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Gamma Knife® Radiosurgery

Trigeminal Neuralgia Bibliography
2008 - September, 2016

TRIGEMINAL NEURALGIA

Includes Gamma Knife-focused abstracts posted to PubMed during 2008 to September, 2016.

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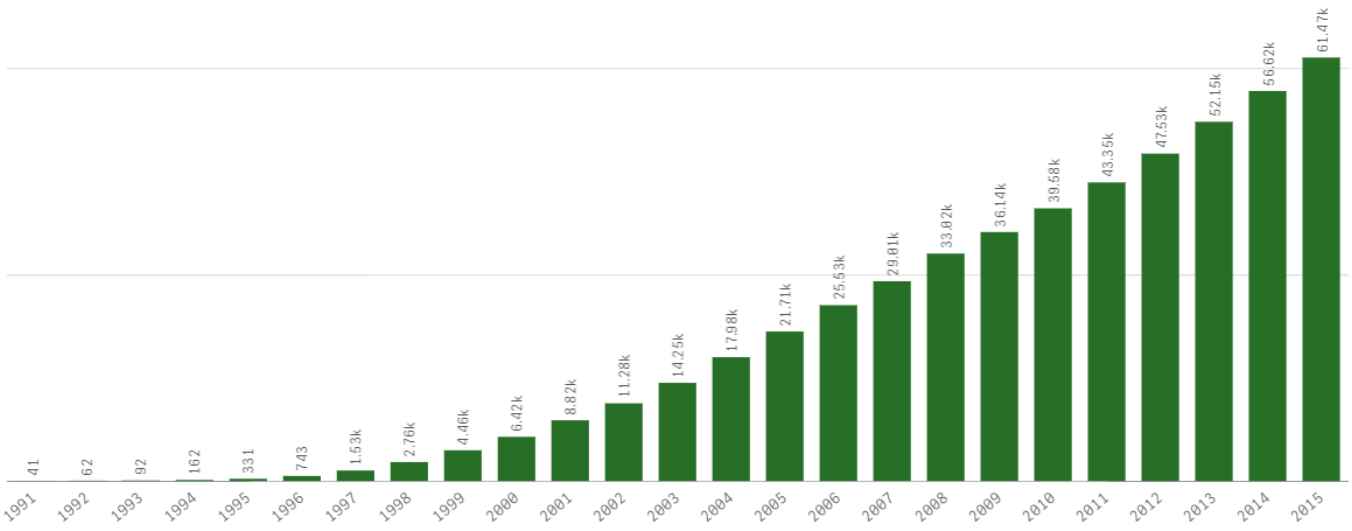

Trigeminal Neuralgia, cumulative patients treated with Leksell Gamma Knife® worldwide
1991 reflects cumulative numbers. 68-100% centers reporting

Dose Considerations

International Journal of Radiation Oncology, Biology, Physics.2016;96(2s):E503-e504.Epub 2016/09/28
Effects of Machine and Collimator Dose Rates on Pain Control and Facial Numbness in Stereotactic Radiosurgery for Trigeminal Neuralgia
Chaung, K. V., Kotecha, R., Modugula, S., Barnett, G. H., Murphy, E. S., Reddy, C. A., Suh, J. H., Neyman, G., Machado, A., Nagel, S. and Chao, S. T., Case Western Reserve University School of Medicine, Cleveland, OH.
Cleveland Clinic, Cleveland, OH.
Department of Radiation Oncology, Cleveland Clinic, Cleveland, OH.

International Journal of Radiation Oncology, Biology, Physics.2016;96(2s):E403-e404.Epub 2016/09/28
The Impact of Dose Escalation Upon Cost Reduction Following Stereotactic Radiosurgery for Trigeminal Neuralgia
Miller, J. A., Kotecha, R., Barnett, G. H., Murphy, E. S., Reddy, C. A., Suh, J. H., Neyman, G., Machado, A., Nagel, S., Modugula, S. and Chao, S. T., Cleveland Clinic Lerner College of Medicine of Case Western Reserve University, Cleveland, OH.
Cleveland Clinic, Cleveland, OH.
Department of Radiation Oncology, Cleveland Clinic, Cleveland, OH.

J Appl Clin Med Phys.2016;17(4):5547.Epub 2016/07/28
Two-year experience with the commercial Gamma Knife Check software
Xu, A. Y., Bhatnagar, J., Bednarz, G., Novotny, J., Jr., Flickinger, J., Lunsford, L. D. and Huq, M. S., University of Pittsburgh Cancer Institute. andyxu55@gmail.com.
The Gamma Knife Check software is an FDA approved second check system for dose calculations in Gamma Knife radiosurgery. The purpose of this study was to evaluate the accuracy and the stability of the commercial software package as a tool for independent dose verification. The Gamma Knife Check software version 8.4 was commissioned for a Leksell Gamma Knife Perfexion and a 4C unit at the University of Pittsburgh Medical Center in May 2012. Independent dose verifications were performed using this software for 319 radiosurgery cases on the Perfexion and 283 radiosurgery cases on the 4C units. The cases on each machine were divided into groups according to their diagnoses, and an averaged absolute percent dose difference for each group was calculated. The percentage dose difference for each treatment target was obtained as the relative difference between the Gamma Knife Check dose and the dose from the tissue maximum ratio algorithm (TMR 10) from the GammaPlan software version 10 at the reference point. For treatment plans with imaging skull definition, results obtained from the Gamma Knife Check software using the measurement-based skull definition method are used for comparison. The collected dose difference data were also analyzed in terms of the distance from the treatment target to the skull, the number of treatment shots used for the target, and the gamma angles of the treatment shots. The averaged percent dose differences between the Gamma Knife Check software and the GammaPlan treatment planning system are 0.3%, 0.89%, 1.24%, 1.09%, 0.83%, 0.55%, 0.33%, and 1.49% for the trigeminal neuralgia, acoustic neuroma, arteriovenous malformation (AVM), meningioma, pituitary adenoma, glioma, functional disorders, and metastasis cases on the Perfexion unit. The corresponding averaged percent dose differences for the 4C unit are 0.33%, 1.2%, 2.78% 1.99%, 1.4%, 1.92%, 0.62%, and 1.51%, respectively. The dose difference is, in general, larger for treatment targets in the peripheral regions of the skull owing to the difference in the numerical methods used for skull shape simulation in the GammaPlan and the Gamma Knife Check software. Larger than 5% dose differences were observed on both machines for certain targets close to patient skull surface and for certain targets in the lower half of the brain on the Perfexion, especially when shots with 70 and/or 110 gamma angles are used. Out of the 1065 treatment targets studied, a 5% cutoff criterion cannot always be met for the dose differences between the studied versions of the Gamma Knife Check software and the planning system for 40 treatment targets.

International Journal of Radiation Oncology, Biology, Physics.2016;96(1):142-8.Epub 2016/06/22
Trigeminal Neuralgia Treated With Stereotactic Radiosurgery: The Effect of Dose Escalation on Pain Control and Treatment Outcomes

Kotecha, R., Kotecha, R., Modugula, S., Murphy, E. S., Jones, M., Kotecha, R., Reddy, C. A., Suh, J. H., Barnett, G. H., Neyman, G., Machado, A., Nagel, S. and Chao, S. T., Department of Radiation Oncology, Taussig Cancer Institute, Cleveland Clinic, Cleveland, Ohio.
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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.

Neurol India.2014;62(4):400-5. Epub 2014/09/23

Effect of radiation dose on the outcomes of gamma knife treatment for trigeminal neuralgia: A multi-factor analysis

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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.

Journal of Neurosurgery.2013;Epub 2013/04/23

Long-term outcome of high-dose Gamma Knife surgery in treatment of trigeminal neuralgia

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Object 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.

Journal of Neurosurgery.2012;117 Suppl(189-96. Epub 2012/12/12

Dose-volume effects on brainstem dose tolerance in radiosurgery

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Object Dose-volume data concerning the brainstem in stereotactic radiosurgery (SRS) for trigeminal neuralgia (TN) were analyzed in relation to associated complications. The authors present their set of data and compare it with currently cited information on brainstem dose tolerance associated with conventional fractionated radiation therapy and hypofractionated radiation treatment of other diseases. Methods Stereotactic radiosurgery for TN delivers a much higher radiation dose to the brainstem in a single fraction than doses delivered by any other procedures. A literature survey of articles on radiosurgery for TN revealed no incidences of severe toxicity, unlike other high-dose procedures involving the brainstem. Published data on brainstem dose tolerance were investigated and compared with dose-volume data in TN radiosurgery. The authors also performed a biological modeling study of dose-volume data involving the brainstem in cases of TN treated with the Gamma Knife, CyberKnife, and linear accelerator-based systems. Results The brainstem may receive a maximum dose as high as 45 Gy during radiosurgery for TN. The major complication after TN radiosurgery is mild to moderate facial numbness, and few other severe toxic responses to radiation are observed. The biologically effective dose of 45 Gy in a single fraction is much higher than any brainstem dose tolerance currently cited in conventional fractionation or in single or hypofractionated radiation treatments. However, in TN radiosurgery, the dose falloff is so steep and the

delivery so accurate that brainstem volumes of 0.1-0.5 cm(3) or larger receive lower planned and delivered doses than those in other radiation-related procedures. Current models are suggestive, but an extensive analysis of detailed dose-volume clinical data is needed. Conclusions Patients whose TN is treated with radiosurgery are a valuable population in which to demonstrate the dose-volume effects of an extreme hypofractionated radiation treatment on the brainstem. The result of TN radiosurgery suggests that a very small volume of the brainstem can tolerate a drastically high dose without suffering a severe clinical injury. The authors believe that the steep dose gradient in TN radiosurgery plays a key role in the low toxicity experienced by the brainstem.

