in the GKS group. There were no deaths in either group. At the 2-year follow-up, 183 patients (83%) in the MVD group reported complete pain relief, 5 (2%) had obvious pain relief, and 20 (9%) had no relief. In the GKS group, 55 patients (25%) reported complete pain relief, 106 (48%) had obvious pain relief, and 37 (17%) had no relief. There was no significant difference in the recurrence rate (0.45% vs. 0.9%) between the 2 groups. The most common complications in the MVD group were chemical meningitis (6%), cerebrospinal fluid leakage (4%), and facial palsy (4%). Loss of corneal reflex (6%) and facial numbness (5%) were the most common complications in the GKS group. **CONCLUSIONS:** Both MVD and GKS are effective surgical treatments for trigeminal neuralgia. The rate of complete pain relief in the MVD group was significantly superior to the rate of complete pain relief in the GKS group. There was no significant difference in recurrence rates between the groups; however, there were more severe complications in the MVD group than in the GKS group.

[22] Early Stereotactic Radiosurgery for Medically Refractory Trigeminal Neuralgia.
World neurosurgery. 2018;112:e569-e575
Lee CC, Chen CJ, Chong ST, Hung SC, Yang HC, Lin CJ, Wu CC, Chung WY, Guo WY, Hung-Chi Pan D, Wu HM, Lin CP
PMID: 29371169 DOI: 10.1016/j.wneu.2018.01.088
OBJECTIVE: To evaluate effectiveness of early Gamma Knife radiosurgery (GKRS) in treatment of medically refractory trigeminal neuralgia (TN). **METHODS:** This retrospective review comprised 108 consecutive patients with medically refractory idiopathic TN between 2006 and 2014. All patients underwent GKRS targeting the root entry zone with a median maximum dose of 90 Gy and isodose line of 20%. Outcomes pertaining to pain and facial numbness were scored using Barrow Neurological Institute scales. **RESULTS:** Following a median latency period of 4 weeks, we observed complete or adequate pain relief (Barrow Neurological Institute scores of I-IIIB) in 86 of 108 patients (90%). At a median time of 17 months, 22 patients (26%) experienced pain recurrence. New-onset facial numbness was reported by 59 patients (55%). Treatment failure rates were highest among patients with a longer history of pain. Compared with patients with pain history of </=5 years, patients with pain history of >5 years experienced longer latency before pain relief (P = 0.027). Univariate and multivariate analyses demonstrated that pain history of </=5 years was a significant predictor of pain relief (P = 0.049 and P = 0.045, respectively). **CONCLUSIONS:** GKRS achieves a high rate of pain relief among patients with medically refractory idiopathic TN. Pain history of </=5 years is a reliable predictor of pain relief and appears to be associated with shorter latency to pain relief after GKRS. Therefore, early GKRS for patients with medically refractory idiopathic TN is recommended.

[23] The relationship of dose to nerve volume in predicting pain recurrence after stereotactic radiosurgery in trigeminal neuralgia.
Journal of neurosurgery. 2018;128(3):891-896
Wolf A, Tyburczy A, Ye JC, Fatterpekar G, Silverman JS, Kondziolka D
PMID: 28524797 DOI: 10.3171/2016.12.JNS161862
OBJECTIVE: Approximately 75%-92% of patients with trigeminal neuralgia (TN) achieve pain relief after Gamma Knife surgery (GKS), although a proportion of these patients will experience recurrence of their pain. To evaluate the reasons for durability or recurrence, this study determined the impact of trigeminal nerve length and volume, the nerve dose-volume relationship, and the presence of neurovascular compression (NVC) on pain outcomes after GKS for TN. **METHODS:** Fifty-eight patients with 60 symptomatic nerves underwent GKS for TN between 2013 and 2015, including 15 symptomatic nerves secondary to multiple sclerosis (MS). High-resolution MRI was acquired the day of GKS. The median maximum dose was 80 Gy for initial GKS and 65 Gy for repeat GKS.

NVC, length and volume of the trigeminal nerve within the subarachnoid space of the posterior fossa, and the ratio of dose to nerve volume were assessed as predictors of recurrence. **RESULTS:** Follow-up was available on 55 patients. Forty-nine patients (89.1%) reported pain relief (Barrow Neurological Institute [BNI] Grades I-IIIb) after GKS at a median duration of 1.9 months. The probability of maintaining pain relief (BNI Grades I-IIIb) without requiring resumption or an increase in medication was 93% at 1 year and 84% at 2 years for patients without MS, and 68% at 1 year and 51% at 2 years for all patients. The nerve length, nerve volume, target distance from the brainstem, and presence of NVC were not predictive of pain recurrence. Patients with a smaller volume of nerve (< 35% of the total nerve volume) that received a high dose (>/= 80% isodose) were less likely to experience recurrence of their TN pain after 1 year (mean time to recurrence: < 35%, 32.2 +/- 4.0 months; > 35%, 17.9 +/- 2.8 months, log-rank test, chi(2) = 4.3, p = 0.039). **CONCLUSIONS:** The ratio of dose to nerve volume may predict recurrence of TN pain after GKS. Prospective studies are needed to determine the optimal dose to nerve volume ratio and whether this will result in longer pain-free outcomes.

[24] Gamma Knife Surgery for Recurrent Trigeminal Neuralgia in Cases with Previous Microvascular Decompression.
World neurosurgery. 2018;110:e593-e598
Wang Y, Zhang S, Wang W, Gao X, Gong F, Gao Y, Xu Y, Li P
PMID: 29175572 DOI: 10.1016/j.wneu.2017.11.062
BACKGROUND: Microvascular decompression (MVD) and Gamma Knife surgery (GKS) are the primary treatments for trigeminal neuralgia (TN). However, many patients require further surgical treatment after initial surgery for recurrent TN. The aim of this study was to evaluate efficacy and safety of GKS for recurrent TN cases with prior MVD. **METHODS:** From October 2008 to June 2015, 658 patients at West China Hospital underwent GKS as the only surgical treatment, and 42 patients underwent GKS with prior MVD. The single 4-mm isocenter was located at the cisternal portion of the trigeminal nerve in all patients. Median maximum prescription dose was 85 Gy (range, 70-90 Gy). **RESULTS:** Median follow-up time was 6.2 years (range, 1.1-10 years). The percentage of patients with or without previous MVD within 1 year was 56.81%, and the percentage of patients who were pain-free was 74.74%. The recurrence rates within 10 years were 49.11% and 43.74% for patients with and without MVD, respectively. Also, 9.52% and 11.04% of patients with and without previous MVD experienced complications as a result of GKS during the long-term follow-up period. Patients who underwent previous MVD showed a significantly lower pain-free rate compared with patients without previous MVD (P = 0.01). There was no statistical significance in the recurrence rate (P = 0.82) or the complications (P = 0.93) in the 2 groups during the long-term follow-up period. **CONCLUSIONS:** For patients with recurrent TN who previously underwent MVD, GKS remains an efficacious and safe mode of treatment.

[25] A proposed plan for personalized radiosurgery in patients with trigeminal neuralgia.
Journal of neurosurgery. 2018;128(2):452-459
Mousavi SH, Niranjan A, Akpinar B, Monaco EA, Cohen J, Bhatnagar J, Chang YF, Kano H, Huq S, Flickinger JC, Dade Lunsford L
PMID: 28298016 DOI: 10.3171/2016.10.JNS16747
OBJECTIVE: During the last 25 years, more than 100,000 patients worldwide with trigeminal neuralgia (TN) have undergone stereotactic radiosurgery (SRS) with a standard dose of radiation. However, the radiobiological effect of radiation is determined by the amount of energy delivered to the tissue (integral dose [ID] = mean dose x target volume) and is directly associated with the nerve volume. Although the trigeminal nerve volume varies among patients with TN, the clinical impact of this variation in delivered energy is unknown. The objective of this study was to evaluate the effect of delivered ID on the outcome of TN radiosurgery. **METHODS:** The authors evaluated 155 patients with unilateral TN who had undergone SRS as their initial surgical management over a 13-year period. The authors measured the postganglionic ID within the SRS target and retrospectively stratified patients into 3 groups: low (< 1.4 mJ), medium (1.4-2.7 mJ), and high (> 2.7 mJ) ID. Clinical outcomes, which included pain status (scored using the Barrow Neurological Institute Pain Scale) and sensory dysfunction (scored using the Barrow Neurological Institute Numbness Scale), were evaluated at a median follow-up of 71 months. **RESULTS:** Patients who were treated with a medium ID had superior pain relief either with or without medications (p = 0.006). In the medium ID group, the rates of complete pain relief without medications at 1, 3, and 6 years after SRS were 67%, 54%, and 33%, respectively, while the rates in the rest of the cohort were 55%, 36%, and 19%, respectively. Patients given a high ID had a higher rate of post-SRS trigeminal sensory deterioration (p < 0.0001). At 1, 3, and 6 years after SRS, the high ID group had an estimated rate for developing sensory dysfunction of 35%, 45%, and 50%, respectively, while the rates in patients receiving low and medium IDs were 3%, 4%, and 9%, respectively. The optimal clinical outcome (maximum pain relief and minimal trigeminal sensory dysfunction) was obtained in patients who had received a medium ID. **CONCLUSIONS:** With current dose selection methods, nerve volume affects long-term clinical outcomes in patients with TN who have undergone SRS. This study suggests that the prescribed SRS dose should be customized for each TN patient based on the nerve volume.

[26] Effectiveness of Gamma Knife Radiosurgery in Improving Psychophysical Performance and Patient's Quality of Life in Idiopathic Trigeminal Neuralgia.
World neurosurgery. 2018;110:e776-e785
Gagliardi F, Spina A, Bailo M, Boari N, Cavalli A, Franzin A, Fava A, Del Vecchio A, Bolognesi A, Mortini P
PMID: 29174233 DOI: 10.1016/j.wneu.2017.11.096
OBJECTIVE: To assess effectiveness of Gamma Knife Radiosurgery (GKRS) in improving quality of life (QoL) in patients with idiopathic trigeminal neuralgia (TN). **METHODS:** Between January 2001 and October 2013, 166 patients with medically resistant TN were treated at our institution with GKRS. Patients were divided into 2 groups: patients with typical TN (TTN) and patients with atypical TN (ATN). All patients underwent clinical evaluation using Marseille and Barrow Neurological Institute pain and numbness scales; in addition, they completed the Short-Form 36 Health Survey, Activities of Daily Living, and Excellent Good Fair Poor questionnaires and underwent psychological and neurologic examination. **RESULTS:** Mean follow-up time was 64.7 months. All Short-Form 36 domains were significantly improved in both groups after treatment, with an evident trend to reach the median values of healthy Italian population. Mean postoperative Activities of Daily Living score in the TTN group and ATN group were 5.8 and 5.4, respectively, and Karnofsky Performance Status increased to 94.2 and 86.4, respectively. Pain recurrence negatively affected patients' QoL and psychofunctional performance without reaching statistical significance. At the last follow-up, 73% of patients were clustered in the pain-relief group. **CONCLUSIONS:** GKRS significantly improves QoL and functional and psychosocial performance of patients with idiopathic trigeminal neuralgia. A trend was observed toward a more favorable outcome in patients with TTN, compared with patients with ATN, without reaching a statistically significant distinction.

[27] Outcomes of Two-Isocenter Gamma Knife Radiosurgery for Patients with Typical Trigeminal Neuralgia: Pain Response and Quality of Life.
World neurosurgery. 2018;109:e531-e538
Zhao H, Shen Y, Yao D, Xiong N, Abdelmaksoud A, Wang H
PMID: 29038085 DOI: 10.1016/j.wneu.2017.10.014
OBJECTIVE: To evaluate the effectiveness and safety of 2-isocenter Gamma Knife surgery (GKS) by reviewing patients with trigeminal neuralgia (TN) from the last 10 years. **METHODS:** A total of 247 patients were followed up and the Barrow Neurological Institute scale was used to evaluate pain degree. Patients' age, gender, pain duration and location, preoperative/postoperative Barrow Neurological Institute scale score, time to initial pain relief, recurrence time, and complications were documented and analyzed. **RESULTS:** Patients who underwent a 2-isocenter GKS achieved earlier initial pain relief. The median

time of initial pain relief was 2.0 months. Kaplan-Meier analysis showed that the patients with a shorter history of TN and the patients without preoperative surgery achieved earlier initial pain relief. During the 122.8 months of follow-up, the median time of recurrence-free pain relief was 49.7 months. Age was found to be a risk factor of recurrence. Patients who underwent 2-isocenter GKS had a higher rate of postoperative facial numbness, but only 9 cases reported bothersome facial numbness. Multibranch involvement was a risk factor for postoperative facial numbness. **CONCLUSIONS:** Compared with other modalities, 2-isocenter GKS was a safe and highly effective option for patients with TN. However, more data need to be collected to verify its long-term effect.

[28] Outcome of Gamma Knife radiosurgery for trigeminal neuralgia associated with neurovascular compression.
Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia. 2018;47:174-177
Chang CS, Huang CW, Chou HH, Lin LY, Huang CF
PMID: 29074316 DOI: 10.1016/j.jocn.2017.09.016
We reviewed 130 patients from 1999 to 2012 to evaluate whether neurovascular compression (NVC) has prognostic value for pain relief in idiopathic trigeminal neuralgia (TN) treated by Gamma Knife radiosurgery (GKRS). Patients were assigned to one of the following groups based on NVC identified by MRI: no NVC, small vessel NVC, and large vessel (defined as part of the vertebrobasilar arterial system) NVC. Follow-up ranged from 4 to 14years. Primary outcome was pain graded by the Barrow Neurological Institute (BNI) pain scale. Successful pain control was defined asa score within Grade I-IIIb. Among the 130 patients, 53 had no neurovascular compression (group 1), 60 had a small vessel NVC (group 2), and 17 had a large vessel NVC (group 3). Successful pain control was 85% in group 1, 75% in group 2, and 88% in group 3 (X(2)=2.480, p=.289). Secondary outcome was new onset facial numbness which was 21% in group 1, 28% in group 2, and 35% in group 3 (X(2)=1.683, p=.431). NVC did not affect pain outcome for TN patients treated by GKRS. The lack of poorer response with large vessel NVC that has been reported in literature may be explained by treatment of multiple 4mm shots (as opposed to a single shot in 11/17 patients) to cover a larger compression area of the nerve root by a tortuous vessel.

2017

[29] Stereotactic Radiosurgery for Type 1 versus Type 2 Trigeminal Neuralgias.
World neurosurgery. 2017;108:581-588
Chen CJ, Paisan G, Buell TJ, Knapp K, Ding D, Xu Z, Raper DM, Taylor DG, Dallapiazza RF, Lee CC, Sheehan JP
PMID: 28927915 DOI: 10.1016/j.wneu.2017.09.055
INTRODUCTION: It remains unclear whether stereotactic radiosurgery (SRS) offers the same benefit for patients with type 2 trigeminal neuralgia (TN2) as for those with type 1 trigeminal neuralgia (TN1). The objective of this study is to compare the outcomes of patients with TN1 and TN2 after SRS. **METHODS:** SRS outcomes of patients with trigeminal neuralgia treated at a single center from 1994 to 2016 were analyzed. Patients with TN1 were matched to those with TN2 in a 1:1 ratio based on sex, age, pretreatment Barrow Neurological Institute (BNI) pain score, previous treatment, previous facial numbness, and maximum dose. The primary outcome was defined as a BNI pain score of </=3. **RESULTS:** The matched TN1 and TN2 cohorts each comprised 56 patients. There were no differences in BNI pain scores at last follow-up, new/worse facial numbness, or pain recurrence, or time to recurrence. Time to initial pain relief after SRS was longer for patients with TN2 (5.4 vs. 4.4 months; P = 0.0016). Actuarial initial pain relief rates were 75%, 90%, and 90% for TN1 and 47%, 77%, and 87% for TN2 at 5, 10, and 15 months, respectively. Actuarial pain relief maintenance rates were 72%, 67%, and 52% for TN1 and 53%, 32%, and 32% for TN2 at 1, 2, and 3 years, respectively. **CONCLUSIONS:** SRS offers similar rates of initial pain relief, pain score distribution, pain recurrence, and time to pain recurrence between patients with TN1 and TN2. The time to initial pain relief was longer for patients with TN2.

[30] Long-term outcomes of microvascular decompression and Gamma Knife surgery for trigeminal neuralgia: a retrospective comparison study.
Acta neurochirurgica. 2017;159(11):2127-2135
Inoue T, Hirai H, Shima A, Suzuki F, Yamaji M, Fukushima T, Matsuda M
PMID: 28905114 DOI: 10.1007/s00701-017-3325-7
BACKGROUND: There is still no clear guideline for surgical treatment for patients with medically refractory trigeminal neuralgia (TN). When it comes to which surgical treatment to choose, microvascular decompression (MVD) or Gamma Knife surgery (GKS), we should know the long-term outcome of each treatment. **METHODS:** We analyzed 179 patients undergoing MVD and 52 patients undergoing GKS followed for 1 year or longer. We evaluated the patient's neurological status including pain relief, complications and recurrence. **RESULTS:** were assessed with Barrow Neurological Institute (BNI) pain intensity and facial numbness scores. Overall outcomes were compared between the two groups based on pain relief and complications. **RESULTS:** BNI pain intensity and facial numbness scores at the final visit were significantly lower in the MVD group than in the GKS group (P < 0.001, P = 0.04, respectively). Overall outcomes were superior following MVD than following GKS (P < 0.001). Following whichever treatment, there were initially high rates of pain-free status "without medication": 96.6% in the MVD group and 96.2% in the GKS group. However, 6.1% in the MVD group and 51.9% in the GKS group fell into a "with medication" state within median periods of 1.83 and 3.92 years, respectively (P < 0.001). Kaplan-Meier analysis revealed that pain recurred more often and later in the GKS group than in the MVD group (P < 0.001). **CONCLUSIONS:** Considering the long-term outcomes, MVD should be chosen as the initial surgical treatment for patients with medically refractory TN.

[31] Trigeminal neuralgia and neuropathy in large sporadic vestibular schwannomas.
Journal of neurosurgery. 2017;127(5):992-999
Neff BA, Carlson ML, O'Byrne MM, Van Gompel JJ, Driscoll CLW, Link MJ
PMID: 28084915 DOI: 10.3171/2016.9.JNS16515
OBJECTIVE: The aim of this study was to evaluate the incidence, presentation, and treatment outcomes of trigeminal nerve-mediated symptoms secondary to large vestibular schwannomas (VSs) with trigeminal nerve contact. Specifically, the symptomatic results of pain, paresthesias, and numbness after microsurgical resection or stereotactic radiosurgery (SRS) were examined. **METHODS:** The authors conducted a retrospective review of a database for concomitant diagnosis of trigeminal neuralgia (TN) or trigeminal neuropathy and VS between 1994 and 2014 at a tertiary academic center. All patients with VS with TN or neuropathy were included, with the exception of those patients with neurofibromatosis Type 2 and patients who elected observation. Patient demographic data, symptom evolution, and treatment outcomes were collected. Population data were summarized, and outcome comparisons between microsurgery and SRS were analyzed at last follow-up. **RESULTS:** Sixty (2.2%) of 2771 total patients who had large VSs and either TN or neuropathy symptoms met inclusion criteria. The average age of trigeminal symptom onset was 53.6 years (range 24-79 years), the average age at VS diagnosis was 54.4 years (range 25-79 years), and the average follow-up for the microsurgery and SRS groups was 30 and 59 months, respectively (range 3-132 months). Of these patients, 50 (83%) had facial numbness, 16 (27%) had TN pain, and 13 (22%) had paresthesias (i.e., burning or tingling). Subsequently, 50 (83%) patients underwent resection and 10 (17%) patients received SRS. Treatment of VS with SRS did not improve trigeminal symptoms in any patient. This included 2 subjects with unimproved facial numbness and 4 patients with worsened numbness. Similarly, SRS worsened TN pain and paresthesias in 5 patients and failed to improve pain in 2 additional patients. The Barrow Neurological Institute neuralgia and hypesthesia scale scores

were significantly worse for patients undergoing SRS compared with microsurgery. Resection alleviated facial numbness in 22 (50%) patients, paresthesias in 5 (42%) patients, and TN in 7 (70%) patients. In several patients, surgery was not successful in relieving facial numbness, which failed to improve in 17 (39%) cases and became worse in 5 (11%) cases. Also, surgery did not change the intensity of facial paresthesias or neuralgia in 6 (50%) and 3 (25%) patients, respectively. Microsurgery exacerbated facial paresthesias in 1 (8%) patient but, notably, did not aggravate TN in any patient. **CONCLUSIONS:** Overall, resection of large VSs provided improved outcomes for patients with concomitant TN, facial paresthesia, and numbness compared with SRS. However, caution should be used when counseling surgical candidates because a number of patients did not experience improvement. This was especially true in patients with preoperative facial numbness and paresthesias, who frequently reported that these symptoms were unchanged following surgery.

[32] Microvascular decompression for trigeminal neuralgia in patients with failed gamma knife surgery: Analysis of efficacy and safety.
Clinical neurology and neurosurgery. 2017;161:88-92
Cheng J, Liu W, Hui X, Lei D, Zhang H
PMID: 28865322 DOI: 10.1016/j.clineuro.2017.08.017
OBJECTIVE: Though it is usually successful, failure or delayed pain recurrence may occur after gamma knife surgery (GKS) in patients with trigeminal neuralgia (TN), and additional intervention may be required. This study aimed to investigate whether the safety and efficacy of microvascular decompression (MVD) were influenced by prior GKS. **PATIENTS AND METHODS:** The authors retrospectively evaluated 36 consecutive TN patients who underwent MVD after failed GKS from January 2012 to June 2013. The clinical features, operative findings and surgical outcomes were reviewed and statistically analyzed, and the operation results were further compared with a cohort of 60 patients with no prior GKS. **RESULTS:** At surgery, atrophy of the trigeminal nerve was observed in 13 patients (36.1%), arachnoid thickening in 6 patients (16.7%), adhesions between vessels and the trigeminal nerve in 8 patients (22.2%), and atherosclerotic plaque in the offending vessels in 3 patients (8.3%). The complete pain relief rates were 83.3% immediately after MVD and 72.2% at last follow-up, which showed no statistical difference when compared with patients without GKS. New or worsened facial numbness occurred in 7 patients (19.4%), which was significantly higher than those without GKS (p=0.02). Univariate analysis suggested that a positive pain response to the prior GKS correlated with better long-term outcome (p=0.015), and the existence of arachnoid adhesions correlated with higher risk of facial numbness (p=0.03). **CONCLUSIONS:** MVD remains an appropriate and effective alternative therapy for patients with failed GKS, with no added technical difficulty. However, the risk of facial numbness seems to be higher than those with MVD alone.

[33] Gamma Knife Radiosurgery for Idiopathic Trigeminal Neuralgia: Does the Status of Offending Vessels Influence Pain Control or Side Effects?
World neurosurgery. 2017;104:687-693
Jung HH, Park CK, Jung NY, Kim M, Chang WS, Chang JW
PMID: 28532912 DOI: 10.1016/j.wneu.2017.05.058
OBJECTIVE: To evaluate pain control and side effects after gamma knife radiosurgery (GKRS) for classical idiopathic trigeminal neuralgia (TN) with or without neurovascular compression (NVC). **METHODS:** This study included 47 patients with type 1 idiopathic TN and Barrow Neurological Institute (BNI) pain class IV or V who were treated with GKRS, with a maximum dose of 85 Gy targeting the root entry zone, as an initial treatment modality between January 2005 and March 2015. A retrospective analysis of NVC status, pain control, side effects, recurrence, and cross-sectional area was conducted. **RESULTS:** During follow-up (median, 21.5 months; range, 3-119 months), 36 of the 47 patients (76.6%) demonstrated good outcomes (i.e., improved to below BNI class IIIa). Twenty-two patients did not have NVC (group A) and 25 had NVC (group B). The rate of good outcomes did not differ significantly between the 2 groups (group A, 86.4% [19 of 22] vs. group B, 68% [17 of 25]; P = 0.138). The number of cases in BNI class I or II and the number of recurrences also did not differ significantly between the 2 groups (P = 0.532 and 0.786, respectively). The mean area was 8.64 +/- 2.59 mm(3) in nondeviated cases (n = 27) and 2.59 +/- 1.68 mm(3) in deviated (n = 10). Side effects were significantly more frequent in deviated cases (80% [8 of 10]) than in nondeviated cases (25.9% [7 of 27]; P = 0.003). **CONCLUSIONS:** NVC is not a predictive factor for pain control after GKRS for the treatment of idiopathic TN. Side effects may occur more frequently in patients with NVC at the target coordinate when a root entry zone is used, but the subjective symptoms are not always bothersome.

[34] Stereotactic Radiosurgery for Trigeminal Neuralgia Improves Patient-Reported Quality of Life and Reduces Depression.
International journal of radiation oncology, biology, physics. 2017;98(5):1078-1086
Kotecha R, Miller JA, Modugula S, Barnett GH, Murphy ES, Reddy CA, Suh JH, Neyman G, Machado A, Nagel S, Chao ST
PMID: 28721891 DOI: 10.1016/j.ijrobp.2017.04.008
PURPOSE: To characterize quality-of-life (QOL) outcomes after stereotactic radiosurgery (SRS) for trigeminal neuralgia (TN). **METHODS AND MATERIALS:** The EuroQOL 5 Dimensions (EQ-5D) and Patient Health Questionnaire 9 (PHQ-9) were prospectively collected before and after SRS for 50 patients with TN. Pain response and treatment-related facial numbness were classified by Barrow Neurological Institute (BNI) scales. Differences in pooled QOL outcomes were tested with paired t tests and sign tests. The Kaplan-Meier method was used to estimate time-dependent improvements in the EQ-5D index, EQ-5D perceived health status (PHS), PHQ-9 score, and freedom from pain failure (BNI class IV-V) or facial numbness (BNI class III-IV). **RESULTS:** Following SRS, the 12-month rate of freedom from pain failure was 92% (95% confidence interval [CI], 77%-97%) while the 12-month rate of freedom from facial numbness was 89% (95% CI, 66%-97%). Significant improvements in the EQ-5D index (P<.01), PHS (P=.01), and PHQ-9 (P=.03) were observed, driven by the EQ-5D subscores for self-care and for pain and/or discomfort (P=.02 and P<.01, respectively). At 12 months after SRS, the actuarial rates of improvement in the EQ-5D, PHS, and PHQ-9 were 55% (95% CI, 40%-70%), 59% (95% CI, 40%-76%), and 59% (95% CI, 39%-76%), respectively. The median time to improvement in each of the QOL measures was 9 months (95% CI, 3-36 months) for the EQ-5D index, 5 months (95% CI, 3-36 months) for PHS, and 9 months (95% CI, 3-18 months) for the PHQ-9. On multivariate analysis, only higher prescription dose (86 Gy vs </=82 Gy) was associated with improvement in the EQ-5D index (hazard ratio, 5.73; 95% CI, 1.85-22.33; P<.01). **CONCLUSIONS:** Patients with TN treated with SRS reported significant improvements in multiple QOL measures, with the therapeutic benefit strongly driven by improvements in pain and/or discomfort and in self-care, along with lower rates of depression. In this analysis, there appears to be a correlation between prescription dose and treatment response as measured by the EQ-5D.

[35] The clinical significance of persistent trigeminal nerve contrast enhancement in patients who undergo repeat radiosurgery.
Journal of neurosurgery. 2017;127(1):219-225
Mousavi SH, Akpinar B, Niranjan A, Agarwal V, Cohen J, Flickinger JC, Kondziolka D, Lunsford LD
PMID: 27471888 DOI: 10.3171/2016.5.JNS16111
OBJECTIVE: Contrast enhancement of the retrogasserian trigeminal nerve on MRI scans frequently develops after radiosurgical ablation for the management of medically refractory trigeminal neuralgia (TN). The authors sought to evaluate the clinical significance of this imaging finding in patients who underwent a second radiosurgical procedure for recurrent TN. **METHODS:** During a 22-year period, 360 patients underwent Gamma Knife stereotactic radiosurgery (SRS) as their first surgical procedure for TN at the authors' center. The authors retrospectively analyzed the data from 59 patients (mean age 72 years, range 33-89 years) who underwent repeat SRS for recurrent pain at a median of 30 months (range 6-146 months) after the first SRS. The isocenter was 4 mm, and the median maximum doses for the first and second procedures were 80 Gy and 70 Gy, respectively.