J Clin Neurosci.2012;19(1):71-4. Epub 2011/12/14

Clinical outcomes of 114 patients who underwent Gamma-knife radiosurgery for medically refractory idiopathic trigeminal neuralgia

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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 80-90Gy 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 29.6months. 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 12.7months, 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 3.6weeks. 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.

Journal of Neurosurgery.2010;113 Suppl(199-206. Epub 2011/01/12

A dosimetric comparison between Gamma Knife and CyberKnife treatment plans for trigeminal neuralgia

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OBJECT: The Leksell Gamma Knife and the Accuray CyberKnife systems have been used in the radio surgical treatment of trigeminal neuralgia. The 2 techniques use different delivery methods and different treatment parameters. In the past, CyberKnife treatments have been associated with an increased incidence of treatment-related complications, such as facial numbness. The goal of this study was to develop a method for planning a CyberKnife treatment for trigeminal neuralgia that would reproduce the dosimetric characteristics of a Gamma Knife plan. A comparison between Gamma Knife and CyberKnife treatment plans obtained with this method is presented. METHODS: Five patients treated using the Gamma Knife Perfexion Unit were selected for this study. All patients underwent CT cisternography to accurately identify the position of the trigeminal nerve. The Gamma Knife plans used either one 4-mm-diameter collimator or two coincident 4-mm collimators (one open and one with sector blocking) placed at identical isocenter coordinates. A maximum local dose of 80 Gy was prescribed. Critical structures and representative isodose lines were outlined in GammaPlan and exported to the CyberKnife treatment planning platform. CyberKnife treatments were developed using the 5-mm-diameter cone and the trigeminal node set, which provides an effective collimation diameter of 4 mm at the isocenter. The 60-Gy isodose volume imported from GammaPlan was used as the target in the CyberKnife plans. The CyberKnife treatments were optimized to achieve target dose and critical structure sparing similar to the Gamma Knife plans. Isocentric and

nonisocentric delivery techniques were investigated. Treatment plans were compared in terms of dosimetric characteristics, delivery, and planning efficiency. RESULTS: CyberKnife treatments using the 5-mm cone and the trigeminal node set can closely reproduce the dose distribution of Gamma Knife plans. CyberKnife isocentric and nonisocentric plans provide comparable results. The average length of the trigeminal nerve receiving a dose of 60 Gy was 4.5, 4.5, and 4.4 mm for Gamma Knife, nonisocentric CyberKnife, and isocentric CyberKnife, respectively. However, minimizing the dose to the critical structures was more difficult with the CyberKnife and required the use of tuning structures. In addition, the dose fall off away from the target was steeper in Gamma Knife plans, probably due to the larger number of beams (192 beams for perfexion vs ~ 100 beams for cyberknife). While the treatment time with the cyberknife is generally shorter, the planning time is significantly longer. CONCLUSIONS: CyberKnife radiosurgical parameters can be optimized to mimic the dose distribution of Gamma Knife plans. However, Gamma Knife plans result in superior sparing of critical structures (brainstem, temporal lobe,and cranial nerves VII and VIII) and in steeper dose fall off away from the target. The clinical significance of these effects is unknown.

Journal of Neurosurgery.2010;113 Suppl(168-71. Epub 2010/12/09

Does the Gamma Knife dose rate affect outcomes in radiosurgery for trigeminal neuralgia?

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OBJECT: The object of this study was to determine whether the radiation dose rate affects clinical outcomes in patients who undergo stereotactic Gamma Knife surgery (GKS) to manage typical trigeminal neuralgia (TN). METHODS: The authors retrospectively studied pain relief in 165 patients with medically intractable TN, who underwent 80-Gy GKS using a single 4-mm collimator between 1994 and 2005. No patient had received prior radiation treatment. The measured relative helmet output factor of the Gamma Knife was 0.8 throughout this interval, and the dose rate varied from 1.21 Gy/minute to 3.74 Gy/minute (median 2.06 Gy/minute). Irradiation time varied from 26.73 to 95.11 minutes. The authors divided patients into a low-dose-rate (LDR) group, in which the dose rate varied from 1.21 to 2.05 Gy/minute, and a high-dose-rate (HDR) group, in which the dose rate varied from 2.06 to 3.74 Gy/minute. Post-GKS, the patients' pain control was determined using the Barrow Neurological Institute (BNI) pain scale. There was no statistically significant difference between groups with respect to history of prior microvascular decompression ($p = 0.410$) or peripheral neuroablative procedures ($p = 0.583$). The length of symptoms in patients varied from 3 to 414 months with a median of 84 months ($p = 0.698$). Median follow-up was 26 months with a maximum of 139 months. RESULTS: Initial pain relief was obtained in 71% of patients in the LDR group and 78% in the HDR group ($p = 0.547$). Patients who initially obtained improved pain relief (BNI Scores I-IIIa) after GKS maintained pain control for median durations of 52 months (LDR group) and 54 months (HDR group) ($p = 0.403$). New or increased facial sensory dysfunction was found in 14.5% of patients in the LDR group and in 19.3% of patients in the HDR group ($p = 0.479$). CONCLUSIONS: The authors found that the GKS dose rate did not affect pain control or morbidity within the range of 1.21-3.74 Gy/minute. Cobalt 60 source decay did not affect outcomes of GKS for TN pain management, even for dose rates approximating a 2-half-life decay of the isotope.

Stereotactic and Functional Neurosurgery.2010;88(3):169-76. Epub 2010/05/01

Is it effective to raise the irradiation dose from 80 to 85 Gy in gamma knife radiosurgery for trigeminal neuralgia?

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OBJECTIVE: In order to assess the effect of raising gamma knife radiosurgery (GKS) doses from 80 to 85 Gy for the treatment of trigeminal neuralgia (TN), the authors analyzed the outcomes of GKS in each group. PATIENTS AND METHODS: The authors retrospectively collected follow-up data of 104 GKS procedures conducted for TN. Doses of 80 and 85 Gy were prescribed for 60 and 44 patients, respectively. The target was 2-4 mm anterior to the junction of the trigeminal nerve and pons. Outcomes were quantified based on facial pain levels and classified using the Barrow Neurological Institute scale. RESULTS: Actuarial rates of a favorable pain control outcome at 1 and 3 years after GKS were 75.0 and 61.2% for 80 Gy and 65.9 and 60.3% for 85 Gy. Post-GKS facial sensory loss developed in 20.6%. There was no statistically significant difference in pain control rate between the two groups. Time to maximal pain relief was shorter in the 85-

Gy group. Protracted morbidity before GKS was a favorable prognostic factor of pain control in a multivariate analysis. CONCLUSION: According to our finding that 85 Gy brought more rapid clinical improvement without causing more complications, 85 Gy seems to be preferable to 80 Gy, but prospective randomized trials are mandatory to get a more definite conclusion on the optimal dose for GKS of TN.

Idiopathic

Neurologia.2014;Epub 2014/08/31

Effectiveness of gamma knife treatment in patients affected by idiopathic recurrent trigeminal neuralgia

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INTRODUCTION: Gamma Knife Surgery (GNS) is one of the many techniques used to treat the idiopathic form of trigeminal neuralgia (TN). The aim of this review is to analyse the effectiveness of treatment with GNS in patients affected by recurrent TN. DEVELOPMENT: a literature search conducted using MEDLINE, CINAHL, and Scopus in January of 2013 yielded 125 results. After applying the inclusion and exclusion criteria, we selected16 articles evaluating the effectiveness of GNS for reducing symptoms in patients with recurrent TN. Assessment criteria were degree of pain, time to pain relief, pain maintenance, and disease recurrence after the procedure. CONCLUSIONS: GNS is considered a non-invasive, safe, and effective treatment for patients with idiopathic TN refractory to medication and surgery. It is currently considered the most advanced means of treating this disease.

Clinical Neurology and Neurosurgery.2011;113(6):447-52. Epub 2011/02/19

Gamma knife radiosurgery for idiopathic trigeminal neuralgia as primary vs. secondary treatment option

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OBJECTIVE: To enable physicians to remain informed of secondary GKR after multiple surgical choices. This study compares gamma knife radiosurgery (GKR) as a first and a second treatment for the management of medically refractory idiopathic trigeminal neuralgia (TN). METHODS: Between May 1998 and May 2008, a total of 86 patients with idiopathic TN underwent GKR, with 62 patients receiving the treatment as a first therapy (primary GKR group) and 24 patients receiving the treatment as a second procedure (secondary GKR group). The median follow-up time was 76.4 months (range 12-161 months). The mean prescription marginal dose delivered to the involved trigeminal nerve root entry zone was 82.4+/-6.25Gy for the primary GKR group, and 81.0+/-4.89Gy for the secondary GKR group. In the secondary group, eleven patients underwent percutaneous radiofrequency rhizotomy (PRFR), seven underwent microvascular decompression (MVD), three underwent percutaneous glycerol rhizotomy and another three underwent GKR as their first treatment. We excluded a typical, multiple sclerosis or secondary trigeminal neuralgia. RESULTS: No significant differences in radiation dose, time to initial response, recurrence or pain relief were observed between the use of GKR as a primary and a secondary procedure for idiopathic TN. The occurrence of new onset after GKR were the same for the two groups, but overall facial sensory changes was higher in the secondary GKR group. CONCLUSION: For pain control, GKR can be offered both as a primary and as a secondary procedure, but shows higher overall facial sensory changes in secondary GKR group. The results of our study enable physicians to remain informed of secondary GKR after multiple surgical choices. GKR would be an alternative treatment modality after other surgical treatments including GKR, MVD, PRFR and Glycerol.