A neuroradiologist and a neurosurgeon blinded to the treated side evaluated the presence of nerve contrast enhancement on MRI series at the time of the repeat procedure. The authors correlated the presence of this imaging change with clinical outcomes. Pain outcomes and development of trigeminal sensory dysfunction were evaluated with the Barrow Neurological Institute (BNI) Pain Scale and BNI Numbness Scale, respectively. The mean length of follow-up after the second SRS was 58 months (95% CI 49-68 months). **RESULTS:** At the time of the repeat SRS, contrast enhancement of the trigeminal nerve on MRI scans was observed in 31 patients (53%). Five years after the SRS, patients with this enhancement had lower actuarial rates of complete pain relief after the repeat SRS (27% [95% CI 7%-47%]) than patients without the enhancement (76% [95% CI 58%-94%]) ($p < 0.001$). At the 5-year follow-up, patients with the contrast enhancement also had a higher risk for trigeminal sensory loss after repeat SRS (75% [95% CI 59%-91%]) than patients without contrast enhancement (26% [95% CI 10%-42%]) ($p = 0.001$). Dysesthetic pain after repeat SRS was observed for 8 patients with and for 2 patients without contrast enhancement. **CONCLUSIONS:** Trigeminal nerve contrast enhancement on MRI scans observed at the time of a repeat SRS for TN was associated with less satisfactory pain control and more frequently detected facial sensory loss. Residual contrast enhancement at the time of a repeat SRS may warrant consideration of dose reduction or further separation of the radiosurgical targets.

[36] Stereotactic Radiosurgery as Initial Surgical Management for Elderly Patients with Trigeminal Neuralgia.

Stereotactic and functional neurosurgery. 2017;95(3):158-165
Cohen J, Mousavi SH, Faraji AH, Akpinar B, Monaco EA, Flickinger JC, Niranjan A, Lunsford LD
PMID: 28501876 DOI: 10.1159/000468526
BACKGROUND: Management of older patients with medically refractory trigeminal neuralgia (TN) is yet a matter of debate. **OBJECTIVE:** We sought to determine the benefit of stereotactic radiosurgery (SRS) as the sole surgical management in older patients (>/=70 years). **METHODS:** One hundred and twenty-seven patients (>/=70 years) with typical TN underwent SRS as initial surgical management. The median maximum dose for the first procedure was 80 Gy. Repeat SRS was performed in 46 patients who developed recurrent pain. **RESULTS:** After the first SRS, the initial pain control was achieved in 91% of patients. Complete pain relief (Barrow Neurological Institute [BNI] score I) developed in 75 patients (59%) and was maintained in 59, 39, and 22% of patients at 1, 3, and 5 years. Following repeat SRS, the rate of complete pain relief was 79, 55, and 41% at 1, 3, and 5 years. The chance of BNI I preservation was greater after repeat SRS compared to initial SRS (hazards ratio: 2.02, $p < 0.0001$). The incidence of trigeminal sensory loss was 17% after initial SRS but increased to 39% after repeat SRS. **CONCLUSIONS:** SRS alone was used effectively in older TN patients to achieve pain control. Recurrent pain responded to retreatment but was associated with an increased risk of sensory dysfunction.

[37] Comparison of Percutaneous Retrogasserian Balloon Compression and Gamma Knife Radiosurgery for the Treatment of Trigeminal Neuralgia in Multiple Sclerosis.

World neurosurgery. 2017;97:590-594
Alvarez-Pinzon AM, Wolf AL, Swedberg HN, Barkley KA, Cucalon J, Curia L, Valerio JE
PMID: 27756676 DOI: 10.1016/j.wneu.2016.10.028
OBJECTIVE: We compared and evaluated percutaneous retrogasserian balloon compression (PBC) and Gamma Knife radiosurgery (GKRS) for treatment of trigeminal neuralgia (TN) in patients with multiple sclerosis (MS). **METHODS:** In this single-center, retrospective comparative study, 202 patients with MS and concomitant TN were evaluated. A minimum follow-up of 24 months was required. Patients with a history of microvascular decompression or previous intervention were excluded. Between February 2009 and December 2013, 78 PBC procedures and 124 first-dosage GKRS procedures were performed. PBC procedures were successfully completed in all cases. The 2 groups were compared with regard to initial effect, duration of effect, and complications including type and severity. **RESULTS:** Immediate pain relief occurred in 87% of patients treated with PBC and in 23% of patients treated with GKRS. Kaplan-Meier plots for the 2 treatment modalities were similar. The 50% recurrence rate was at 12 months for the PBC group and 18 months for the GKRS group. Complication (excluding numbness) rates were 3% for GKRS and 21% for PBC. The difference was statistically significant (chi(2) test, $P = 0.03$). **CONCLUSIONS:** PBC and GKRS are effective techniques for treatment of TN in patients with MS. Fewer complications and superior long-term relief were associated with GKRS. We consider GKRS as the first option for the treatment of TN in patients with MS, reserving PBC for patients with acute, intractable pain.

2016

[38] Long-Term Outcomes in the Treatment of Classical Trigeminal Neuralgia by Gamma Knife Radiosurgery: A Retrospective Study in Patients With Minimum 2-Year Follow-up.

Neurosurgery. 2016;79(6):879-888
Martinez Moreno NE, Gutierrez-Sarraga J, Rey-Portoles G, Jimenez-Huete A, Martinez Alvarez R
PMID: 27560193 DOI: 10.1227/NEU.0000000000001404
BACKGROUND: Gamma knife radiosurgery (GKRS) is one of the alternatives for treatment for classical trigeminal neuralgia (TN). **OBJECTIVE:** To retrospectively analyze long-term outcomes for TN using GKRS achieved at our institution. **METHODS:** One hundred seventeen patients with medically refractory TN treated by GKRS at our institution were followed up between 1993 and 2011. Mean maximum dose was 86.5 Gy (range: 80-90 Gy; median: 90 Gy). Clinical response was defined based on the Burchiel classification. We considered classes I and II as a complete response. For toxicity, we use the Barrow Neurological Institute facial numbness scale. Mean duration of follow-up was 66 months (range: 24-171 months). **RESULTS:** Complete response at last follow-up in our patients was 81%, with an excellent response while off medication in 52%. Pain-free rates without medication (class I) were 85% at 3 years (confidence interval [CI]: 78%-94%), 81% at 5 years (CI: 72%-91%), and 76% at 7 years (CI: 65%-90%). Complete response rates (classes I-II) were 91% at 3 years (CI: 86%-97%), 86% at 5 years (CI: 79%-93%), and 82% at 7 years (CI: 72%-93%). Poor treatment response rates differed significantly between patients who had undergone previous surgery and were refractory to management with medication prior to GKRS. New or worsening facial numbness was reported in 32.5% (30% score II and 2.5% score III). No anesthesia dolorosa was reported. Permanent recurrence pain rate was 12%. **CONCLUSION:** GKRS achieved favorable outcomes compared with surgery in terms of pain relief and complication rates in our cohort of patients, notwithstanding decreasing pain-free survival rates over time. We consider GKRS to be an initial treatment in the management of medically intractable TN in selected patients. ABBREVIATIONS: CI, confidence intervalGKRS, gamma knife radiosurgeryMVD, microvascular decompressionRS, radiosurgeryTN, trigeminal neuralgia.

[39] A Clinical Analysis of Secondary Surgery in Trigeminal Neuralgia Patients Who Failed Prior Treatment.

Journal of Korean Neurosurgical Society. 2016;59(6):637-642
Kang IH, Park BJ, Park CK, Malla HP, Lee SH, Rhee BA
PMID: 27847579 DOI: 10.3340/jkns.2016.59.6.637
OBJECTIVE: Although many treatment modalities have been introduced for trigeminal neuralgia (TN), the long-term clinical results remain unsatisfactory. It has been particularly challenging to determine an appropriate treatment strategy for patients who have responded poorly to initial therapies. We analyzed the surgical outcomes in TN patients who failed prior treatments. **METHODS:** We performed

a retrospective analysis of 37 patients with recurrent or persistent TN symptoms who underwent surgery at our hospital between January 2010 and December 2014. Patients with follow-up data of at least one year were included. The prior treatment modalities of the 37 patients included microvascular decompression (MVD), gamma knife radiosurgery (GKRS), and percutaneous procedures such as radiofrequency rhizotomy (RFR), balloon compression, and glycerol rhizotomy (GR). The mean follow-up period was 69.9 months (range : 16-173). The mean interval between the prior treatment and second surgery was 26 months (range : 7-123). We evaluated the surgical outcomes using the Barrow Neurological Institute (BNI) pain intensity scale. **RESULTS:** Among the 37 recurrent or persistent TN patients, 22 underwent MVD with partial sensory rhizotomy (PSR), 8 received MVD alone, and 7 had PSR alone. Monitoring of the surgical treatment outcomes via the BNI pain intensity scale revealed 8 (21.6%) patients with a score of I, 13 (35.1%) scoring II, 13 (35.1%) scoring III, and 3 (8.2%) scoring IV at the end of the follow-up period. Overall, 91.8% of patients had good surgical outcomes. With regard to postoperative complications, 1 patient had transient cerebrospinal fluid rhinorrhea (2.7%), another had a subdural hematoma (2.7%), and facial sensory changes were noted in 8 (21.1%) patients after surgery. **CONCLUSION:** Surgical interventions, such as MVD and PSR, are safe and very effective treatment modalities in TN patients who failed initial or prior treatments. We presume that the combination of MVD with PSR enabled us to obtain good short- and long-term surgical outcomes. Therefore, aggressive surgical treatment should be considered in patients with recurrent TN despite failure of various treatment modalities.

[40] Trigeminal Neuralgia Treated With Stereotactic Radiosurgery: The Effect of Dose Escalation on Pain Control and Treatment Outcomes.

International journal of radiation oncology, biology, physics. 2016;96(1):142-8
Kotecha R, Kotecha R, Modugula S, Murphy ES, Jones M, Kotecha R, Reddy CA, Suh JH, Barnett GH, Neyman G, Machado A, Nagel S, Chao ST
PMID: 27325473 DOI: 10.1016/j.ijrobp.2016.04.013
PURPOSE: To analyze the effect of dose escalation on treatment outcome in patients undergoing stereotactic radiosurgery (SRS) for trigeminal neuralgia (TN). **METHODS AND MATERIALS:** A retrospective review was performed of 870 patients who underwent SRS for a diagnosis of TN from 2 institutions. Patients were typically treated using a single 4-mm isocenter placed at the trigeminal nerve dorsal root entry zone. Patients were divided into groups based on treatment doses: </=82 Gy (352 patients), 83 to 86 Gy (85 patients), and >/=90 Gy (433 patients). Pain response was classified using a categorical scoring system, with fair or poor pain control representing treatment failure. Treatment-related facial numbness was classified using the Barrow Neurological Institute scale. Log-rank tests were performed to test differences in time to pain failure or development of facial numbness for patients treated with different doses. **RESULTS:** Median age at first pain onset was 63 years, median age at time of SRS was 71 years, and median follow-up was 36.5 months from the time of SRS. A majority of patients (827, 95%) were clinically diagnosed with typical TN. The 4-year rate of excellent to good pain relief was 87% (95% confidence interval 84%-90%). The 4-year rate of pain response was 79%, 82%, and 92% in patients treated to </=82 Gy, 83 to 86 Gy, and >/=90 Gy, respectively. Patients treated to doses </=82 Gy had an increased risk of pain failure after SRS, compared with patients treated to >/=90 Gy (hazard ratio 2.0, P=.0007). Rates of treatment-related facial numbness were similar among patients treated to doses >/=83 Gy. Nine patients (1%) were diagnosed with anesthesia dolorosa. **CONCLUSIONS:** Dose escalation for TN to doses >82 Gy is associated with an improvement in response to treatment and duration of pain relief. Patients treated at these doses, however, should be counseled about the increased risk of treatment-related facial numbness.

[41] Radiosurgery for the management of refractory trigeminal neuralgia.

Neurology India. 2016;64(4):624-9
Niranjan A, Lunsford LD
PMID: 27381104 DOI: 10.4103/0028-3886.185393
Gamma Knife stereotactic radiosurgery (SRS) is a minimally invasive surgical approach for managing medically refractory trigeminal neuralgia (TN). The goal of trigeminal neuralgia SRS is to eliminate or reduce the facial pain in order to improve the quality of life. Over the past 28 years, 1250 patients have undergone gamma knife SRS for TN at our institution. In our retrospective review of 503 patients who underwent SRS for management of refractory TN, 449 patients (89%) experienced initial pain relief at a median latency of 1 month. At the one year mark, 73% patients were pain free (with or without medications) and 80% had pain control. Repeat radiosurgery was performed for 193 patients (43%). At the one year mark, 26% of these patients were completely pain free and 78% were pain free with or without medications. The role of gamma Knife SRS in the management of medically refractory trigeminal neuralgia has evolved over the past two decades. SRS is a minimally invasive procedure and is associated with 60-90% rate of pain relief in patents with medical refractory trigeminal neuralgia. Early intervention with SRS as the initial surgical procedure for management of refractory trigeminal neuralgia is associated with faster, better, and longer pain relief. As SRS is the least invasive procedure for TN, it is a good treatment option for patients with other high-risk medical conditions. SRS is an attractive alternative especially to those who do not want to accept the greater risk associated with other surgical procedures.

[42] The Very Long-Term Outcome of Radiosurgery for Classical Trigeminal Neuralgia.

Stereotactic and functional neurosurgery. 2016;94(1):24-32
Regis J, Tuleasca C, Resseguier N, Carron R, Donnet A, Yomo S, Gaudart J, Levivier M
PMID: 26882097 DOI: 10.1159/000443529
BACKGROUND: Radiosurgery is one of the neurosurgical alternatives for intractable trigeminal neuralgia (TN). **OBJECTIVE:** Although acceptable short-/mid-term outcomes have been reported, long-term results have not been well documented. **METHODS:** We report the long-term results in 130 patients who underwent radiosurgery for classical TN and were subsequently monitored through at least 7 years (median = 9.9, range = 7-14.5) of follow-up. **RESULTS:** The median age was 66.5 years. A total of 122 patients (93.8%) became pain free (median delay = 15 days) after the radiosurgery procedure (Barrow Neurological Institute, BNI class I-IIIa). The probability of remaining pain free without medication at 3, 5, 7 and 10 years was 77.9, 73.8, 68 and 51.5%, respectively. Fifty-six patients (45.9%) who were initially pain free experienced recurrent pain (median delay = 73.1 months). However, at 10 years, of the initial 130 patients, 67.7% were free of any recurrence requiring new surgery (BNI class I-IIIa). The new hypesthesia rate was 20.8% (median delay of onset = 12 months), and only 1 patient (0.8%) reported very bothersome hypesthesia. **CONCLUSIONS:** The long-term results were comparable to those from our general series (recently published), and the high probability of long-lasting pain relief and rarity of consequential complications of radiosurgery may suggest it as a first- and/or second-line treatment for classical, drug-resistant TN.

[43] Predictors of trigeminal nerve dysfunction following stereotactic radiosurgery for trigeminal neuralgia.