World Neurosurg.2010;73(5):523-8. Epub 2010/10/06

Surgical management of trigeminal neuralgia patients with recurrent or persistent pain despite three or more prior operations

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OBJECTIVE: To compare facial pain outcomes from different surgical techniques for patients with idiopathic trigeminal neuralgia (TN) who continue to have persistent or recurrent TN despite multiple operations.

METHODS: Review of a prospective surgical database identified 62 TN patients with ongoing facial pain despite having undergone three or more prior operations (mean = 3.4) from July 1999 to March 2008. The mean patient age was 66.5 years and the mean pain duration was 11.8 years. Twenty-six patients (42%) underwent 33 additional procedures during the follow-up period. In total, 95 operations were performed: posterior fossa exploration (PFE n = 37, 39%), stereotactic radiosurgery (n = 31, 33%), glycerol rhizotomy (n = 18, 19%), and balloon compression (n = 9, 10%). Follow-up (median = 35 months range = 1 day to 103 months) was censored at time of subsequent surgery, last patient contact, or death. RESULTS: Complete pain relief after surgery (no pain, no medications) was 66% at 1 year and 50% at 3 years. Patients having PFE had better facial pain outcomes (70% complete relief at 3 years) compared to other procedures (36% at 3 years) (hazard ratio = 2.6, 95% CI = 1.3-5.1, P < .01). No difference was noted between radiosurgery and the percutaneous techniques. Additional surgery was performed in 8 patients after PFE (22%) compared to 25 patients (48%) after radiosurgery (n = 16), glycerol rhizotomy (n = 7), or balloon compression (n = 2 P = .02). CONCLUSIONS: Although no procedure is best for all patients, PFE gives the operating surgeon the option of performing either a nondestructive (microvascular decompression) or destructive (partial sensory rhizotomy) procedure and is associated with better facial pain outcomes for this difficult patient group.

Journal of Neurosurgery.2010;112(4):758-65. Epub 2009/09/15

Gamma Knife stereotactic radiosurgery for idiopathic trigeminal neuralgia

Kondziolka, D., Zorro, O., Lobato-Polo, J., Kano, H., Flannery, T. J., Flickinger, J. C. and Lunsford, L. D.,Department of Neurological Surgery, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania 15213, USA. kondziolkads@upmc.edu

OBJECT: Trigeminal neuralgia pain causes severe disability. Stereotactic radiosurgery is the least invasive surgical option for patients with trigeminal neuralgia. Since different medical and surgical options have different rates of pain relief and morbidity, it is important to evaluate longer-term outcomes. METHODS: The authors retrospectively reviewed outcomes in 503 medically refractory patients with trigeminal neuralgia who underwent Gamma Knife surgery (GKS). The median patient age was 72 years (range 26-95 years). Prior surgery had failed in 205 patients (43%). The GKS typically was performed using MR imaging guidance, a single 4-mm isocenter, and a maximum dose of 80 Gy. RESULTS: Patients were evaluated for up to 16 years after GKS 107 patients had > 5 years of follow-up. Eighty-nine percent of patients achieved initial pain relief that was adequate or better, with or without medications (Barrow Neurological Institute [BNI] Scores I-IIIb). Significant pain relief (BNI Scores I-IIIa) was achieved in 73% at 1 year, 65% at 2 years, and 41% at 5 years. Including Score IIIb (pain adequately controlled with medication), a BNI score of I-IIIb was found in 80% at 1 year, 71% at 3 years, 46% at 5 years, and 30% at 10 years. A faster initial pain response including adequate and some pain relief was seen in patients with trigeminal neuralgia without additional symptoms, patients without prior surgery, and patients with a pain duration of < or = 3 years. One hundred ninety-three (43%) of 450 patients who achieved initial pain relief reported some recurrent pain 3-144 months after initial relief (median 50 months). Factors associated with earlier pain recurrence that failed to maintain adequate or some pain relief were trigeminal neuralgia with additional symptoms and > or = 3 prior failed surgical procedures. Fifty-three patients (10.5%) developed new or increased subjective facial paresthesias or numbness and 1 developed deafferentation pain these symptoms resolved in 17 patients. Those who developed sensory loss had better long-term pain control (78% at 5 years). CONCLUSIONS: Gamma Knife surgery proved to be safe and effective in the treatment of medically refractory trigeminal neuralgia and is of value for initial or recurrent pain management. Despite the goal of minimizing sensory loss with this procedure, some sensory loss may improve long-term outcomes. Pain relapse is amenable to additional GKS or another procedure.

Imaging

Neurosurgery.2016;63 Suppl 1(177.Epub 2016/07/12

195 How Well Do Neuroradiologists Predict the Side of Trigeminal Neuralgia?

Wolf, A. M., Aguiar-Littig, I., Fatterpekar, G. and Kondziolka, D.,

INTRODUCTION: With improving MRI techniques, physicians can better visualize neurovascular compression (NVC) of the trigeminal nerve, as well as proximal and distal nerve atrophy, nerve distortion, and demyelinating plaques. This study aimed to determine the interrater reliability of these different anatomical variables, as well as the accuracy in predicting the side of trigeminal neuralgia (TN) for 2 neuroradiologists.
METHODS: High-resolution MRI sequences including T1-Gadolinium and constructive interference in steady state (CISS) sequences were reviewed in 43 patients, with symptomatic TN in 44 nerves, who subsequently underwent Gamma Knife radiosurgery. Thirteen patients had multiple sclerosis (MS)-associated TN. Two neuroradiologists (NR1, NR2), blinded to the side of TN, assessed for the presence or absence of NVC, proximal or distal atrophy, distorted nerve course, as well as predicted the side of TN.
RESULTS: The presence of ipsilateral NVC was reported in 79.5% (NR1) and 70.5% (NR2) of nerves, proximal nerve atrophy in 36.4% (NR1) and 40.9% (NR2), distal nerve atrophy in 20.5% (NR1) and 9.1% (NR2), and nerve distortion in 56.8% (NR1) and 38.6% (NR2). Moderate interrater reliability was seen for the assessment of NVC (kappa = 0.52, P < .001), while there was only fair reliability for proximal and distal nerve atrophy and nerve distortion (kappa = 0.14-0.24, P > .05). MS patients were less likely to have ipsilateral NVC. Sensitivity and specificity of predicting the side of TN was 75.6% and 58.0% for NR1 and 61.4% and 58.2% for NR2, respectively. Interrater reliability on predicting the side of TN was also moderate (kappa = 0.42, P < .001).
CONCLUSION: Despite improving MRI, the accuracy of predicting the side of TN is limited with moderate interrater reliability. Newer MRI techniques assessing the trigeminal nerve pathway are needed to improve diagnostic accuracy and to better understand the underlying etiology of TN.

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Gamma Knife radiosurgery with CT image-based dose calculation
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The Leksell GammaPlan software version 10 introduces a CT image-based segmentation tool for automatic skull definition and a convolution dose calculation algorithm for tissue inhomogeneity correction. The purpose of this work was to evaluate the impact of these new approaches on routine clinical Gamma Knife treatment planning. Sixty-five patients who underwent CT image-guided Gamma Knife radiosurgeries at the University of Pittsburgh Medical Center in recent years were retrospectively investigated. The diagnoses for these cases include trigeminal neuralgia, meningioma, acoustic neuroma, AVM, glioma, and benign and metastatic brain tumors. Dose calculations were performed for each patient with the same dose prescriptions and the same shot arrangements using three different approaches: 1) TMR 10 dose calculation with imaging skull definition; 2) convolution dose calculation with imaging skull definition; 3) TMR 10 dose calculation with conventional measurement-based skull definition. For each treatment matrix, the total treatment time, the target coverage index, the selectivity index, the gradient index, and a set of dose statistics parameters were compared between the three calculations. The dose statistics parameters investigated include the prescription isodose volume, the 12 Gy isodose volume, the minimum, maximum and mean doses on the treatment targets, and the critical structures under consideration. The difference between the convolution and the TMR 10 dose calculations for the 104 treatment matrices were found to vary with the patient anatomy, location of the treatment shots, and the tissue inhomogeneities around the treatment target. An average difference of 8.4% was observed for the total treatment times between the convolution and the TMR algorithms. The maximum differences in the treatment times, the prescription isodose volumes, the 12 Gy isodose volumes, the target coverage indices, the selectivity indices, and the gradient indices from the convolution and the TMR 10 calculations are 14.9%, 16.4%, 11.1%, 16.8, 6.9%, and 11.4%, respectively. The maximum differences in the minimum and the mean target doses between the two calculation algorithms are 8.1% and 4.2% of the corresponding prescription doses. The maximum differences in the maximum and the mean doses for the critical structures between the two calculation algorithms are 1.3 Gy and 0.7 Gy. The results from the two skull definition methods with the TMR 10 algorithm agree either within +/- 2.5% or 0.3 Gy for the dose values, except for a 4.9% difference in the treatment times for a lower cerebellar lesion. The imaging skull definition method does not affect Gamma Knife dose calculation considerably when compared to the conventional measurement-based skull definition method, except in some extreme cases. Large differences were observed between the TMR 10

and the convolution calculation method for the same dose prescription and the same shot arrangements, indicating that the implementation of the convolution algorithm in routine clinical use might be desirable for optimal dose calculation results.