Journal of radiosurgery and SBRT. 2016;4(2):117-123
Lucas JT Jr, Huang AJ, Bourland JD, Laxton AW, Tatter SB, Chan MD
PMID: 29296436 DOI:
BACKGROUND/AIMS: To evaluate clinical and dosimetric predictors of trigeminal nerve dysfunction (TND) following stereotactic radiosurgery (SRS) for Trigeminal Neuralgia (TN). **METHODS:** We retrospectively reviewed our cohort of 446 patients with TN who underwent SRS between 1999-2008. Median follow-up was 25.1 and 17.4 months (mo) in those with and without TND respectively. Dosimetric and anatomic measurements and clinical features including Burchiel subtype, pain quality, prior procedures, comorbidities, and medications were evaluated for their influence on the TND using univariate and multivariate logistic

regression modeling. **RESULTS:** TND was observed in 44.6% of patients and was similar across facial pain types. Those with TND had prolonged time to pain relapse [(TND, 68.48 mo) vs. (No TND, 29.37 mo)]. Multivariate analysis identified sharp pain at diagnosis (OR 0.594; 95%CI 0.38-0.91), and dorsal root entry zone (DREZ) maximum dose (OR 1.022; 95%CI 1.00-1.04) as predictors of TND. **CONCLUSIONS:** The presence of sharp pain and increasing DREZ maximum dose were independently associated with TND. Patients with atypical facial pain were at lower risk of TND with increasing dose relative to Type 1 and Type 2 TN.

[44] Efficacy of stereotactic gamma knife surgery and microvascular decompression in the treatment of primary trigeminal neuralgia: a retrospective study of 220 cases from a single center.
Journal of pain research. 2016;9:535-42
Dai ZF, Huang QL, Liu HP, Zhang W
PMID: 27555796 DOI: 10.2147/JPR.S110161
OBJECTIVES: A retrospective study was undertaken to compare the efficacy of stereotactic gamma knife surgery (GKS) and microvascular decompression (MVD) in the treatment of primary trigeminal neuralgia (TN) at a single center. The study included the evaluation of clinical outcomes of pain relief and pain recurrence and complications associated with GKS and MVD. **METHODS:** The study included 202 patients with primary TN and was conducted between January 2013 and December 2014; about 115 patients were treated with GKS and 87 patients were treated with MVD. TN pain was evaluated using the Barrow Neurological Institute and the visual analog scale scoring systems. Preoperative magnetic resonance tomographic angiography was performed for all patients. Microscope-assisted MVD used the suboccipital retrosigmoid sinus approach. GKS targeted the trigeminal nerve root entry zone with a margin radiation dose of 59.5 Gy, and brainstem dose <12 Gy. Posttreatment follow-up was for 2 years. **RESULTS:** Postoperative Barrow Neurological Institute scores for patients treated with GKS and MVD were significantly improved compared with preoperative scores (P<0.01). Reduction in postoperative pain following MVD (95.4% patients) was significantly greater than that following GKS (88.7% patients) (P<0.01). Postoperative visual analog scale scores of the MVD group were significantly reduced compared with those of patients treated with GKS at the same postoperative time points (P<0.01). Patients treated with GKS had a significantly increased rate of loss of corneal reflex compared with patients treated with MVD (P=0.002). **CONCLUSION:** Both GKS and MVD are safe and effective first-line and adjunctive treatment options for patients with TN. The clinical outcomes of pain relief and reduction of pain recurrence were better with MVD. For GKS, this study showed that the optimal radiation therapeutic dose range was 70-90 Gy, but brainstem radiation protection is recommended.

[45] Stereotactic Radiosurgery Treatment of Trigeminal Neuralgia: Clinical Outcomes and Prognostic Factors.
World neurosurgery. 2016;90:604-612.e11
Taich ZJ, Goetsch SJ, Monaco E, Carter BS, Ott K, Alksne JF, Chen CC
PMID: 26915701 DOI: 10.1016/j.wneu.2016.02.067
BACKGROUND: Stereotactic radiosurgery (SRS) is a minimally invasive surgical option for the treatment of trigeminal neuralgia (TN). Here we review our institutional experience to identify prognostic factors associated with pain relief after SRS. **METHODS:** 263 patients with TN treated at the University of California, San Diego/San Diego Gamma Knife (2001-2013) were followed for more than 6 months. Univariate and multivariate Cox proportional hazard models analysis of factors associated with outcome was performed. **RESULTS:** Of the 263 patients, 229 (87%) presented with classical idiopathic TN, 31 (12%) presented with atypical TN, and 4 (1%) presented with secondary TN. 143 (54%) had undergone prior treatment. Most patients were treated with 85 (52%) or 90 Gy (42%). 79% of the SRS treated patients experienced a favorable response (defined as Barrow Neurological Institute Pain Scale <3 pain relief), with a median time to relief of 2.5 months. In a multivariate analysis, diagnosis of classical TN, previous percutaneous procedures, and age older than 70 years were associated with favorable responses; classical TN was associated with sustained pain relief. Dose prescription >85 Gy and prior SRS were associated with bothersome facial numbness posttreatment. For patients presenting with classical TN, diagnosis of multiple sclerosis (MS) did not decrease the likelihood of pain relief after SRS. **CONCLUSIONS:** Excellent TN pain relief was achieved with the delivery of 85 Gy in a single-shot, 4-mm isocenter SRS targeting the dorsal root entry zone. Patients with classical TN, with age older than 70 years, or who underwent previous percutaneous procedures were more likely to benefit from SRS. SRS is efficacious in patients with classical TN despite concurrent diagnosis of MS.

[46] Gamma knife radiosurgery for trigeminal neuralgia secondary to benign lesions.
Headache. 2016;56(5):883-889
Cho KR, Lee MH, Im YS, Kong DS, Seol HJ, Nam DH, Lee JI
PMID: 27041354 DOI: 10.1111/head.12801
BACKGROUND: Investigate the clinical outcomes of gamma knife radiosurgery (GKS) in patients with benign intracranial lesions and accompanying trigeminal neuralgia (TN). **METHODS:** From February 2002 to November 2011, 50 patients (11 males, 39 females) underwent GKS for intracranial lesions accompanied by TN. Pathological diagnoses included meningioma in 30 patients, vestibular schwannoma in 11, trigeminal schwannoma in 7, epidermoid cyst in 1, and arteriovenous malformation in 1. Twenty-two (44%) had a lesion dominantly located in the middle fossa and 26 patients (52%) in the posterior fossa. Twenty-five (50%) patients complained of type I pain, and 18 patients (36%) suffered from type II pain. The other 7 patients (14%) presented with facial pain that could not be determined. Pain was assessed retrospectively by subjective descriptions and with the Barrow Neurological Institute pain intensity score before and after GKS. **RESULTS:** Tumor control was evaluated with magnetic resonance imaging in 44 (95.7%) of 46 patients over a median follow-up period of 54.8 months (range, 13-142 months). Initial improvement in pain after GKS was observed in 46 (92%) patients. The percentage of patients with improved Barrow Neurological Institute score was 73.5% at 1 year, 70.7% at 2 years, and 76.5% at 3 years. Complete pain relief at the final follow-up was achieved in 18 patients (36%). Pain recurred in 13 patients (28.3%) after initial improvement. Pathological diagnosis, location of the lesion, and type of facial pain did not influence the initial pain response after GKS. Pain recurred more frequently in patients with meningioma than in those with schwannoma (P = .045). Type II pain showed better response to the treatment (P = .006). **CONCLUSION:** The majority of patients with facial pain secondary to a benign intracranial lesion showed improvement after GKS. However, a substantial proportion of the patients experienced incomplete pain relief and recurrence. GKS needs to be combined with an additional modality or the technique must be modified to achieve complete and durable pain control.

[47] Long-term safety and efficacy of Gamma Knife surgery in classical trigeminal neuralgia: a 497-patient historical cohort study.
Journal of neurosurgery. 2016;124(4):1079-87
Regis J, Tuleasca C, Resseguier N, Carron R, Donnet A, Gaudart J, Levivier M
PMID: 26339857 DOI: 10.3171/2015.2.JNS142144
OBJECTIVE: Gamma Knife surgery (GKS) is one of the surgical alternatives for the treatment of drug-resistant trigeminal neuralgia (TN). This study aims to evaluate the safety and efficacy of GKS in a large population of patients with TN with very long-term clinical follow-up. **METHODS:** Between July 1992 and November 2010, 737 patients presenting with TN were treated using GKS. Data were collected prospectively and were further retrospectively evaluated at Timone University Hospital. The frequency and severity of pain, as well as trigeminal nerve function, were evaluated before GKS and regularly thereafter. Radiosurgery using the Gamma Knife (model B, C, 4C, or Perfexion) was performed with the help of both MR and CT targeting. A single 4-mm isocenter was positioned in the cisternal portion of the trigeminal nerve at a median distance of 7.6 mm (range 4-14 mm) anterior to the emergence of the nerve (retrogasserian target). A median maximum dose of 85 Gy (range 70-90 Gy) was prescribed. **RESULTS:** The safety

and efficacy are reported for 497 patients with medically refractory classical TN who were never previously treated by GKS and had a follow-up of at least 1 year. The median age in this series was 68.3 years (range 28.1-93.2 years). The median follow-up period was 43.8 months (range 12-174.4 months). Overall, 456 patients (91.75%) were initially pain free in a median time of 10 days (range 1-180 days). Their actuarial probabilities of remaining pain free without medication at 3, 5, 7, and 10 years were 71.8%, 64.9%, 59.7%, and 45.3%, respectively. One hundred fifty-seven patients (34.4%) who were initially pain free experienced at least 1 recurrence, with a median delay of onset of 24 months (range 0.6-150.1 months). However, the actuarial rate of maintaining pain relief without further surgery was 67.8% at 10 years. The hypesthesia actuarial rate at 5 years was 20.4% and at 7 years reached 21.1%, but remained stable until 14 years with a median delay of onset of 12 months (range 1-65 months). Very bothersome facial hypesthesia was reported in only 3 patients (0.6%). **CONCLUSIONS:** Retrogasserian GKS proved to be safe and effective in the long term and in a very large number of patients. Even if the probability of long-lasting effects may be modest compared with microvascular decompression, the rarity of complications prompts discussion of using GKS as the pragmatic surgical first- or second-intention alternative for classical TN. However, a randomized trial, or at least a case-matched control study, would be required to compare with microvascular decompression.

[48] Management of Recurrent Trigeminal Neuralgia Associated with Petroclival Meningioma.
Journal of neurological surgery. Part B, Skull base. 2016;77(1):47-53
Bir SC, Maiti TK, Bollam P, Nanda A
PMID: 26949588 DOI: 10.1055/s-0035-1558834
OBJECTIVE: Petroclival meningioma (PM) presents with trigeminal neuralgia (TN) in < 5% of cases. Neurosurgeons often face the dilemma of formulating a treatment protocol when TN recurs. In this study, we sought to set up a protocol in patients with PM who had a recurrent TN. **MATERIALS AND METHODS:** We performed a retrospective review of 57 patients with PM. Of the 57 patients, only 7 patients presented with TN, and six patients experienced recurrent TN. The study population was evaluated clinically and radiographically after treatment. **RESULTS:** Overall improvement of pain control after various treatments was 67%, and tumor control was 100%. The pain-free period was 2 years for the Gamma Knife radiosurgery (GKRS) group and 4 years for the resection group when treated as a primary treatment (p = 0.034). Of the six patients, four patients had Barrow Neurosurgical Institute (BNI) score I (no TN, no medication), and two patients had BNI score III (some pain controlled with medication). The Karnofsky performance scale score was significantly improved after treatment compared with the pretreated status (78 versus 88; p = 0.044). **CONCLUSION:** Microsurgical resection is superior to GKRS in achieving and maintaining pain-free status in patients with recurrent trigeminal pain associated with PM.

2015

[49] Early radiosurgery provides superior pain relief for trigeminal neuralgia patients.
Neurology. 2015;85(24):2159-65
Mousavi SH, Niranjan A, Huang MJ, Laghari FJ, Shin SS, Mindlin JL, Flickinger JC, Lunsford LD
PMID: 26561286 DOI: 10.1212/WNL.0000000000002216
OBJECTIVE: We evaluated factors associated with better outcomes after stereotactic radiosurgery (SRS) when it was performed as the first surgical procedure for medically refractory trigeminal neuralgia. **METHODS:** A total of 121 patients (median age 72 years) with medically refractory pain and no prior surgery underwent Gamma Knife SRS as their initial surgical procedure for trigeminal neuralgia. Using a single 4-mm isocenter, patients received an average maximum dose of 80 Gy, delivered to the trigeminal nerve target defined by intraoperative MRI. The median follow-up was 36 months. **RESULTS:** Pain relief (Barrow Neurological Institute [BNI] score I-IIIa) was achieved in 107 (88%) patients at a median time of 1 month. Patients who underwent earlier SRS (within 3 years of pain onset) had a shorter interval until pain relief (1 week, $p < 0.001$), had a longer interval of pain relief off medication (BNI-I, $p < 0.001$), and had a longer duration of adequate pain control (BNI-I-IIIa, $p < 0.001$). Median pain-free intervals for patients who underwent SRS at 1, 2, 3, and more than 3 years after trigeminal neuralgia diagnosis were 68, 37, 36, and 10 months, respectively. Patients who responded to SRS within the first 3 weeks after SRS had a longer duration of complete pain relief compared to those with longer response times (p = 0.001). Fifteen patients (12%) reported new sensory dysfunction after SRS. **CONCLUSION:** Early SRS as the initial surgical procedure for management of refractory trigeminal neuralgia was associated with faster, better, and longer pain relief when compared to late SRS. **CLASSIFICATION OF EVIDENCE:** This study provides Class IV evidence that in patients with medically refractory trigeminal neuralgia, early stereotactic radiosurgery as the initial procedure provides faster, better, and longer pain relief.

[50] Repeat Radiosurgery for Trigeminal Neuralgia.
Neurosurgery. 2015;77(5):755-61; discussion 761
Helis CA, Lucas JT Jr, Bourland JD, Chan MD, Tatter SB, Laxton AW
PMID: 26214319 DOI: 10.1227/NEU.0000000000000915
BACKGROUND: Repeat Gamma Knife radiosurgery (GKRS) is an established option for patients whose pain has recurred after the initial procedure, with reported success rates varying from 68% to 95%. Predictive factors for response to the repeat GKRS are ill-defined. **OBJECTIVE:** This cohort study aimed to report the outcomes and factors predictive of success for patients who have undergone repeated GKRS for trigeminal neuralgia at Wake Forest University Baptist Medical Center. **METHODS:** Between 1999 and 2013, 152 patients underwent repeat GKRS at Wake Forest, 125 of whom were available for long-term follow-up. A retrospective chart review and telephone interviews were conducted to determine background medical history, dosimetric data, outcomes, and adverse effects of the procedure. **RESULTS:** Eighty-four percent of patients achieved at least Barrow Neurological Institute (BNI) IIIb pain relief, with 46% achieving BNI I. The 1-, 3-, and 5-year rates of BNI I pain relief were 63%, 50%, and 37%, respectively. The 1-, 3-, and 5-year rates of BNI IIIb or better pain relief were 74%, 59%, and 46%, respectively. One patient experienced bothersome numbness and 2 patients developed anesthesia dolorosa. The dominant predictive factors for pain relief were facial numbness after the first GKRS and a positive pain response to the first GKRS. **CONCLUSION:** Repeat GKRS is an effective method of treating recurrent trigeminal neuralgia. Patients who have facial numbness after the first treatment and a positive pain response to the first GKRS are significantly more likely to respond well to the second treatment.