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CT-only planning for Gamma Knife radiosurgery in the treatment of trigeminal neuralgia: Methodology and outcomes from a single institution

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Introduction: Gamma Knife radiosurgery (GKRS) has been established as a safe and effective treatment option for trigeminal neuralgia. Some patients have contraindications to magnetic resonance imaging (MRI), the standard stereotactic imaging used for GKRS treatment planning. Computerized tomography (CT) imaging may be used as an alternative in this scenario. We sought to evaluate the outcomes of our patients treated using this technique. Methods: Between August 2001 and November 2009, 19 patients with trigeminal neuralgia were treated with GKRS using CT-only planning. The course of the trigeminal nerve was determined based upon anatomical landmarks when the nerve was not directly visualized on the treatment-planning CT. Median dose used was 90 Gy (range 85-90 Gy). Follow-up data based on Barrow Neurological Institute (BNI) pain score and toxicity were obtained using electronic medical records and by telephone interview. Results: With median follow-up time of 18 months (range 4-36 months), improvement in quality of life after GKRS was reported in 17 of 19 patients. Freedom from BNI IV-V pain relapse was 82% at 24 months. By 3 months post-GKRS, 50% of patients were able to discontinue medications completely. Three patients reported numbness after GKRS none of these patients described bothersome numbness. Use of contrast did not affect treatment outcome (P = 0.31). Conclusions: Stereotactic CT-only treatment planning of GKRS for the treatment of trigeminal neuralgia is feasible and safe. Further studies are necessary to determine if the long-term durability of pain relief is comparable to that of MRI-based GKRS planning.

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Tractography delineates microstructural changes in the trigeminal nerve after focal radiosurgery for trigeminal neuralgia

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PURPOSE: Focal radiosurgery is a common treatment modality for trigeminal neuralgia (TN), a neuropathic facial pain condition. Assessment of treatment effectiveness is primarily clinical, given the paucity of investigational tools to assess trigeminal nerve changes. Since diffusion tensor imaging (DTI) provides information on white matter microstructure, we explored the feasibility of trigeminal nerve tractography and assessment of DTI parameters to study microstructural changes after treatment. We hypothesized that trigeminal tractography provides more information than 2D-MR imaging, allowing detection of unique, focal changes in the target area after radiosurgery. Changes in specific diffusivities may provide insight into the mechanism of action of radiosurgery on the trigeminal nerve. METHODS AND MATERIALS: Five TN patients (4 females, 1 male, average age 67 years) treated with Gamma Knife radiosurgery, 80 Gy/100% isodose line underwent 3Tesla MR trigeminal nerve tractography before and sequentially up to fourteen months after treatment. Fractional anisotropy (FA), radial (RD) and axial (AD) diffusivities were calculated for the radiosurgical target area defined as the region-of-interest. Areas outside target and the contralateral nerve served as controls. RESULTS: Trigeminal tractography accurately detected the radiosurgical target. Radiosurgery resulted in 47% drop in FA values at the target with no significant change in FA outside the target, demonstrating highly focal changes after treatment. RD but not AD changed markedly, suggesting that radiosurgery primarily affects myelin. Tractography was more sensitive than conventional gadolinium-enhanced post-treatment MR, since FA changes were detected regardless of trigeminal nerve enhancement. In subjects with long term follow-up, recovery of FA/RD correlated with pain recurrence. CONCLUSIONS: DTI parameters accurately detect the effects of focal radiosurgery on the trigeminal nerve, serving as an in vivo imaging tool to study TN. This study is a proof of principle for further assessment of DTI parameters to understand the pathophysiology of TN and treatment effects.

Clinical Neurology and Neurosurgery.2011;113(9):758-61. Epub 2011/09/13

MR-based follow-up of the superior cerebellar artery after radiosurgery for trigeminal neuralgia

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PURPOSE: To study with a non invasive method any potential radiological change on the superior cerebellar artery (SCA) in patients treated radiosurgically for classic trigeminal neuralgia (CTN). MATERIALS AND METHODS: A retrospective measure of maximal dose received by SCA was performed analyzing the treatment planning in 55 consecutive patients treated by Gamma Knife radiosurgery for an CTN, then, a prospective study was designed using high resolution MR, with T2 SPIR, T1 without and with gadolinium enhancement, Proton density, 3D TONE and MIP reconstructions. Inclusion criteria were: patients followed at our institution, follow-up of one year or more, dose received by the SCA of 15 Gy or more and voluntary patient participation in the study. Patients with repeated Gamma Knife radiosurgery for failure or recurrence were excluded. The end points were: SCA occlusion, stenosis or infarction in the territory supplied by SCA. RESULTS: Sixteen patients were studied, with a mean follow-up of 25.2 months (12-42 months). The mean maximal dose received by the SCA was 57.5 Gy. (15-87 Gy). Among these 16 patients studied, neither obstruction of the SCA nor infarction was demonstrated. In one patient a suspicion of asymptomatic SCA stenosis was visualized distant to the irradiation field. CONCLUSIONS: SCA can receive a high dose of irradiation during radiosurgical treatment for CTN. This study does not confirm any vascular damage to the SCA after radiosurgery for CTN.

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Computed tomography-guided gamma knife stereotactic radiosurgery for trigeminal neuralgia

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BACKGROUND: Gamma knife stereotactic radiosurgery (GKSR) is an effective minimally invasive option for the treatment of medically refractory trigeminal neuralgia (TN). Optimal targeting of the retrogasserian trigeminal nerve target requires thin-slice, high-definition stereotactic magnetic resonance imaging (MRI). The purpose of this study was to evaluate management outcomes in TN patients ineligible for MRI and who instead underwent GKSR using computed tomography (CT). METHODS: The authors reviewed their experience with CT-guided GKSR in 21 patients (median age: 75 years) with idiopathic TN. Contraindications to MRI included implanted pacemakers (n = 16), aneurysm clips (n = 2), cochlea implants (n = 1), metallic vascular stents (n = 1) or severe obesity (weight of 163 kg, n = 1). Contrast-enhanced CT at 1- or 1.25-mm intervals was acquired in all patients. One patient also underwent CT cisternography. The median target dose for GKSR was 80 Gy. The median follow-up was 35 months after GKSR. Treatment outcomes were compared to 459 patients who underwent MRI-guided GKSR for TN at our institute in the same time interval. RESULTS: Targeting of the trigeminal nerve guided by CT scan was feasible in all patients. Stereotactic frame titanium pin-related artifacts that interfered with full visualization of the trigeminal nerve were found in one patient who had the ipsilateral posterior pin placed near the inion. After GKSR, 90% of patients achieved initial pain relief that was adequate or better, with or without medication (Barrow Neurological Institute pain scores I-IIIb). Median time to pain relief was 2.6 weeks. Pain relief was maintained in 81% at 1 year, 66% at 2 years, and 46% at 5 years. Eight (42%) of 19 patients who achieved initial pain relief reported some recurrent pain at a median of 18 months after GKSR. Some degree of facial sensory dysfunction occurred in 19% of patients within 24 months of GKSR. These results are comparable to those of patients who had MRI-guided GKSR. CONCLUSIONS: CT-guided GKSR provides a similar rate of pain relief as MRI-guided radiosurgery. The posterior pins should be placed at least 1 cm away from the inion to reduce pin and frame-related artifacts on the targeting CT scan. This study indicates that GKSR using CT targeting is appropriate for patients with medically refractory TN who are unsuitable for MRI.

Stereotactic and Functional Neurosurgery.2010;88(4):239-45. Epub 2010/06/10

Image registration strategy of T(1)-weighted and FIESTA MRI sequences in trigeminal neuralgia gamma knife radiosurgery

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BACKGROUND/AIMS: In Gamma Knife radiosurgery, T(1) MRI is most commonly used and is generally sufficient for targeting the trigeminal nerve. For patients whose trigeminal nerves are unclear on T(1) MRI, FIESTA MRI supplements anatomical structure visualization and may improve trigeminal nerve delineation. The purpose of this study was to develop a registration strategy for T(1) and FIESTA MRIs. METHODS: We conducted a retrospective study on 54 trigeminal neuralgia patients. All patients were scanned with T(1) and FIESTA MRIs. We evaluated 4 methods of registration: automatic image definition, superior-slice definition, middle-slice definition and inferior-slice definition. Target discrepancies were measured by deviations from an intracranial landmark on T(1) and FIESTA MR images. RESULTS: The overall range in registration error was 0.10-5.19 mm using superior-, 0.10-1.56 mm using middle- and 0.14-2.89 mm using inferior-slice definition. Registration error >2 mm was observed in 11% of the patients using superior-, 4% using middle- and 7% using inferior-slice FIESTA MRI definition. CONCLUSIONS: Among patients for whom FIESTA and T(1) MRI are used, registration based on middle-slice definition reduces registration error and improves targeting of the trigeminal nerve.

Journal of Neurosurgery.2010;113(1):53-8. Epub 2009/10/27
Gamma Knife radiosurgery for trigeminal neuralgia: the impact of magnetic resonance imaging-detected vascular impingement of the affected nerve
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OBJECT: Trigeminal neuralgia is believed to be related to vascular compression of the affected nerve. Radiosurgery has been shown to be reasonably effective for treatment of medically refractory trigeminal neuralgia. This study explores the rate of occurrence of MR imaging-demonstrated vascular impingement of the affected nerve and the extent to which vascular impingement affects pain relief in a population of trigeminal neuralgia patients undergoing Gamma Knife radiosurgery (GKRS). METHODS: The authors performed a retrospective analysis of 106 cases involving patients treated for typical trigeminal neuralgia using GKRS. Patients with or without single-vessel impingement on CISS MR imaging sequences and with no previous surgery were included in the study. Pain relief was assessed according to the Barrow Neurological Institute (BNI) pain intensity score at the last follow-up. Degree of impingement, nerve diameter preand post-impingement, isocenter placement, and dose to the point of maximum impingement were evaluated in relation to the improvement of BNI score. RESULTS: The overall median follow-up period was 31 months. Overall, a BNI pain score of 1 was achieved in 59.4% of patients at last follow-up. Vessel impingement was seen in 63 patients (59%). There was no significant difference in pain relief between those with and without vascular impingement following GKRS ($p > 0.05$). In those with vascular impingement on MR imaging, the median fraction of vessel impingement was 0.3 (range 0.04-0.59). The median dose to the site of maximum impingement was 42 Gy (range 2.9-79 Gy). Increased dose ($p = 0.019$) and closer proximity of the isocenter to the site of maximum vessel impingement ($p = 0.012$) correlated in a statistically significant fashion with improved BNI scores in those demonstrating vascular impingement on the GKRS planning MR imaging. CONCLUSIONS: Vascular impingement of the affected nerve was seen in the majority of patients with trigeminal neuralgia. Overall pain relief following GKRS was comparable in those with and without evidence of vascular compression on MR imaging. In subgroup analysis of those with MR imaging evidence of vessel impingement of the affected trigeminal nerve, pain relief correlated with a higher dose to the point of contact between the impinging vessel and the trigeminal nerve. Such a finding may point to vascular changes affording at least some degree of relief following GKRS for trigeminal neuralgia.

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Patterns of neurovascular compression in patients with classic trigeminal neuralgia: A high-resolution MRI-based study
Lorenzoni, J., David, P. and Levivier, M.,Department of Neurosurgery, School of Medicine, Pontificia Universidad Catolica de Chile, Chile.
PURPOSE: To describe the anatomical characteristics and patterns of neurovascular compression in patients suffering classic trigeminal neuralgia (CTN), using high-resolution magnetic resonance imaging (MRI).

MATERIALS AND METHODS: The analysis of the anatomy of the trigeminal nerve, brain stem and the vascular structures related to this nerve was made in 100 consecutive patients treated with a Gamma Knife radiosurgery for CTN between December 1999 and September 2004. MRI studies (T1, T1 enhanced and T2-SPIR) with axial, coronal and sagital simultaneous visualization were dynamically assessed using the software GammaPlan. Three-dimensional reconstructions were also developed in some representative cases. RESULTS: In 93 patients (93%), there were one or several vascular structures in contact, either, with the trigeminal nerve, or close to its origin in the pons. The superior cerebellar artery was involved in 71 cases (76%). Other vessels identified were the antero-inferior cerebellar artery, the basilar artery, the vertebral artery, and some venous structures. Vascular compression was found anywhere along the trigeminal nerve. The mean distance between the nerve compression and the origin of the nerve in the brainstem was 3.76+/-2.9mm (range 0-9.8mm). In 39 patients (42%), the vascular compression was located proximally and in 42 (45%) the compression was located distally. Nerve dislocation or distortion by the vessel was observed in 30 cases (32%). CONCLUSIONS: The findings of this study are similar to those reported in surgical and autopsy series. This non-invasive MRI-based approach could be useful for diagnostic and therapeutic decisions in CTN, and it could help to understand its pathogenesis.

Multiple Sclerosis Associated Trigeminal Neuralgia

J Neurosurg. 2014 Dec;121(6):1508-13. Epub 2014 Sep 26.
Gamma Knife rhizotomy-induced histopathology in multiple sclerosis-related trigeminal neuralgia.
Phillips DB1, Del Bigio MR, Kaufmann AM.
OBJECT:
In this report, the authors describe the pathological changes in the human trigeminal nerve after Gamma Knife radiosurgery.
METHODS:
Three trigeminal nerves of patients with multiple sclerosis (MS)-related trigeminal neuralgia (MSTN) after Gamma Knife radiosurgery and other ablative procedures were examined by a neuropathologist. These cases were compared with 3 patients with typical TN who underwent partial surgical rhizotomy following recurrent symptoms after gasserian injury procedures, as well as with autopsy specimens from patients with and without MSTN.
RESULTS:
The three irradiated MS-TN specimens exhibited axon loss, demyelination, myelin debris, and fibrosis. Mild lymphocytic infiltrate was present in all 3 samples from MS-TN patients. The nonirradiated trigeminal nerve samples were generally well myelinated with rare degenerating axons. The microscopic findings in trigeminal nerve autopsy specimens were normal in patients without TN, with MS but not TN, and MS-TN.
CONCLUSIONS:
The inflammation observed in MS-TN specimens collected following Gamma Knife radiosurgery has not previously been described in the literature. These data provide new insight into the changes that occur in trigeminal nerve following stereotactic radiosurgery.

Stereotact Funct Neurosurg.2014;92(4):203-10. Epub 2014/07/12
Multiple sclerosis-related trigeminal neuralgia: a prospective series of 43 patients treated with gamma knife surgery with more than one year of follow-up
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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. (c) 2014 S. Karger AG, Basel.

Stereotact Funct Neurosurg.2014;92(1):53-8. Epub 2013/11/13

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

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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.

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Treatment of Trigeminal Neuralgia Associated with Multiple Sclerosis

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Comparative study of Gamma Knife surgery and percutaneous retrogasserian glycerol rhizotomy for trigeminal neuralgia in patients with multiple sclerosis

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Object Among patients with multiple sclerosis (MS) there is a high incidence of trigeminal neuralgia (TN), and outcomes after treatment seem inferior to those in patients suffering from idiopathic TN. The goal of this study was to evaluate clinical outcomes in patients with MS-related TN after Gamma Knife surgery (GKS) and compare them with those obtained using percutaneous retrogasserian glycerol rhizotomy (PRGR). Methods The authors retrospectively reviewed the charts of 45 patients with MS-related TN. The first procedure undertaken was GKS in 27 patients and PRGR in 18 patients. Pain had been present for a median of 60 months (range 12-276 months) in patients who underwent GKS and 48 months (range 12-240 months) in patients who underwent PRGR. The following outcome measures were assessed in both groups of patients: pain relief (using the Barrow Neurological Institute [BNI] Pain Scale), procedure-related morbidity, time to pain relief and recurrence, and subsequent procedures that were performed. Results The median duration of follow-up was 39 months (range 13-69 months) in the GKS group and 38 months (range 2-75 months) in the PRGR group. Reasonable pain control (BNI Pain Scale Scores I-IIIb) was noted in 22 patients (81.5%) who underwent GKS and in 18 patients (100%) who underwent PRGR. For patients who underwent GKS, the median time to pain relief was 6 months for those who underwent PRGR, pain relief was immediate. In the GKS group12 patients required subsequent procedures (3 patients for absence of response and 9 patients for pain recurrence), whereas in the PRGR group 6 patients required subsequent procedures (all for pain recurrence). As of the last follow-up, complete or reasonable pain control was finally

achieved in 23 patients (85.2%) in the GKS group and in 16 patients (88.9%) in the PRGR group. The morbidity rate was 22.2% in the GKS group (all due to sensory loss and paresthesia) and 66.7% in the PRGR group (mostly hypalgesia, with 2 patients having corneal reflex loss and 1 patient suffering from meningitis). Conclusions Both GKS and PRGR are satisfactory strategies for treating MS-related TN. Gamma Knife surgery has a lower rate of sensory and overall morbidity than PRGR, but requires a delay before pain relief occurs. The authors propose that patients with extreme pain in need of fast relief should undergo PRGR. For other patients, both management strategies can lead to satisfactory pain relief, and the choice should be made based on patient preference and expectations.

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160 Surgical outcomes of trigeminal neuralgia in patients with multiple sclerosis

Mohammadi, A. M., Lee, J. H. and Barnett, G. H.,INTRODUCTION: : Trigeminal neuralgia (TN) is relatively frequent in Multiple Sclerosis (MS) patients and procedural treatments are less effective than when used for classical TN. Outcomes from direct comparisons between different procedures for MS-related TN is lacking. In this study, initial pain-free rates (IPFR), duration of pain-free intervals (PFI) and associated prognostic factors were evaluated. METHODS: : This was a retrospective IRB-approved analysis performed on 96 MS-related TN patients who underwent 277 procedures (1-11/patient) in our institution (1996-2011). Patient, disease and treatments characteristics, as well as outcomes were statistically evaluated. RESULTS: : Most patients were female (60%). Median age at diagnosis of MS and TN were 39 and 50 years, respectively. 44 patients (47%) had brainstem plaques on MRI. At treatment, most of the patients had secondary-progressive (33%) or relapsing-remitting (31%) MS and 50% were receiving MS treatment. Overall, 89 patients (32%) underwent Glycerol Injection (GI), 82 (30%) Balloon Compression (BC), 54 (19%) Stereotactic Radiosurgery (SRS) and 52 (19%) other procedures. As upfront treatments GI (41%) and SRS (24%) were most common. IPFR was 72%, BC had the best (77%) and SRS the worst (56%) results. Overall failure-rate after 277 procedures was 77% with no significant difference between treatment modalities. Median PFI was 9 months. BC had the best (12 months) and SRS the worst (5 month) median PFI. Complications occurred after 94 procedures (34%), 77 of them (28%) were temporary or minor. SRS had the lowest complication rate (10%). In multivariable analysis, treatment type had significant effect on IPFR with better results for BC and GI. CONCLUSION: : The results of treatment in MS-related TNs are suboptimal. In our large series, treatment failure occurred frequently (77%) independent of procedure type. The best IPFRs were achieved after BC and GI. SRS had the lowest complication rate (10%) but also the lowest IPFR (56%) and the shortest PFI (5 months).