[51] Higher dose rate Gamma Knife radiosurgery may provide earlier and longer-lasting pain relief for patients with trigeminal neuralgia.
Journal of neurosurgery. 2015;123(4):961-8
Lee JY, Sandhu S, Miller D, Solberg T, Dorsey JF, Alonso-Basanta M
PMID: 26252452 DOI: 10.3171/2014.12.JNS142013
Gamma Knife radiosurgery (GKRS) utilizes cobalt-60 as its radiation source, and thus dose rate varies as the fixed source decays over its half-life of approximately 5.26 years. This natural decay results in increasing treatment times when delivering the same cumulative dose. It is also possible, however, that the biological effective dose may change based on this dose rate even if the total dose is kept constant. Because patients are generally treated in a uniform manner, radiosurgery for trigeminal neuralgia (TN) represents a clinical model whereby biological efficacy can be tested. The authors hypothesized that higher dose rates would result in earlier and more complete pain relief but only if measured with a sensitive pain assessment tool. **METHODS:** One hundred thirty-three patients were treated with the Gamma Knife Model 4C unit at a single center by a single neurosurgeon

during a single cobalt life cycle from January 2006 to May 2012. All patients were treated with 80 Gy with a single 4-mm isocenter without blocking. Using an output factor of 0.87, dose rates ranged from 1.28 to 2.95 Gy/min. The Brief Pain Inventory (BPI)-Facial was administered before the procedure and at the first follow-up office visit 1 month from the procedure (mean 1.3 months). Phone calls were made to evaluate patients after their procedures as part of a retrospective study. Univariate and multivariate linear regression was performed on several independent variables, including sex, age in deciles, diagnosis, follow-up duration, prior surgery, and dose rate. **RESULTS:** In the short-term analysis (mean 1.3 months), patients' self-reported pain intensity at its worst was significantly correlated with dose rate on multivariate analysis (p = 0.028). Similarly, patients' self-reported interference with activities of daily living was closely correlated with dose rate on multivariate analysis (p = 0.067). A 1 Gy/min decrease in dose rate resulted in a 17% decrease in pain intensity at its worst and a 22% decrease in pain interference with activities of daily living. In longer-term follow-up (mean 1.9 years), GKRS with higher dose rates (> 2.0 Gy/min; p = 0.007) and older age in deciles (p = 0.012) were associated with a lower likelihood of recurrence of pain. **DISCUSSION:** Prior studies investigating the role of dose rate in Gamma Knife radiosurgical ablation for TN have not used validated outcome tools to measure pain preoperatively. Consequently, differences in pain outcomes have been difficult to measure. By administering pain scales both preoperatively as well as postoperatively, the authors have identified statistically significant differences in pain intensity and pain interference with activities of daily living when comparing higher versus lower dose rates. Radiosurgery with a higher dose rate results in more pain relief at the early follow-up evaluation, and it may result in a lower recurrence rate at later follow-up.

[52] Decreased Probability of Initial Pain Cessation in Classic Trigeminal Neuralgia Treated With Gamma Knife Surgery in Case of Previous Microvascular Decompression: A Prospective Series of 45 Patients With >1 Year of Follow-up.
Neurosurgery. 2015;77(1):87-94; discussion 94-5
Tuleasca C, Carron R, Resseguier N, Donnet A, Roussel P, Gaudart J, Levivier M, Regis J
PMID: 25812065 DOI: 10.1227/NEU.0000000000000739
BACKGROUND: Microvascular decompression (MVD) is the reference technique for pharmacoresistant trigeminal neuralgia (TN). **OBJECTIVE:** To establish whether the safety and efficacy of Gamma Knife surgery for recurrent TN are influenced by prior MVD. **METHODS:** Between July 1992 and November 2010, 54 of 737 patients (45 of 497 with >1 year of follow-up) had a history of MVD (approximately half also with previous ablative procedure) and were operated on with Gamma Knife surgery for TN in the Timone University Hospital. A single 4-mm isocenter was positioned in the cisternal portion of the trigeminal nerve at a median distance of 7.6 mm (range, 3.9-11.9 mm) anterior to the emergence of the nerve. A median maximum dose of 85 Gy (range, 70-90 Gy) was delivered. **RESULTS:** The median follow-up time was 39.5 months (range, 14.1-144.6 months). Thirty-five patients (77.8%) were initially pain free in a median time of 14 days (range, 0-180 days), much lower compared with our global population of classic TN (P = .01). Their actuarial probabilities of remaining pain-free without medication at 3, 5, 7, and 10 years were 66.5%, 59.1%, 59.1%, and 44.3%. The hypoesthesia actuarial rate at 1 year was 9.1% and remained stable until 12 years (median, 8 months). **CONCLUSION:** Patients with previous MVD showed a significantly lower probability of initial pain cessation compared with our global population with classic TN (P = .01). The toxicity was low (only 9.1% hypoesthesia); furthermore, no patient reported bothersome hypoesthesia. However, the probability of maintaining pain relief without medication was 44.3% at 10 years, similar to our global series of classic TN (P = .85).

[53] Long term efficacy and patient satisfaction of microvascular decompression and gamma knife radiosurgery for trigeminal neuralgia.
Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia. 2015;22(5):818-22
Nanda A, Javalkar V, Zhang S, Ahmed O
PMID: 25769254 DOI: 10.1016/j.jocn.2014.11.028
The aim of our study was to evaluate the long term efficacy of microvascular decompression (MVD) and gamma knife radiosurgery (GKRS) with respect to pain relief and patient satisfaction. Both these modalities are accepted modalities of treatment for intractable trigeminal neuralgia. We excluded deceased patients, those who had a prior intervention and those requiring an additional intervention following initial treatment. A total of 69 patients were included in the study. Of these, 49 patients underwent treatment by GKRS and 20 by MVD. Pain status was assessed using the Barrow Neurological Institute (BNI) pain scale. The median follow up was 5.3years. There was no significant difference between the two groups with respect to initial pain relief (100% MVD, 84% GKRS; p=0.055). There was no significant difference in pain recurrence between the two groups (39% GKRS, 20% MVD; p=0.133). At last follow up, 85% of patients who underwent MVD had total pain relief (BNI scale I) compared to only 45% of GKRS patients (p=0.002). There was no significant difference in the patient satisfaction with respect to undergoing the same procedure again (90% MVD, 69% GKRS; p=0.1) and recommending it to family members (95% MVD, 84% GKRS; p=0.2). MVD offered total pain relief in a significantly higher number of patients than GKRS. There was no significant difference in the patient satisfaction rate between the two groups.

[54] Results of radiosurgery for trigeminal neuralgia: Ankara experience.
British journal of neurosurgery. 2015;29(1):54-58
Aykol S, Borcek AO, Emmez H, Ocal O, Pasaoglu A
PMID: 25222337 DOI: 10.3109/02688697.2014.957153
OBJECTIVE: The purpose of this retrospective study is to demonstrate the effectiveness of Gamma Knife radiosurgery for essential trigeminal neuralgia (TGN) and assess the long-term outcome in a cohort from Turkey. **METHODS:** From 2004 to 2011, 93 cases of essential TGN were treated with single radiosurgery (RS). Female:male ratio was 45:48 and the mean age of the population was 57.06 years. Mean suffering time before treatment was 88.26 months. V2 + V3 was the most effected branch. 38.7% of the cases had no previous invasive procedures. Each case received doses ranging from 70 to 90 Gy in a target located at the pontine trigeminal root entry zone of the trigeminal nerve. Statistical analyses were performed to evaluate the outcome and factors leading to outcome status. **RESULTS:** The median follow-up period was 28 months. Of the cases 31.2% had poor outcome related to treatment failure after single RS session. The excellent and good outcomes were achieved in 29% and 39.8% of patients, respectively. The probability of maintaining pain relief was calculated as 67% at 36 months and 58% at 72 months. The only complication encountered was facial dysesthesia and was positive in 68.8% of patients. The presence of facial dysesthesia was significantly correlated with better outcomes. In this study, no other factor was determined to have significant influence on outcome. **CONCLUSION:** RS treatment for TGN is safe and effective. A multicenter, prospective, randomized controlled trial is needed to determine a guideline for better treatment protocols.

2014

[55] Repeat Gamma Knife surgery for recurrent trigeminal neuralgia: long-term outcomes and systematic review.
Journal of neurosurgery. 2014;121 Suppl:210-21
Tuleasca C, Carron R, Resseguier N, Donnet A, Roussel P, Gaudart J, Levivier M, Regis J
PMID: 25434955 DOI: 10.3171/2014.8.GKS141487
OBJECTIVE: The purpose of this study was to establish the safety and efficacy of repeat Gamma Knife surgery (GKS) for recurrent trigeminal neuralgia (TN).

LEKSELL GAMMA KNIFE SOCIETY

METHODS: Using the prospective database of TN patients treated with GKS in Timone University Hospital (Marseille, France), data were analyzed for 737 patients undergoing GKS for TN Type 1 from July 1992 to November 2010. Among the 497 patients with initial pain cessation, 34.4% (157/456 with >/= 1-year follow-up) experienced at least 1 recurrence. Thirteen patients (1.8%) were considered for a second GKS, proposed only if the patients had good and prolonged initial pain cessation after the first GKS, with no other treatment alternative at the moment of recurrence. As for the first GKS, a single 4-mm isocenter was positioned in the cisternal portion of the trigeminal nerve at a median distance of 7.6 mm (range 4-14 mm) anterior to the emergence of the nerve (retrogasserian target). A median maximum dose of 90 Gy (range 70-90 Gy) was delivered. Data for 9 patients with at least 1-year followup were analyzed. A systematic review of literature was also performed, and results are compared with those of the Marseille study. **RESULTS:** The median time to retreatment in the Marseille study was 72 months (range 12-125 months) and in the literature it was 17 months (range 3-146 months). In the Marseille study, the median follow-up period was 33.9 months (range 12-96 months), and 8 of 9 patients (88.9%) had initial pain cessation with a median of 6.5 days (range 1-180 days). The actuarial rate for new hypesthesia was 33.3% at 6 months and 50% at 1 year, which remained stable for 7 years. The actuarial probabilities of maintaining pain relief without medication at 6 months and 1 year were 100% and 75%, respectively, and remained stable for 7 years. The systematic review analyzed 20 peer-reviewed studies reporting outcomes for repeat GKS for recurrent TN, with a total of 626 patients. Both the selection of the cases for retreatment and the way of reporting outcomes vary widely among studies, with a median rate for initial pain cessation of 88% (range 60%-100%) and for new hypesthesia of 33% (range 11%-80%). **CONCLUSIONS:** Results from the Marseille study raise the question of surgical alternatives after failed GKS for TN. The rates of initial pain cessation and recurrence seem comparable to, or even better than, those of the first GKS, according to different studies, but toxicity is much higher, both in the Marseille study and in the published data. Neither the Marseille study data nor literature data answer the 3 cardinal questions regarding repeat radiosurgery in recurrent TN: which patients to retreat, which target is optimal, and which dose to use.

[56] Effect of radiation dose on the outcomes of gamma knife treatment for trigeminal neuralgia: a multi-factor analysis.

Neurology India. 2014;62(4):400-5

Zhang X, Li P, Zhang S, Gong F, Yang S, Wang W

PMID: 25237946 DOI: 10.4103/0028-3886.141272

AIM: To analyze the effect of different radiation variables on the outcomes of treatment for trigeminal neuralgia (TN). **MATERIALS AND METHODS:** Seventy-three patients with refractory TN were treated with a maximum dose of 75-90 Gy using either one (n = 41) or two (n = 32) isocenters and were intensively followed up. The integrated dose delivered to the trigeminal nerve root within the prepontine cistern and the nerve root volume was calculated using the Gamma-Plan system. Relationships between the clinical outcomes and radiation variables were statistically analyzed using a combination of Fisher's exact test and multivariate analyses. **RESULTS:** At their last follow up, 21 patients (28.8%), 22 patients (30.1%), 19 patients (26%), 6 patients (8.2%), and 5 patients (6.8%) had Grade I-V pain outcomes, respectively, and the average mean dose delivered to the trigeminal nerve root, average integrated dose (mJ) and nerve root volume in prepontine cistern were 45.29 Gy, 4,26 mJ, and 98.47 mm 3 , respectively. The pain relief rate was not significantly improved by a higher amount of integrated dose received by the trigeminal nerve root in prepontine cistern, however, incidence of trigeminal nerve toxicity was increased (P = 0.005). **CONCLUSIONS:** Our limited results suggested that a higher integrated dose might increase the incidence of trigeminal nerve toxicity with no significant benefits in pain relief when the maximal doses were within 75-90 Gy. The protocol for increasing radiation variables such as longer nerve exposure length and higher maximal dose is not recommended as a routine approach and more randomized studies with large number of cases would be required to verify the best treatment strategy of gamma knife radiosurgery for TN.

[57] Effect of the gamma knife treatment on the trigeminal nerve root in Chinese patients with primary trigeminal neuralgia.

Turkish neurosurgery. 2014;24(2):163-9

Song ZX, Qian W, Wu YQ, Sun FJ, Fei J, Huang RS, Fang JY, Wu CZ, An YM, Wang D, Yang J

PMID: 24831355 DOI: 10.5137/1019-5149.JTN.6709-12.1

AIM: To understand the mechanism of the gamma knife treating the trigeminal neuralgia. **MATERIAL AND METHODS:** Using the MASEP-SRRS type gamma knife treatment system, 140 Chinese patients with trigeminal neuralgia (NT) were treated in our hospital from 2002 to 2010, in which the pain relief rate reached 95% and recurrence rate was 3% only. We investigated the effect of the gamma knife treatment on the trigeminal nerve root in 20 Chinese patients with primary trigeminal neuralgia by the magnetic resonance imager (MRI) observation. **RESULTS:** 1) The cross-sectional area of trigeminal nerve root became smaller and MRI signals were lower in the treatment side than those in the non-treatment side after the gamma knife treatment of primary trigeminal neuralgia; 2) in the treatment side, the cross-sectional area of the trigeminal nerve root decreased significantly after the gamma knife treatment; 3) there was good correlation between the clinical improvement and the MRI findings; and 4) the straight distance between the trigeminal nerve root and the brainstem did not change after the gamma knife treatment. **CONCLUSION:** The pain relief induced the gamma knife radiosurgery might be related with the atrophy of the trigeminal nerve root in Chinese patients with primary trigeminal neuralgia.

[58] Single-institution retrospective series of gamma knife radiosurgery in the treatment of multiple sclerosis-related trigeminal neuralgia: factors that predict efficacy.

Stereotactic and functional neurosurgery. 2014;92(1):53-8

Weller M, Marshall K, Lovato JF, Bourland JD, deGuzman AF, Munley MT, Shaw EG, Tatter SB, Chan MD

PMID: 24217153 DOI: 10.1159/000354815

BACKGROUND: Gamma knife radiosurgery (GKRS) has been reported as a treatment option for multiple sclerosis (MS)-related trigeminal neuralgia. **OBJECTIVE:** To report the outcomes of a single-institution retrospective series of MS-related trigeminal neuralgia. **METHODS:** Between 2002 and 2010, 35 patients with MS-related trigeminal neuralgia were treated with GKRS. The median maximum dose was 90 Gy. Data were analyzed to determine the response to GKRS and factors that may predict for efficacy. **RESULTS:** Of the 35 patients, 88% experienced a Barrow Neurological Institute (BNI) pain score of I-III at 3 months after GKRS. Kaplan-Meier estimates of 1-, 2- and 5-year freedom from BNI IV-V pain relapse were 57, 57 and 52%, respectively. Numbness was experienced by 39% of patients after GKRS, though no patients reported bothersome numbness. Several differences were noted between how the MS-related variant responded to GKRS and what has previously been reported for idiopathic trigeminal neuralgia. These include the observations that development of post-GKRS numbness did not predict for treatment response (p = 0.62) and that dorsal root entry zone dose did not predict for freedom from pain relapse (odds ratio 1.01, p = 0.1). Active smoking predicted for freedom from pain relapse (odds ratio 67.4, p = 0.04). **CONCLUSION:** GKRS is a viable noninvasive treatment option for MS-related trigeminal neuralgia.

[59] Multiple sclerosis-related trigeminal neuralgia: a prospective series of 43 patients treated with gamma knife surgery with more than one year of follow-up.

Stereotactic and functional neurosurgery. 2014;92(4):203-10

Tuleasca C, Carron R, Resseguier N, Donnet A, Roussel P, Gaudart J, Levivier M, Regis J

PMID: 25011487 DOI: 10.1159/000362173

BACKGROUND: Trigeminal neuralgia (TN) related to multiple sclerosis (MS) is more difficult to manage pharmacologically and surgically. **OBJECTIVE:** This article aims to evaluate the safety and efficacy of Gamma Knife surgery (GKS) in

this special group of patients. **METHODS:** Between July 1992 and November 2010, 43 cases with more than 1 year of follow-up were operated with GKS for TN related to MS and prospectively evaluated in the Timone University Hospital, Marseille, France. Radiosurgery using the Gamma Knife (model B or C or Perfexion) was performed. A single 4-mm isocenter was positioned at a median distance of 8 mm (range 5.7-14.7) anterior to the emergence of the nerve. A median maximum dose of 85 Gy (range 75-90) was delivered. **RESULTS:** The median follow-up period was 53.8 months (12-157.1). Thirty-nine patients (90.7%) were initially pain free. Their actuarial probability of remaining pain free without medication at 6 months, 1, 3, 5 and 10 years was 87.2, 71.8, 43.1, 38.3 and 20.5%, respectively, and remained stable till 12 years. The hypoesthesia actuarial rate at 6 months, 1 and 2 years was 11.5, 11.5 and 16%, and remained stable till 12 years. **CONCLUSIONS:** GKS proved safe and effective in this special group of patients.

[60] Trigeminal neuralgia treatment outcomes following Gamma Knife radiosurgery with a minimum 3-year follow-up.
Journal of radiation oncology. 2014;3:125-130
Karam SD, Tai A, Wooster M, Rashid A, Chen R, Baig N, Jay A, Harter KW, Randolph-Jackson P, Omogbehin A, Aulisi EF, Jacobson J
PMID: 24955219 DOI: 10.1007/s13566-013-0134-3
OBJECTIVE: Effective short-term outcomes have been well documented for trigeminal neuralgia (TN) patients treated with Gamma Knife radiosurgery (GKRS) with reported success rates of 70-90 % with median follow-up intervals of 19-75 months. Fewer series, however, have described uniform long-term follow-up data. In this study, we report our long-term institutional outcomes in patients treated with GKRS after a minimum follow-up of 36 months. **METHODS:** Thirty-six consecutive patients with medically intractable TN received a median radiation dose of 45 Gy applied with a single 4-mm isocenter to the affected trigeminal nerve. Follow-up data were obtained by clinical examination and telephone questionnaire. Outcome results were categorized based on the Barrow Neurological Institute (BNI) pain scale with BNI I-III considered to be good outcomes and BNI IV-V considered as treatment failure. BNI facial numbness score was used to assess treatment complications. **RESULTS:** The incidence of early pain relief was high (80.5 %) and relief was noted in an average of 1.6 months after treatment. At minimum follow-up of 3 years, 67 % were pain free (BNI I) and 75 % had good treatment outcome. At a mean last follow-up of 69 months, 32 % were free from any pain and 63 % were free from severe pain. Bothersome posttreatment facial numbness was reported in 11 % of the patients. A statistically significant correlation was found between age and recurrence of any pain with age >70 predicting a more favorable outcome after radiosurgery. **CONCLUSION:** The success rate of GKRS for treatment of medically intractable TN declines over time with 32 % reporting ideal outcome and 63 % reporting good outcome. Patients older than age 70 are good candidates for radiosurgery. This data should help in setting realistic expectations for weighing the various available treatment options.

[61] Trigeminal nerve asymmetry in classic trigeminal neuralgia - pretreatment volumetry and clinical evaluation in patients irradiated by Leksell Gamma Knife.
Neuro endocrinology letters. 2014;35(4):285-9
Urgosik D, Keller J, Svehlik V, Pingle M, Horinek D
PMID: 25038607 DOI:
OBJECTIVES: The etiology of classic trigeminal neuralgia (CTN) is still under debate and, together with neurovascular compression (NVC), other anatomical abnormalities have been considered, including differences of trigeminal nerve (TN) volume. **DESIGN:** We evaluated the volumes of affected and non-affected nerves and the presence and type of NVC in large group of 84 CTN subjects prior to gamma knife treatment (GKS) on MR images. Correlation between affected nerve volume and NVC, treatment outcome and demographic characteristics were explored. **RESULTS:** NVC was detected in 71% of affected nerves, 52% of non-affected nerves, and in 31% of subjects bilaterally. Lower trigeminal nerve volume was detected on the affected side (p<0.001, affected mean 34.9 mm3 +/- 14.4 SD, non-affected mean 41.9 mm3 +/- 17.7 SD), however, no correlation between affected nerve volume and the presence and type NVC, treatment outcome or demographic data was detected. **CONCLUSION:** Our results suggest that NVC may trigger CTN in susceptible subjects but is not a reliable disease marker. Lower trigeminal nerve volume appears to manifest independently of NVC, and may represent nerve asymmetry rather than atrophy. No correlation between volumetry and clinical data was detected including treatment outcome after GKS.

[62] Predictive nomogram for the durability of pain relief from gamma knife radiation surgery in the treatment of trigeminal neuralgia.
International journal of radiation oncology, biology, physics. 2014;89(1):120-6
Lucas JT Jr, Nida AM, Isom S, Marshall K, Bourland JD, Laxton AW, Tatter SB, Chan MD
PMID: 24613811 DOI: 10.1016/j.ijrobp.2014.01.023
PURPOSE: To determine factors associated with the durability of stereotactic radiation surgery (SRS) for treatment of trigeminal neuralgia (TN). **METHODS AND MATERIALS:** Between 1999 and 2008, 446 of 777 patients with TN underwent SRS and had evaluable follow-up in our electronic medical records and phone interview records. The median follow-up was 21.2 months. The Barrow Neurologic Institute (BNI) pain scale was used to determine pre- and post-SRS pain. Dose-volume anatomical measurements, Burchiel pain subtype, pain quality, prior procedures, and medication usage were included in this retrospective cohort to identify factors impacting the time to BNI 4-5 pain relapse by using Cox proportional hazard regression. An internet-based nomogram was constructed based on predictive factors of durable relief pre- and posttreatment at 6-month intervals. **RESULTS:** Rates of freedom from BNI 4-5 failure at 1, 3, and 5 years were 84.5%, 70.4%, and 46.9%, respectively. Pain relief was BNI 1-3 at 1, 3, and 5 years in 86.1%, 74.3%, and 51.3% of type 1 patients; 79.3%, 46.2%, and 29.3% of type 2 patients; and 62.7%, 50.2%, and 25% of atypical facial pain patients. BNI type 1 pain score was achieved at 1, 3, and 5 years in 62.9%, 43.5%, and 22.0% of patients with type 1 pain and in 47.5%, 25.2%, and 9.2% of type 2 patients, respectively. Only 13% of patients with atypical facial pain achieved BNI 1 response; 42% of patients developed post-Gamma Knife radiation surgery (GKRS) trigeminal dysfunction. Multivariate analysis revealed that post-SRS numbness (hazard ratio [HR], 0.47; P<.0001), type 1 (vs type 2) TN (HR, 0.6; P=.02), and improved post-SRS BNI score at 6 months (HR, 0.009; P<.0001) were predictive of a durable pain response. **CONCLUSIONS:** The durability of SRS for TN depends on the presenting Burchiel pain type, the post-SRS BNI score, and the presence of post-SRS facial numbness. The durability of pain relief can be estimated pre- and posttreatment by using our nomogram for situations when the potential of relapse may guide the decision for initial intervention.

[63] Impact of target location on the response of trigeminal neuralgia to stereotactic radiosurgery.
Journal of neurosurgery. 2014;120(3):716-24
Xu Z, Schlesinger D, Moldovan K, Przybylowski C, Sun X, Lee CC, Yen CP, Sheehan J
PMID: 24313616 DOI: 10.3171/2013.10.JNS131596
OBJECTIVE: The authors evaluate the impact of target location on the rate of pain relief (PR) in patients with intractable trigeminal neuralgia (TN) undergoing stereotactic radiosurgery (SRS). **METHODS:** The authors conducted a retrospective review of 99 patients with idiopathic TN who were identified from a prospectively maintained database and were treated with SRS targeting the dorsal root entry zone with a maximum dose of 80 Gy. Targeting of the more proximal portion of a trigeminal nerve with the 50% isodose line overlapping the brainstem was performed in 36 patients (proximal group). In a matched group, 63 patients received SRS targeting the 20% isodose line tangential to the emergence of the brainstem (distal group). The median follow-up time was 33 months (range 6-124 months). **RESULTS:** The actuarial rate of maintenance of Barrow Neurological Institute (BNI) Pain Score I-IIIa was attained in 89% of patients at 1 year, 81%

at 2 years, and 69% at 4 years, respectively, after SRS. Kaplan-Meier analysis revealed that durability of PR was only associated with the proximal location of the radiosurgical target (log-rank test, p = 0.018). Radiosurgery-induced facial numbness (BNI Score II or III) developed in 35 patients, which was significantly more frequent in the proximal group (19 patients [53%] compared with 16 [25%] in the distal group [p = 0.015]). **CONCLUSIONS:** The radiosurgical target appears to affect the duration of pain relief in patients with idiopathic trigeminal neuralgia with the target closer to the brainstem affording extended pain relief. However, the proximal SRS target was also associated with an increased risk of mild to moderate facial numbness.

[64] Trigeminal neuralgia pain relief after gamma knife stereotactic radiosurgery.
Clinical neurology and neurosurgery. 2014;117:107-111
Baschnagel AM, Cartier JL, Dreyer J, Chen PY, Pieper DR, Olson RE, Krauss DJ, Maitz AH, Grills IS
PMID: 24438815 DOI: 10.1016/j.clineuro.2013.12.003
OBJECTIVES: To report outcomes of patients with medical and/or surgical refractory trigeminal neuralgia (TN) treated with gamma knife stereotactic radiosurgery (GK SRS). **METHODS:** One hundred and forty-nine patients with 152 cases of TN treated with GK SRS were analyzed. All patients, except one, received a dose of 40Gy to the 50% isodose volume. The Barrow Neurological Institute (BNI) pain intensity score was used to grade pain. Actuarial rates of pain relief were calculated. Multiple factors were analyzed for association with pain relief. **RESULTS:** The median follow up was 27 months (4-71 months). Overall 92% of cases achieved a BNI score I-III after GK SRS. Of those who had pain relief after GK SRS, 32% developed pain recurrence defined as a BNI score of IV or V. The actuarial rate of freedom from pain recurrence (BNI scores I-III) of all treated cases at 1, 2 and 3-years was 76%, 69% and 60%, respectively. On univariate analysis age >/=70 was predictive of better pain relief (p=0.046). Type of pain, prior surgery, multiple sclerosis, number of isocenters, treated nerve length, volume and thickness and distance from the root entry zone to the isocenter were not significant for maintaining a BNI score of I-III. Those who achieved a BNI score of I or II were more likely to maintain pain relief compared to those who only achieved a BNI score of III (93% vs 38% at three years, p<0.01). The rate of pain relief of twenty-seven patients who underwent repeat GK SRS was 70% and 62% at 1 and 2 years, respectively. Toxicity after first GK SRS was minimal with 25% of cases experiencing only new or worsening post-treatment numbness. **CONCLUSION:** GK SRS provides acceptable pain relief with limited morbidity in patients with medical and/or surgical refractory TN.