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Gamma knife radiosurgery for multiple sclerosis-related trigeminal neuralgia

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BACKGROUND: Surgical options for multiple sclerosis (MS) related to trigeminal neuralgia (TN), a severe and disabling pain disorder, include percutaneous rhizotomy, stereotactic radiosurgery, or microsurgical nerve section. Our goal was to evaluate clinical outcomes after gamma knife radiosurgery (GKRS) in patients with MS with TN. METHODS: We evaluated clinical outcomes in 37 patients with TN managed over a 12-year period. The maximum TN target dose varied between 70 and 90 Gy. Seventy-eight percent of patients had failed prior surgery. In 9, GKRS was the first procedure. Median follow-up was 56.7 months (range, 6-174). Pain relief was assessed in each patient by physicians who did not participate in the surgery. RESULTS: Eventual complete pain relief (BNI grade I) after GKRS and reasonable pain control (BNI grade I-IIIb) after GKRS were noted in 23 patients (62.1%) and 36 patients (97.3%) at some point in their course. Reasonable pain control (BNI grade I-IIIb) after GKRS was maintained in 82.6%, 73.9%, and 54.0% of patients after 1, 3, and 5 years. Fourteen patients (37.8%) underwent a second or a subsequent procedure for residual or recurrent pain. Eight patients underwent a second GKRS, 5 underwent percutaneous glycerol rhizotomy, and 1 underwent balloon microcompression. The complication rate after GKRS was 5.4% (new onset of nondisabling paresthesias). No patient developed dysesthesias. CONCLUSIONS: Gamma knife radiosurgery is the most minimally invasive surgical technique for multiple sclerosis-related trigeminal neuralgia and has low morbidity. For this reason, gamma knife radiosurgery proved to be a satisfactory management strategy for multiple sclerosis-related trigeminal neuralgia.

Prognostic Factors

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The Role of Internationally Standardized Radiosurgery Treatment Parameters in Predicting Long-Term Trigeminal Neuralgia Outcomes
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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
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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.

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Stereotactic Radiosurgery Treatment of Trigeminal Neuralgia: Clinical Outcomes and Prognostic Factors
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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.

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Early radiosurgery provides superior pain relief for trigeminal neuralgia patients

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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.

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Predictive Nomogram for the Durability of Pain Relief From Gamma Knife Radiation Surgery in the Treatment of Trigeminal Neuralgia

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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.

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Clinical outcomes of gamma knife radiosurgery in the treatment of patients with trigeminal neuralgia

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Since its introduction by Leksell, Gamma Knife radiosurgery (GKRS) has become increasingly popular as a management approach for patients diagnosed with trigeminal neuralgia (TN). For this reason, we performed a modern review of the literature analyzing the efficacy of GKRS in the treatment of patients who suffer from TN. For patients with medically refractory forms of the condition, GKRS has proven to be an effective initial and repeat treatment option. Cumulative research suggests that patients treated a single time with GKRS exhibit similar levels of facial pain control when compared to patients treated multiple times with GKRS. However, patients treated on multiple occasions with GKRS are more likely to experience facial numbness and other facial sensory changes when compared to patients treated once with GKRS. Although numerous articles have reported MVD to be superior to GKRS in achieving facial pain relief, the findings of these comparison studies are weakened by the vast differences in patient age and comorbidities between the two studied groups and cannot be considered conclusive. Questions remain regarding optimal GKRS dosing and targeting strategies, which warrants further investigation into this controversial matter.

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Predictive Variables for the Successful Treatment of Trigeminal Neuralgia with Gamma Knife Radiosurgery

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BACKGROUND:: Gamma Knife Radiosurgery (GKRS) has been reported as an effective modality to treat trigeminal neuralgia (TN). 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 TN were performed at our institution. Evaluable follow-up data were obtained for 448 patients. Median follow-up time was 20.9 months (3-86 months). The mean maximum prescribed dose was 88 Gy (80-97 Gy). Dosimetric variables recorded included dorsal root entry zone dose (DREZ), pons maximum dose, dose to the petrous dural ridge, and the cisternal nerve length. RESULTS:: 86% of patients achieved BNI I-III pain scores by 3 months after GKRS, with 43% of patients achieving a BNI I pain score. 26% of patients reported post-treatment 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 post-surgical numbness (OR 2.76, p=0.006) was the dominant factor predictive of efficacy. Longer cisternal nerve length (OR 0.85, p=0.005), prior radiofrequency ablation (OR 0.35, p=0.028), and diabetes (OR 0.38, p=0.013) predicted decreased efficacy. The mean dose delivered to the DREZ in patients who developed facial numbness (57.6 Gy) was more than the mean dose (47.3 Gy) to patients who did not develop numbness (p=0.02). CONCLUSION:: The development of post-GKRS facial numbness is a dominant factor that predicts for efficacy of GKRS. History of diabetes or previous RFA may portend worsened outcome.

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Stereotactic radiosurgery for trigeminal neuralgia: outcomes and complications

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Abstract 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.

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Stereotactic radiosurgery of essential trigeminal neuralgia using Leksell Gamma Knife model C with automatic positioning system: technical nuances and evaluation of outcome in 130 patients with at least 2 years follow-up after treatment

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The objective of the present study was the evaluation of outcome in 130 patients with essential trigeminal neuralgia, who were treated using Leksell Gamma Knife model C with automatic positioning system and followed at least 24 months thereafter. Radiosurgery was guided by fused thin-sliced magnetic resonance (MR) and "bone window" computed tomographic (CT) images. In all cases, retrogasserian part of the trigeminal nerve at the level of trigeminal incisura was selected as a target, and one 4-mm collimator was used for delivery of the maximum irradiation dose of 90 Gy. The coordinates of the isocenter were adjusted for positioning of the nerve in the center of 80% isodose area, and were corrected in each individual case with regard to presence of distortion artifacts on MR images. Initial relief of the typical paroxysmal facial pain was marked in 127 patients (98%) within a median interval of 3 weeks after treatment. However, in 23 patients the pain re-appeared later on. Overall, at the time of the last follow-up 112 patients (86%) were pain-free, including 86 who remained both pain- and medication-free after initial radiosurgery. In 31 cases (24%), treatment was complicated by facial hypesthesia and/or paresthesia. In conclusion, radiosurgery of essential trigeminal neuralgia results in a high rate of initial pain relief, but pain recurrences and associated complications are not uncommon. The outcome may be influenced by various technical nuances therefore, treatment should be preferably done in specialized clinical centers with sufficient expertise in the management of this disorder.

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A Prospective Analysis of Quality-of-Life Outcomes Following Stereotactic Radiosurgery for Trigeminal Neuralgia
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The Very Long-Term Outcome of Radiosurgery for Classical Trigeminal Neuralgia
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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.

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Quality-of-life outcomes after Gamma Knife surgery for trigeminal neuralgia
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OBJECT: Gamma Knife surgery (GKS) is an important part of the neurosurgical armamentarium for treatment of patients with trigeminal neuralgia (TN) and is regarded as the first-line treatment in patients with TN who have serious medical comorbidities. In this study, the authors investigated the efficacy of GKS on TN in patients with serious medical comorbidities. METHODS: Between May 2004 and September 2007, 52 severely ill patients who also had TN with Barrow Neurological Institute (BNI) facial pain scores of IV or V were entered into this study. The patients' medical records and imaging findings were reviewed by an anesthesiologist and neurosurgeons to determine whether GKS was a reasonable approach to palliate the patient's pain. All patients underwent GKS, in which a maximum dose of 80 Gy was targeted to the trigeminal nerve with or without plugging to keep the dose received by the brainstem at less than 16 Gy. After treatment, every patient had clinical follow-up every 1-3 months and filled out questionnaires designed to assess BNI facial pain and numbness scores, visual analog scale scores, and 36-Item Short Form Health Survey (SF-36) scores every 3 months until the end of the study. Statistical analysis was performed to find favorable prognostic factors related to pain relief and changes in quality of life. RESULTS: The median age of the patients was 71 years, and the male/female ratio was 30:22. The median follow-up period was 54 months (at least 2 years). All patients had a positive initial response to GKS, with BNI facial pain scores at least 1 point less than respective pre-GKS scores. Three patients (5.7%) obtained BNI facial pain Score I. Twenty-three patients (44.2%) experienced pain recurrence at a median follow-up of 33 months. One patient suffered from angina and required time in an intensive care unit another patient had bleeding from a pin wound that required suturing. Alterations in BNI scores were highly correlated to visual analog scale scores (R(2) = 0.978). In both univariate and multivariate analyses, a decreased BNI facial pain score at

different time points was significantly (p < 0.05) related to younger patient age, no previous treatment, evidence of vessel compression on MR imaging, time of first GKS </= 24 months, physical function (SF-36), role limitation due to a physical problem (SF-36), role limitation due to an emotional problem (SF-36), mental health (SF-36), social functioning (SF-36), bodily pain (SF-36), and general health (SF-36), but was not related to vitality (SF-36). Five patients (9.6%) experienced facial numbness at a mean of 13.2 +/- 3.1 months after GKS (4 patients with BNI facial numbness Score II and 1 with BNI facial numbness Score III). Post-GKS MR imaging changes, including focal contrast enhancement or T2-weighted signal alterations, were identified in 3 patients (5.7%). CONCLUSIONS: Gamma Knife surgery produced significant pain relief in severely ill patients who had TN without causing appreciable morbidity. The effect of reduced pain significantly paralleled an improvement in SF-36 quality-of-life indices.

Clinical Neurology and Neurosurgery.2009;111(2):174-8. Epub 2008/11/11

Gamma knife radiosurgery in patients with trigeminal neuralgia: quality of life, outcomes, and complications

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OBJECTIVE: to assess the outcomes, complications, and alteration in quality of life (QOL) in patients with trigeminal neuralgia who were treated with gamma knife radiosurgery (GKRS) in a prospective observational study.