2013

[65] Long-term outcome of high-dose gamma knife surgery in treatment of trigeminal neuralgia.
Journal of neurosurgery. 2013;119(5):1166-75
Young B, Shivazad A, Kryscio RJ, St Clair W, Bush HM
PMID: 23600932 DOI: 10.3171/2013.1.JNS12875
OBJECTIVE: Despite the widespread use of Gamma Knife surgery (GKS) for trigeminal neuralgia (TN), controversy remains regarding the optimal treatment dose and target site. Among the published studies, only a few have focused on long-term outcomes (beyond 2 years) using 90 Gy, which is in the higher range of treatment doses used (70-90 Gy). **METHODS:** The authors followed up on 315 consecutive patients treated with the Leksell Gamma Knife unit using a 4-mm isocenter without blocks. The isocenter was placed on the trigeminal nerve with the 20% isodose line tangential to the pontine surface (18 Gy). At follow-up, 33 patients were deceased; 282 were mailed an extensive questionnaire regarding their outcomes, but 32 could not be reached. The authors report their analysis of the remaining 250 cases. The patients' mean age at the time of survey response and the mean duration of follow-up were 70.8 +/- 13.1 years and 68.9 +/- 41.8 months, respectively. **RESULTS:** One hundred eighty-five patients (85.6%) had decreased pain intensity after GKS. Modified Marseille Scale (MMS) pain classifications after GKS at follow-up were: Class I (pain free without medication[s]) in 104 (43.7%), Class II (pain free with medication[s]) in 66 (27.7%), Class III (> 90% decrease in pain intensity) in 23 (9.7%), Class IV (50%-90% decrease in pain intensity) in 20 (8.4%), Class V (< 50% decrease in pain intensity) in 11 (4.6%), and Class VI (pain becoming worse) in 14 (5.9%). Therefore, 170 patients (71.4%) were pain free (Classes I and II) and 213 (89.5%) had at least 50% pain relief. All patients had pain that was refractory to medical management prior to GKS, but only 111 (44.4%) were being treated with medication at follow-up (p < 0.0001). Eighty patients (32.9%) developed numbness after GKS, and 74.5% of patients with numbness had complete pain relief. Quality of life and patient satisfaction on a 10-point scale were reported at mean values (+/- SD) of 7.8 +/- 3.1 and 7.7 +/- 3.4, respectively. Most of the patients (87.7%) would recommend GKS to another patient. Patients with prior surgical treatments had increased latency to pain relief and were more likely to continue medicines (p < 0.05). Moreover, presence of altered facial sensations prior to radiosurgery was associated with higher pain intensity, longer pain episodes, more frequent pain attacks, worse MMS pain classification, and more medication use after GKS (p < 0.05). Conversely, increase in numbness intensity after GKS was associated with a decrease in pain intensity and pain length (p < 0.05). **CONCLUSIONS:** Gamma Knife surgery using a maximum dose of 90 Gy to the trigeminal nerve provides satisfactory long-term pain control, reduces the use of medication, and improves quality of life. Physicians must be aware that higher doses may be associated with an increase in bothersome sensory complications. The benefits and risks of higher dose selection must be carefully discussed with patients, since facial numbness, even if bothersome, may be an acceptable trade-off for patients with severe pain.

[66] Long-term outcome of gamma knife surgery using a retrogasserian petrous bone target for classic trigeminal neuralgia.
Acta neurochirurgica. Supplement. 2013;116:127-35
Lee JK, Kim DR, Huh YH, Kim JK, Namgung WC, Hong SH
PMID: 23417470 DOI: 10.1007/978-3-7091-1376-9_20
BACKGROUND: Gamma knife surgery (GKS) is the prevailing method for treatment of medically intractable trigeminal neuralgia (TN), although there are some technical differences among radiosurgical centers. We assessed the long-term outcomes of GKS using retrogasserian petrous bone targeting and evaluated factors associated with the clinical outcomes. **METHODS:** Between December 2003 and June 2009, a total of 91 GKS treatments were performed in 90 patients with classic TN. The surgical target was defined at the anterior portion of the trigeminal nerve, just above the retrogasserian petrous bone. A single 4-mm collimator was used to deliver a median 88.0 Gy (range 75-90 Gy) dose of radiation. **FINDINGS:** During follow-up, which ranged from 24 to 90 months, 89 patients (97.8 %) reported initial pain relief, 75 (82.4 %) experienced pain control, and 47 (51.6 %) achieved a pain-free state without medications at the last follow-up. Barrow Neurological Institute (BNI) scores of I-III at 2, 3, 4, 5, and 7 years were observed in 84 of 91, 68 of 77, 46 of 53, 33 of 36, 17 of 19, and 7 of 7 patients, respectively. Trigeminal nerve dysfunction was experienced by 34 patients, with 12 having BNI facial numbness scores of III-IV (13.2 %). In all, 14 patients (15.4 %) experienced pain recurrence at a mean 32 months (range 10-62 months) after treatment. The actuarial rates of pain control at 2, 4, and 6 years were 93 %, 88 %, and 79 %, respectively. **CONCLUSIONS:** Gamma Knife radiosurgery is an efficient option for intractable TN. Our results can help medical practitioners to counsel their patients on the likelihood of achieving successful pain control.

[67] Gamma knife radiosurgery for typical trigeminal neuralgia: An institutional review of 108 patients.
Surgical neurology international. 2013;4:92
Elaimy AL, Lamm AF, Demakas JJ, Mackay AR, Lamoreaux WT, Fairbanks RK, Pfeffer RD, Cooke BS, Peressini BJ, Lee CM

PMID: 23956935 DOI: 10.4103/2152-7806.115163
BACKGROUND: In this study, we present the previously unreported pain relief outcomes of 108 patients treated at Gamma Knife of Spokane for typical trigeminal neuralgia (TN) between 2002 and 2011. **METHODS:** Pain relief outcomes were measured using the Barrow Neurological Institute (BNI) pain intensity scale. In addition, the effects gender, age at treatment, pain laterality, previous surgical treatment, repeat Gamma Knife radiosurgery (GKRS), and maximum radiosurgery dose have on patient pain relief outcomes were retrospectively analyzed. Statistical analysis was performed using Andersen 95% confidence intervals, approximate confidence intervals for log hazard ratios, and multivariate Cox proportional hazard models. **RESULTS:** All 108 patients included in this study were grouped into BNI class IV or V prior to GKRS. The median clinical follow-up time was determined to be 15 months. Following the first GKRS procedure, 71% of patients were grouped into BNI class I-IIIb (I = 31%; II = 3%; IIIa = 19%; IIIb = 18%) and the median duration of pain relief for those patients was determined to be 11.8 months. New facial numbness was reported in 19% of patients and new facial paresthesias were reported in 7% of patients after the first GKRS procedure. A total of 19 repeat procedures were performed on the 108 patients included in this study. Following the second GKRS procedure, 73% of patients were grouped into BNI class I-IIIb (I = 44%; II = 6%; IIIa = 17%, IIIb = 6%) and the median duration of pain relief for those patients was determined to be 4.9 months. For repeat procedures, new facial numbness was reported in 22% of patients and new facial paresthesias were reported in 6% of patients. **CONCLUSIONS:** GKRS is a safe and effective management approach for patients diagnosed with typical TN. However, further studies and supporting research is needed on the effects previous surgical treatment, number of radiosurgery procedures, and maximum radiosurgery dose have on GKRS clinical outcomes.

[68] Constant face pain in typical trigeminal neuralgia and response to gamma knife radiosurgery.

Stereotactic and functional neurosurgery. 2013;91(2):122-8
Brisman R
PMID: 23343637 DOI: 10.1159/000343206
BACKGROUND/AIMS: Constant pain, especially if prominent, is sometimes considered incompatible with a diagnosis of typical idiopathic trigeminal neuralgia. This study aims to clarify the frequency of patient-reported constant pain in patients with medically intractable, typical, idiopathic trigeminal neuralgia as diagnosed with standard clinical parameters and confirmed by the response to a modified McGill questionnaire, a 'hold-still' test that eliminated triggers and the response to Gamma Knife radiosurgery. **METHOD:** Forty consecutive patients with typical trigeminal neuralgia were given questionnaires prior to Gamma Knife radiosurgery. Those with constant pain were further tested by being advised to hold completely still for up to 3 min. Final pain relief was evaluated after Gamma Knife radiosurgery. **RESULTS:** Twenty of forty patients indicated on a questionnaire that they had constant face pain. Pain decreased on the 'hold-still' test on all 12 patients who were tested. Following Gamma Knife radiosurgery, there was no significant difference in pain relief in those without or with constant pain. **CONCLUSION:** Patients with typical idiopathic trigeminal neuralgia frequently report that 50% or more of their pain is constant. This constant pain is markedly decreased if the patient holds completely still for a few minutes and does not affect the outcome of Gamma Knife radiosurgery.

[69] Stereotactic radiosurgery for trigeminal schwannoma: a clinical retrospective study in 52 cases.

Stereotactic and functional neurosurgery. 2013;91(4):236-42
Sun J, Zhang J, Yu X, Qi S, Du Y, Ni W, Hu Y, Tian Z
PMID: 23548989 DOI: 10.1159/000345258
OBJECTIVE: To evaluate the radiological and clinical outcomes in a series of patients in whom stereotactic radiosurgery (SRS) was used to treat trigeminal schwannomas. **METHODS:** The records of 52 patients who underwent SRS for trigeminal schwannoma were reviewed using a retrospective study. The median patient age was 47.1 years (range, 18-77); 20 patients (38.5%) had undergone prior tumor resection and 32 (61.5%) underwent radiosurgery on the basis of imaging diagnosis only. The most frequent presenting symptoms were facial numbness (29 patients), jaw weakness (11 patients), facial pain (10 patients) and diplopia (4 patients). Fifty-two cases with solid tumors were mainly solid in 44 cases (84.6%), mostly cystic in 2 cases (3.8%), and cystic and solid mixed in 6 cases (11.5%). Two cases of mostly cystic tumor first underwent stereotactic cystic fluid aspiration and intracavitary irradiation, and then had MRI localization scan again for gamma knife treatment. The mean tumor volume was 7.2 ml (range, 0.5-38.2). The mean prescription radiation dose was 13.9 Gy (range, 11-17), and the mean prescription isodose configuration was 47.9%. **RESULTS:** At a mean follow-up of 61 months (range, 12-156), neurological symptoms or signs improved in 35 patients (67.3%), 14 patients (26.9%) had a stable lesion, and worsening of the disease occurred in 2 patients (3.8%). On imaging, the schwannomas almost disappeared in 8 (15.4%), shrank in 32 (61.5%), remained stable in 5 (9.6%), and increased in size in 7 patients (13.5%). Tumor growth control was achieved in 45 (86.5%) of the 52 patients. **CONCLUSIONS:** SRS is an effective and minimally invasive management option for patients with residual or newly diagnosed trigeminal schwannomas. The use of SRS to treat trigeminal schwannomas resulted in good tumor control and functional improvement.

2012

[70] Patterns of pain-free response in 497 cases of classic trigeminal neuralgia treated with Gamma Knife surgery and followed up for least 1 year.

Journal of neurosurgery. 2012;117 Suppl:181-8
Tuleasca C, Carron R, Resseguier N, Donnet A, Roussel P, Gaudart J, Levivier M, Regis J
PMID: 23205808 DOI: 10.3171/2012.8.GKS121015
OBJECTIVE: The goal of this study was to establish whether clear patterns of initial pain freedom could be identified when treating patients with classic trigeminal neuralgia (TN) by using Gamma Knife surgery (GKS). The authors compared hypesthesia and pain recurrence rates to see if statistically significant differences could be found. **METHODS:** Between July 1992 and November 2010, 737 patients presenting with TN underwent GKS and prospective evaluation at Timone University Hospital in Marseille, France. In this study the authors analyzed the cases of 497 of these patients, who participated in follow-up longer than 1 year, did not have megadolichobasilar artery- or multiple sclerosis-related TN, and underwent GKS only once; in other words, the focus was on cases of classic TN with a single radiosurgical treatment. Radiosurgery was performed with a Leksell Gamma Knife (model B, C, or Perfexion) using both MR and CT imaging targeting. A single 4-mm isocenter was positioned in the cisternal portion of the trigeminal nerve at a median distance of 7.8 mm (range 4.5-14 mm) anterior to the emergence of the nerve. A median maximum dose of 85 Gy (range 70-90 Gy) was delivered. Using empirical methods and assisted by a chart with clear cut-off periods of pain free distribution, the authors were able to divide patients who experienced freedom from pain into 3 separate groups: patients who became pain free within the first 48 hours post-GKS; those who became pain free between 48 hours and 30 days post-GKS; and those who became pain free more than 30 days after GKS. **RESULTS:** The median age in the 497 patients was 68.3 years (range 28.1-93.2 years). The median follow-up period was 43.75 months (range 12-174.41 months). Four hundred fifty-four patients (91.34%) were initially pain free within a median time of 10 days (range 1-459 days) after GKS. One hundred sixty-nine patients (37.2%) became pain free within the first 48 hours (Group PF(</= 48 hours)), 194 patients (42.8%) between posttreatment Day 3 and Day 30 (Group PF((>48 hours, </= 30 days))), and 91 patients (20%) after 30 days post-GKS (Group PF(>30 days)). Differences in postoperative hypesthesia were found: in Group PF(</= 48 hours) 18 patients (13.7%) developed postoperative hypesthesia,

compared with 30 patients (19%) in Group PF((>48 hours, </= 30 days)) and 22 patients (30.6%) in Group PF(>30 days) (p = 0.014). One hundred fifty-seven patients (34.4%) who initially became free from pain experienced a recurrence of pain with a median delay of 24 months (range 0.62-150.06 months). There were no statistically significant differences between the patient groups with respect to pain recurrence: 66 patients (39%) in Group PF(</= 48 hours) experienced pain recurrence, compared with 71 patients (36.6%) in Group PF((>48 hours, </= 30 days)) and 27 patients (29.7%) in Group PF(>30 days) (p = 0.515). **CONCLUSIONS:** A substantial number of patients (169 cases, 37.2%) became pain free within the first 48 hours. The rate of hypesthesia was higher in patients who became pain free more than 30 days after GKS, with a statistically significant difference between patient groups (p = 0.014).

[71] Patients with idiopathic trigeminal neuralgia have a sharper-than-normal trigeminal-pontine angle and trigeminal nerve atrophy.
Acta neurochirurgica. 2012;154(9):1627-33
Ha SM, Kim SH, Yoo EH, Han IB, Shin DA, Cho KG, Chung SS, Park YS
PMID: 22688610 DOI: 10.1007/s00701-012-1327-z
BACKGROUND: Trigeminal neuralgia (TN) is primarily diagnosed by symptoms and patient history. Magnetic resonance (MR) imaging can be helpful in visualizing the neurovascular compression of the trigeminal nerve in TN patients, but the current parameters used as diagnostic markers for TN are less than optimal. The aim of this study is to assess whether the angle between the trigeminal nerve and the pons (the trigeminal-pontine angle) on the affected side of patients with idiopathic TN differs from that of the unaffected side and that found in controls without TN. **METHODS:** A case-control study of 30 clinically diagnosed idiopathic TN patients aged 30 to 79 years and 30 age- and sex-matched controls was conducted. We compared the trigeminal-pontine angle and trigeminal nerve atrophy via fast-imaging employing steady-state acquisition (FIESTA) MR imaging. **RESULTS:** A sharp trigeminal-pontine angle was observed in 25 patients (25/30) on the affected side. As such, the mean angle of the trigeminal nerve on the affected side (40.17) was significantly smaller than that on the unaffected side (48.91, p = 0.001) and that in the control group (52.02, p < 0.001). **CONCLUSIONS:** A sharp trigeminal-pontine angle on the affected side was found in idiopathic TN patients by FIESTA imaging. This suggests that a sharp trigeminal-pontine angle increases the chance of neurovascular compression on the medial side of the trigeminal nerve.