METHODS AND MATERIALS: between June 2006 and May 2007, 30 patients of medically refractory trigeminal neuralgia were included in our study and treated with GKRS at Iran Gamma Knife Centre (IGKC), Tehran, Iran. A median maximum prescription dose of 90Gy (range: 85-95) was delivered to the trigeminal nerve root entry zone. All involved patients completed QOL questionnaire SF-36 before GKRS and 9-12 months after it. All data from questionnaires and the basic characteristics of the radiosurgery and patients were analyzed using descriptive statistics, paired T-test, Fisher's exact test, bivariate correlation, and independent sample T-test.

RESULTS: In all SF-36 domains significant changes before and after GKRS were noticed except physical function (PF) and role limitation due to physical problem (RP). Bodily pain after GKRS was 100 (excellent result) in 12 (40%) of study participants, 90-99 (good result) in 3 (10%), 50-89 (fair result) in 10 (33%) and less than 50 (poor result) in five (17%). Four cases (13%) faced to facial numbness. No other complications were noticed.

CONCLUSIONS: GKRS positively changes the several aspect of QOL especially those related to pain relief and mental health component of QOL. The rate of diminishing pain in our study is comparable with other series. The GKRS complication is limited in both variety and number.

Repeat Trigeminal Neuralgia

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The clinical significance of persistent trigeminal nerve contrast enhancement in patients who undergo repeat radiosurgery

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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.

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Repeat Gamma-Knife Radiosurgery for Refractory or Recurrent Trigeminal Neuralgia with Consideration About the Optimal Second Dose
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OBJECTIVE: To investigate adequate radiation doses for repeat Gamma Knife radiosurgery (GKS) for trigeminal neuralgia in our series and meta-analysis. METHODS: Fourteen patients treated by ipsilateral repeat GKS for trigeminal neuralgia were included. Median age of patients was 65 years (range, 28-78), the median target dose, 140-180). Patients were followed a median of 10.8 months (range, 1-151) after the second gamma-knife surgery. Brainstem dose analysis and vote-counting meta-analysis of 19 studies were performed. RESULTS: After the second gamma-knife radiosurgeries, pain was relieved effectively in 12 patients (86%; Barrow Neurological Institute Pain Intensity Score I-III). Post-gamma-knife radiosurgery trigeminal nerve deficits were mild in 5 patients. No serious anesthesia dolorosa was occurred. The second GKS radiation dose </= 60 Gy was significantly associated with worse pain control outcome ($P = 0.018$ in our series, permutation analysis of variance, and $P = 0.009$ in the meta-analysis, 2-tailed Fisher's exact test). Cumulative dose </= 140-150 Gy was significantly associated with poor pain control outcome ($P = 0.033$ in our series and $P = 0.013$ in the meta-analysis, 2-tailed Fisher's exact test). A cumulative brainstem edge dose >12 Gy tended to be associated with trigeminal nerve deficit ($P = 0.077$). CONCLUSION: Our study suggests that the second GKS dose is a potentially important factor.

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Two-session tumor and retrogasserian trigeminal nerve-targeted gamma knife radiosurgery for secondary trigeminal neuralgia associated with benign tumors
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OBJECTIVE: To investigate gamma knife radiosurgery (GKS) for benign tumor-associated secondary trigeminal neuralgia. METHODS: From 2006 to 2015, 21 patients with secondary trigeminal neuralgia from meningioma were treated using GKS. Their mean age was 56.5 +/- 12.2 years. The 50% isodose was 12.5+/- 1.1 Gy for the first GKS for the meningioma. Retrogasserian targeting of the trigeminal nerve at 90 Gy with a 4-mm collimator was used for the second GKS. RESULTS: The pain duration until GKS was 1.9+/- 1.9 years.

The meningiomas were located in the cisternal space in 13 patients (56.5%) and involved the skull base in 8 patients (43.5%). The mean follow-up duration was 3.7+/-2.7 years. The pain control outcomes were Marseilles pain scale (MPS) scores of I-IV in 15 patients (71%). In six patients (29%), the pain control outcome was a score of V. For these patients, we performed a second GKS targeting the trigeminal nerve and resulting in MPS scores of I-IV. The tumor size did not increase in any patient and decreased >10% in 12 (80%) of the 15 patients who were followed for at least 1 year. Trigeminal nerve visibility may improve after tumor shrinkage. Retrogasserian trigeminal nerve targets may be used even with invisible trigeminal nerves using Meckel's cave as an anatomical marker. CONCLUSIONS: Here we show the reproducible feasibility of a two-session GKS procedure using higher radiation doses: the first to treat the tumor, and the second to treat the trigeminal nerves using retrogasserian targeting.

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Repeat Radiosurgery for Trigeminal Neuralgia

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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.

J Neurosurg.2015;1-6. Epub 2015/03/31

A successful case of multiple stereotactic radiosurgeries for ipsilateral recurrent trigeminal neuralgia

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Trigeminal neuralgia is a common pain syndrome primarily managed medically, although many patients require surgical or radiotherapeutic intervention. Stereotactic radiosurgery has become a preferred method of treatment given its high efficacy rates and relatively favorable toxicity profile. However, many patients have refractory pain even after repeat courses of stereotactic radiosurgery. Historically, 2 courses have been the limit in such patients. The authors present a case of multiply recurrent trigeminal neuralgia treated with a third course of radiosurgery in which the patient had successful pain control and no additional toxicity. Meticulous attention to the therapeutic technique allows the continued application of stereotactic radiosurgery in patients.

J Neurosurg. 2014 Dec;121 Suppl:210-21.

Repeat Gamma Knife surgery for recurrent trigeminal neuralgia: long-term outcomes and systematic review.

Tuleasca C1, Carron R, Resseguier N, Donnet A, Roussel P, Gaudart J, Levivier M, Régis J.

OBJECT:
The purpose of this study was to establish the safety and efficacy of repeat Gamma Knife surgery (GKS) for recurrent trigeminal neuralgia (TN).
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.

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The results of a third Gamma Knife procedure for recurrent trigeminal neuralgia
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OBJECT Gamma Knife radiosurgery (GKRS) is the least invasive treatment option for medically refractory, intractable trigeminal neuralgia (TN) and is especially valuable for treating elderly, infirm patients or those on anticoagulation therapy. The authors reviewed pain outcomes and complications in TN patients who required 3 radiosurgical procedures for recurrent or persistent pain. METHODS A retrospective review of all patients who underwent 3 GKRS procedures for TN at 4 participating centers of the North American Gamma Knife Consortium from 1995 to 2012 was performed. The Barrow Neurological Institute (BNI) pain score was used to evaluate pain outcomes. RESULTS Seventeen patients were identified; 7 were male and 10 were female. The mean age at the time of last GKRS was 79.6 years (range 51.2-95.6 years). The TN was Type I in 16 patients and Type II in 1 patient. No patient suffered from multiple sclerosis. Eight patients (47.1%) reported initial complete pain relief (BNI Score I) following their third GKRS and 8 others (47.1%) experienced at least partial relief (BNI Scores II-IIIb). The average time to initial response was 2.9 months following the third GKRS. Although 3 patients (17.6%) developed new facial sensory dysfunction following primary GKRS and 2 patients (11.8%) experienced new or worsening sensory disturbance following the second GKRS, no patient sustained additional sensory disturbances after the third procedure. At a mean follow-up of 22.9 months following the third GKRS, 6 patients (35.3%) reported continued Score I complete pain relief, while 7 others (41.2%) reported pain improvement (BNI Scores II-IIIb). Four patients (23.5%) suffered recurrent TN following the third procedure at a mean interval of 19.1 months. CONCLUSIONS A third GKRS resulted in pain reduction with a low risk of additional complications in most patients with medically refractory and recurrent, intractable TN. In patients unsuitable for other microsurgical or percutaneous strategies, especially those receiving long-term oral anticoagulation or antiplatelet agents, GKRS repeated for a third time was a satisfactory, low risk option.

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Repeat Gamma Knife Radiosurgery for Trigeminal Neuralgia

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BACKGROUND: Trigeminal neuralgia (TN) often recurs 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 brain stem dose >/= 44 Gy was more likely to be associated with 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.

Case Report Med.2011;2011(258910. Epub 2011/09/10

Feasibility of multiple repeat gamma knife radiosurgeries for trigeminal neuralgia: a case report and review of the literature

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Treatment options for trigeminal neuralgia (TN) must be customized for the individual patient, and physicians must be aware of the medical, surgical, and radiation treatment modalities to prescribe optimal treatment courses for specific patients. The following case illustrates the potential for gamma knife radiosurgery (GKRS) to be repeated multiple times for the purpose of achieving facial pain control in cases of TN that have been refractory to other medical and surgical options, as well as prior GKRS. The patient described failed to achieve pain control with initial GKRS, as well as medical and surgical treatments, but experienced significant pain relief for a period of time with a second GKRS procedure and later underwent a third procedure. Only a small subset of patients have reportedly undergone more than two GKRS for TN thus, further research and long-term clinical followup will be valuable in determining its usefulness in specific clinical situations.