[72] Do carbamazepine, gabapentin, or other anticonvulsants exert sufficient radioprotective effects to alter responses from trigeminal neuralgia radiosurgery?
International journal of radiation oncology, biology, physics. 2012;83(4):e501-6
Flickinger JC Jr, Kim H, Kano H, Greenberger JS, Arai Y, Niranjan A, Lunsford LD, Kondziolka D, Flickinger JC Sr
PMID: 22417801 DOI: 10.1016/j.ijrobp.2012.01.016
PURPOSE: Laboratory studies have documented radioprotective effects with carbamazepine. We sought to determine whether carbamazepine or other anticonvulsant/neuroleptic drugs would show significant radioprotective effects in patients undergoing high-dose small-volume radiosurgery for trigeminal neuralgia. **METHODS AND MATERIALS:** We conducted a retrospective review of 200 patients undergoing Gamma Knife (Elekta Instrument AB, Stockholm, Sweden) stereotactic radiosurgery for trigeminal neuralgia between February 1995 and May 2008. We selected patients treated with a maximum dose of 80 Gy with 4-mm diameter collimators, with no previous microvascular decompression, and follow-up >/=6 months (median, 24 months; range, 6-153 months). At the time of radiosurgery, 28 patients were taking no anticonvulsants, 62 only carbamazepine, 35 only gabapentin, 21 carbamazepine plus gabapentin, 17 carbamazepine plus other anticonvulsants, and 9 gabapentin plus other anticonvulsants, and 28 were taking other anticonvulsants or combinations. **RESULTS:** Pain improvement developed post-radiosurgery in 187 of 200 patients (93.5%). Initial complete pain relief developed in 84 of 200 patients (42%). Post-radiosurgery trigeminal neuropathy developed in 27 of 200 patients (13.5%). We could not significantly correlate pain improvement or initial complete pain relief with use of carbamazepine, gabapentin, or use of any anticonvulsants/neuroleptic drugs or other factors in univariate or multivariate analysis. Post-radiosurgery numbness/paresthesias correlated with the use of gabapentin (1 of 36 patients with gabapentin vs. 7 of 28 without, p = 0.017). In multivariate analysis, decreasing age, purely typical pain, and use of gabapentin correlated (p = 0.008, p = 0.005, and p = 0.021) with lower risks of developing post-radiosurgery trigeminal neuropathy. New post-radiosurgery numbness/paresthesias developed in 3% (1 of 36), 5% (4 of 81), and 13% (23 of 187) of patients on gabapentin alone, with age </=70 years, and Type 1 typical trigeminal neuralgia pain compared with 25% (7 of 28), 20% (23 of 114), and 33% (4 of 12) of patients taking no anticonvulsants, age >70 years, and partly atypical Type 2 trigeminal neuralgia, respectively. **CONCLUSIONS:** The use of carbamazepine or gabapentin at the time of radiosurgery does not decrease the rates of obtaining partial or complete pain relief after radiosurgery, but gabapentin may reduce the risks of developing post-radiosurgery trigeminal neuropathy.

[73] Trigeminal nerve integrated dose and pain outcome after gamma knife radiosurgery for trigeminal neuralgia.
Journal of radiosurgery and SBRT. 2012;1(4):295-301
Alahmadi H, Zadeh G, Laperriere N, Vachhrajani S, Mazloom N, Gentili F, Hodaie M
PMID: 29296330 DOI:
BACKGROUND: Gamma knife radiosurgery (GKRS) is an established treatment for trigeminal neuralgia. Identifying factors that influence outcome will help improve patients' results. **METHODS:** We conducted a retrospective review of all patients treated with GKRS for trigeminal neuralgia at our institution from 2005 to 2010. Patients' clinical features and treatment details were reviewed. Analysis was performed to identify predictors of response and recurrence. **RESULTS:** A hundred and forty five patients were treated. Mean follow up period was 24 months. At last follow up, 48 patients (33%) were pain free with no medications, and 48 patients (33%) were pain free maintained on medications. Twenty-eight patients (19%) had pain after the treatment but had significant reduction in their pain severity. Twenty-one patients (15%) did not have any significant pain reduction. Forty-four patients (30%) developed facial numbness. Recurrence occurred in 51 patients (35%). Post-treatment numbness was a predictor of good treatment response (OR 2.720, CI 1.193-6.200, p 0.0173). Higher integrated dose was a predictor of poor pain response to radiosurgery (OR 0.729, CI 0.566-0.940, p 0.0146). At an integrated dose value of 5.3 mJ or less, there was more than 50% chance of pain free outcome. Longer pain duration prior to treatment was the only independent predictor of increased recurrence risk (HR 1.038, 95%CI 1.001-1.075; p=0.0412). **CONCLUSIONS:** Radiosurgery is an effective treatment modality for trigeminal neuralgia. Post treatment numbness is associated with good treatment response and higher integrated dose predicts poor outcome after radiosurgery for trigeminal neuralgia.

[74] Predictive variables for the successful treatment of trigeminal neuralgia with gamma knife radiosurgery.
Neurosurgery. 2012;70(3):566-72; discussion 572-3
Marshall K, Chan MD, McCoy TP, Aubuchon AC, Bourland JD, McMullen KP, deGuzman AF, Munley MT, Shaw EG, Tatter SB, Ellis TL
PMID: 21849918 DOI: 10.1227/NEU.0b013e3182320d36
BACKGROUND: Gamma Knife radiosurgery (GKRS) has been reported to be an effective modality to treat trigeminal neuralgia. **OBJECTIVE:** To determine predictive factors for the successful treatment of trigeminal neuralgia with GKRS. **METHODS:** Between 1999 and 2008, 777 GKRS procedures for patients with trigeminal neuralgia were performed at our institution. Evaluable follow-up data were obtained for 448 patients. Median follow-up time was 20.9 months (range, 3-86 months). The mean maximum prescribed dose was 88 Gy (range, 80-97 Gy). Dosimetric variables recorded included dorsal root entry zone dose, pons maximum dose, dose to the petrous dural ridge, and cisternal nerve length. **RESULTS:** By 3 months after GKRS, 86% of patients achieved Barrow Neurologic Institute I to III pain scores, with 43% of patients achieving a Barrow Neurologic Institute I pain score. Twenty-six percent of patients reported posttreatment facial numbness; 28% of patients reported a post-GKRS procedure for relapsed pain, and median time to

next procedure was 4.4 years. Multivariate analysis revealed that the development of postsurgical numbness (odds ratio [OR], 2.76; P = .006) was the dominant factor predictive of efficacy. Longer cisternal nerve length (OR, 0.85; P = .005), prior radiofrequency ablation (OR, 0.35; P = .028), and diabetes mellitus (OR, 0.38; P = .013) predicted decreased efficacy. The mean dose delivered to the dorsal root entry zone dose in patients who developed facial numbness (57.6 Gy) was more than the mean dose (47.3 Gy) given to patients who did not develop numbness (P = .02). **CONCLUSION:** The development of post-GKRS facial numbness is a dominant factor that predicts for efficacy of GKRS. History of diabetes mellitus or previous radiofrequency ablation may portend worsened outcome.

[75] Repeat gamma knife radiosurgery for trigeminal neuralgia.
Neurosurgery. 2012;70(2):295-305; discussion 305
Park KJ, Kondziolka D, Berkowitz O, Kano H, Novotny J Jr, Niranjan A, Flickinger JC, Lunsford LD
PMID: 21811188 DOI: 10.1227/NEU.0b013e318230218e
BACKGROUND: Trigeminal neuralgia (TN) may recur after treatment by gamma knife stereotactic radiosurgery (GKSR). **OBJECTIVE:** To evaluate management outcomes in patients who underwent repeat GKSR for TN. **METHODS:** The authors reviewed their experience with repeat GKSR in 119 patients with recurrent TN. The median patient age was 74 years (range, 34-96 years). The median interval between procedures was 26 months. The median target dose for repeat GKSR was 70 Gy (range, 50-90 Gy) and the median cumulative dose was 145 Gy (range, 120-170 Gy). The median follow-up was 48 months (range, 6-187 months) after repeat GKSR. **RESULTS:** After repeat GKSR, 87% of patients achieved initial pain relief (Barrow Neurological Institute pain score I-IIIb). Pain relief was maintained in 87.8% at 1 year, 69.8% at 3 years, and 44.2% at 5 years. Facial sensory dysfunction occurred in 21% of patients within 18 months after GKSR. Longer pain relief was observed in patients who had recurrent pain in a reduced pain distribution of the face compared with the pain distribution at the time of their initial GKSR, and in those who developed additional trigeminal sensory loss after a repeat procedure. A cumulative edge of brainstem dose >/= 44 Gy was more likely to be associated with the development of sensory loss. **CONCLUSION:** Repeat GKSR provides a similar rate of pain relief as the first procedure. The best responses were observed in patients who had good pain control after the first procedure and those who developed new sensory dysfunction in the affected trigeminal distribution.

[76] Stereotactic radiosurgery for trigeminal schwannomas.
Acta neurochirurgica. 2012;154(2):277-83
Yianni J, Dinca EB, Rowe J, Radatz M, Kemeny AA
PMID: 21918834 DOI: 10.1007/s00701-011-1146-7
PURPOSE: Traditionally trigeminal schwannomas (TS) have been treated microsurgically; however, this is often associated with significant morbidity, and complete excision remains a challenge. Stereotactic radiosurgery (SRS) offers a minimally invasive alternative in treating TS. We report on our cumulative experience of using SRS in the treatment of TS. **MATERIALS AND METHODS:** Seventy-four TS patients (four with NF2) were treated with SRS using the Leksell Gamma Knife. Mean age (+/-1 SD) at treatment was 47.1 (15.5) years with a mean interval between presentation and treatment of 30.9 months. Thirty (40.5%) patients had undergone previous surgery on average 47.3 months prior to SRS. The average target volume was 5.3 cm(3) (range 0.4-19.9 cm(3)) and was treated with a mean prescription dose of 16.4 (3.9) Gy to the tumour margin. **RESULTS:** Average follow-up was 48.2 months (range 6-168 months). Tumour size remained static in 58 (78.4%) patients and showed radiological evidence of shrinkage in 11 (14.9%). Tumour progression occurred in five (6.6%) patients on average 40 months after SRS (range 12-108). Progression-free survival (PFS) for all patients was 98.5% at 1 year, 92.7% at 5 years and 79.4% at 10 years. Log-rank analysis indicated a significantly worse outcome for NF2 patients (p = 0.001) who demonstrated a PFS of 100% at 1 year and 50% at 5 years. Seven patients developed adverse radiation effects whilst improvements in pre-treatment cranial nerve dysfunction were achieved in eight patients. **CONCLUSIONS:** SRS is an effective treatment option in patients with residual or newly diagnosed TS. In view of the results of this study we would advocate a more front-line role for the Gamma Knife in the treatment of this tumour group.

[77] Stereotactic radiosurgery for trigeminal neuralgia: outcomes and complications.
British journal of neurosurgery. 2012;26(1):45-52
Loescher AR, Radatz M, Kemeny A, Rowe J
PMID: 21815736 DOI: 10.3109/02688697.2011.591849
Stereotactic radiosurgery is one of a number of recognised treatments for the management of trigeminal neuralgia refractory to drug therapy. The reported success of stereotactic radiosurgery in managing patients with trigeminal neuralgia varies in different units from 22 to 75%. This paper reports the outcomes of patients with trigeminal neuralgia who were treated at the National Centre for Stereotactic Radiosurgery in Sheffield, UK. The study reports the outcome of 72 patients treated consecutively between October 2004 and May 2008. Data were collected prospectively by a postal questionnaire sent to patients at 6, 12 and 24 months after treatment. The median age was 65.6 years (39 males: 33 females). Fourteen patients had secondary trigeminal neuralgia (eight multiple sclerosis). Fifteen of the patients included in the study were receiving a second treatment (an initial treatment having improved their pain significantly for at least 6 months). All radiosurgical procedures were performed using a single 4 mm collimator isocenter covering the region of the dorsal root entry zone with a maximal radiation dose of 80 Gy. The percentage of patients defined as having an excellent outcome (pain free without medication) was 39% after 6 months, 36% after 12 months and 64% after 24 months. The percentage of patients who reported being very satisfied with treatment was 71% after 6 months, 57% after 12 months and 53% after 24 months. Half the patients with secondary trigeminal neuralgia were pain free without medication after treatment, and 60% of patients who underwent a second treatment were pain free. A new trigeminal sensory deficit was reported by 31% of patients after radiosurgical treatment.

[78] Clinical outcomes of 114 patients who underwent gamma-knife radiosurgery for medically refractory idiopathic trigeminal neuralgia.
Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia. 2012;19(1):71-4
Li P, Wang W, Liu Y, Zhong Q, Mao B
PMID: 22154202 DOI: 10.1016/j.jocn.2011.03.020
The optimal radiation dose and target of Gamma-knife radiosurgery (GKRS) for medically refractory idiopathic trigeminal neuralgia (TN) are contentious. We investigated the effects and trigeminal nerve deficits of GKRS using two isocenters to treat a great length of the trigeminal nerve. Between January 2005 and March 2010, 129 patients with idiopathic TN underwent GKRS at the West China Hospital of Sichuan University. A maximum central dose of 80-90 Gy was delivered to the trigeminal nerve root with two isocenters via a 4mm collimator helmet. One hundred and fourteen patients were followed-up periodically by telephone interview to determine the effects, trigeminal nerve deficits and time to the onset of pain relief. The mean follow-up duration was 29.6 months. One hundred and nine patients had complete or partial pain relief and the treatment failed in five patients. Nine patients experienced a recurrence after a mean time of 12.7 months, following an initial interval of pain relief. There were no significant differences between patients with different grades of pain relief with respect to central doses. The mean time to the onset of pain relief was 3.6 weeks. The time to the onset of complete pain relief was significantly shorter than that for partial pain relief. Forty-nine patients reported mild-to-moderate facial numbness and one patient experienced paroxysmal temporalis muscle spasms two weeks after the treatment. GKRS treatment for medically refractory idiopathic TN with two isocenters resulted in an initial pain improvement in 95.6% of patients. The early response to the treatment might suggest a good outcome but, given the high incidence of nerve deficits, GKRS for TN with two isocenters is not recommended as a routine treatment protocol.