International Journal of Radiation Oncology, Biology, Physics.2011;81(4):1059-65. Epub 2010/10/12

Repeat gamma knife radiosurgery for trigeminal neuralgia

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PURPOSE: Repeat gamma knife stereotactic radiosurgery (GKRS) for recurrent or persistent trigeminal neuralgia induces an additional response but at the expense of an increased incidence of facial numbness. The present series summarized the results of a repeat treatment series at Wake Forest University Baptist Medical Center, including a multivariate analysis of the data to identify the prognostic factors for treatment success and toxicity. METHODS AND MATERIALS: Between January 1999 and December 2007, 37 patients underwent a second GKRS application because of treatment failure after a first GKRS treatment. The mean initial dose in the series was 87.3 Gy (range, 80-90). The mean retreatment dose was 84.4 Gy (range, 60-90). The dosimetric variables recorded included the dorsal root entry zone dose, pons surface dose, and

dose to the distal nerve. RESULTS: Of the 37 patients, 81% achieved a >50% pain relief response to repeat GKRS, and 57% experienced some form of trigeminal dysfunction after repeat GKRS. Two patients (5%) experienced clinically significant toxicity: one with bothersome numbness and one with corneal dryness requiring tarsorraphy. A dorsal root entry zone dose at repeat treatment of >26.6 Gy predicted for treatment success (61% vs. 32%, p = .0716). A cumulative dorsal root entry zone dose of >84.3 Gy (72% vs. 44%, p = .091) and a cumulative pons surface dose of >108.5 Gy (78% vs. 44%, p = .018) predicted for post-GKRS numbness. The presence of any post-GKRS numbness predicted for a >50% decrease in pain intensity (100% vs. 60%, p = .0015). CONCLUSION: Repeat GKRS is a viable treatment option for recurrent trigeminal neuralgia, although the patient assumes a greater risk of nerve dysfunction to achieve maximal pain relief.

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Repeat Gamma Knife surgery for trigeminal neuralgia: long-term results

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OBJECT: The purpose of this study was to assess the long-term outcome achieved after repeat Gamma Knife surgery (GKS) for trigeminal neuralgia (TN) using a uniform treatment plan. METHODS: Between 1985 and 2010, 53 patients underwent repeat GKS for refractory TN. In the initial GKS, which involved targeting the root entry zone of the trigeminal nerve, a maximal dose of 80 Gy was used with a 4-mm collimator so that the 50% isodose line abutted the pons. In the second GKS, the treatment plan consisted of a 70-Gy dose directed at a target 4-5 mm distal to the first target on the trigeminal nerve. The mean follow-up duration in these patients was 42 months. Outcomes were defined using the Marseille scale: excellent (Class I or II, no pain with or without medications), good (Class III or IV, >/= 50% relief), and poor (Class V, < 50% relief). RESULTS: Trigeminal neuralgia pain was controlled (>/= 50% improvement with or without medications) after repeat GKS in 70% of patients at 1 year, 50% at 3 years, 50% at 5 years, and 50% at 10 years, as defined by a Kaplan-Meier analysis. A correlation was found between facial numbness and pain relief (p = 0.047). No difference was found between patients with Type 1 TN and those with Type 2 TN, and there was no correlation between the best relief obtained and long-term durability of relief from pain. Twenty-two patients (47.8%) described their trigeminal dysfunction in the following manner: numbness (45.6%), dry eye (10.9%), taste change (8.7%), or jaw weakness (2.2%). In only 8.7% of cases did the patient experience facial numbness that was regarded as bothersome. CONCLUSIONS: Repeat GKS for TN at the doses used provides substantial long-term relief. Treatment failure occurred up to 28 months after the second GKS. Facial numbness correlated with more durable pain relief after repeat GKS in this series.

Journal of Neurosurgery.2010;113 Suppl(172-7. Epub 2010/12/09

Gamma Knife surgery for recurrent or residual trigeminal neuralgia after a failed initial procedure

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OBJECT: The purpose of this study was to assess outcomes of Gamma Knife surgery (GKS) as a second treatment for recurrent or residual trigeminal neuralgia (TN) after failure of 3 initial procedures: microvascular decompression (MVD), GKS, and percutaneous radiofrequency rhizotomy (PRR). METHODS: Between 1999 and 2008, 65 patients (31 men [48%] and 34 women [52%]) with recurrent TN were treated with GKS. All 65 patients had undergone previous medical procedures that failed to achieve sufficient pain relief: 27 patients (42%) had undergone MVD, 8 (12%) had undergone PRR, and 30 (46%) had undergone GKS as the initial treatment. The entry zone of the trigeminal nerve was targeted using a 4-mm collimator and treated with 35-90 Gy. The isocenter was positioned so that the brainstem surface was usually irradiated at an isodose no greater than 20% (59 patients) to 30% (6 patients). The median duration of TN symptoms in these patients was 39 months (range 1-192 months). RESULTS: At the clinical evaluation, 42 patients (65%) with idiopathic TN reported successful pain control at a median follow-up point of 64 months (range 18-132 months). Of these patients, 33 (51%) were no longer using medication. At the 1-, 2-, and 3-year follow-up examinations, 74%, 71%, and 66% of patients experienced successful pain control, respectively. There was no significant difference in pain relief in the initial MVD group compared with the initial GKS and initial PRR groups (74% vs 59% and 50%, respectively p = 0.342). Recurrence of pain was noted in 23 patients. Twelve of these 23 patients underwent another GKS, resulting in pain control in 8

patients (67%) 8 other patients underwent MVD, resulting in pain relief in 7 patients (87.5%). The median time from GKS to pain recurrence was 7 months (range 3-48 months). There was no significant difference in new facial numbness among the 3 groups (p = 0.24) however, in the initial GKS group, facial numbness was significantly associated with freedom from pain (p = 0.0012). There was a significant correlation between the total radiation dose and facial numbness. The cutoff value for facial numbness ranged from 115 to 120 Gy (p = 0.037). CONCLUSIONS: Gamma Knife surgery as a second treatment achieved acceptable levels of pain control in 65% of patients with residual or recurrent TN after long-term follow-up. Initial treatment was not a factor that affected pain control, but salvage surgery may be considered separately for each group.

Neurosurgery.2010;67(6):1637-44 discussion 1644-5. Epub 2010/11/26

Outcome predictors after gamma knife radiosurgery for recurrent trigeminal neuralgia

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BACKGROUND: Trigeminal neuralgia (TN) that recurs after surgery can be difficult to manage. OBJECTIVE: To define management outcomes in patients who underwent gamma knife stereotactic radiosurgery (GKSR) after failing 1 or more previous surgical procedures. METHODS: We retrospectively reviewed outcomes after GKSR in 193 patients with TN after failed surgery. The median patient age was 70 years (range, 26-93 years). Seventy-five patients had a single operation (microvascular decompression, n=40 glycerol rhizotomy, n=24 radiofrequency rhizotomy, n=11). One hundred eighteen patients underwent multiple operations before GKSR. Patients were evaluated up to 14 years after GKSR. RESULTS: After GKSR, 85% of patients achieved pain relief or improvement (Barrow Neurological Institute grade I-IIIb). Pain recurrence was observed in 73 of 168 patients 6 to 144 months after GKSR (median, 6 years). Factors associated with better long-term pain relief included no relief from the surgical procedure preceding GKSR, pain in a single branch, typical TN, and a single previous failed surgical procedure. Eighteen patients (9.3%) developed new or increased trigeminal sensory dysfunction, and 1 developed deafferentation pain. Patients who developed sensory loss after GKSR had better long-term pain control (Barrow Neurological Institute grade I-IIIb: 86% at 5 years). CONCLUSION: GKSR proved to be safe and moderately effective in the management of TN that recurs after surgery. Development of sensory loss may predict better long-term pain control. The best candidates for GKSR were patients with recurrence after a single failed previous operation and those with typical TN in a single trigeminal nerve distribution.

Journal of Neurosurgery.2009;111(2):359-64. Epub 2009/03/31

Retreatment of trigeminal neuralgia with Gamma Knife radiosurgery: is there an appropriate cumulative dose? Clinical article

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OBJECT: Trigeminal neuralgia (TN) is a disorder of the trigeminal nerve that results in intense episodic pain. Primary treatment with Gamma Knife surgery (GKS) is well established however, a significant number of patients experience recurrence of TN over time. Repeat GKS can be performed, but the retreatment dose has not been well established. In this study, the authors present their institutional retreatment results and compare them with other series. METHODS: Between December 2003 and January 2006, 28 patients were treated at Tufts Medical Center with repeat GKS for recurrence of TN. All patients had been initially treated with GKS at this institution, and only those with significant pain improvement were offered retreatment. The maximum dose was prescribed using a single isocenter the 4-mm collimator was used. The initial median GKS dose was 80 Gy, the median retreatment dose was 45 Gy, and the median cumulative dose was 125 Gy. The median time between GKS procedures was 18.1 months. Facial pain outcomes were defined using the Marseille scale. Excellent outcome was defined as no pain (with or without medications), and good outcome was defined as > 50% pain relief. Toxicity was categorized as none, mild, or bothersome. The median clinical follow-up after the second GKS was 19.7 months. Our clinical outcomes were compared with 8 previously reported retreatment series (including 1 abstract), both for rate of pain control and for rate of complications. RESULTS: Outcomes after the second GKS were excellent in 29% (8 patients), good in 32% (9), and poor in 39% (11). Four patients (14%) experienced no improvement after repeat GKS. Eight

patients (29%) experienced new trigeminal nerve dysfunction, including numbness (11%), paresthesia (14%), dysesthesia (4%), taste alteration (11%), and bite weakness (4%). None of these were bothersome. No patient developed corneal numbness. Univariate analysis failed to reveal any significant predictors of pain control or complications. Seven published peer-reviewed retreatment series and the authors' data (total 215 patients) were analyzed. There was a cumulative dose-response relationship for both pain control (p = 0.04) and new trigeminal dysfunction (p = 0.08). Successful pain control was strongly correlated with development of new dysfunction (p = 0.02). A cumulative dose > 130 Gy was more likely to result in successful (> 50%) pain control, but was also more likely (> 20%) to result in development of new dysfunction. CONCLUSIONS: Successful retreatment of patients in whom the initial GKS treatment fails is feasible. Patients who respond initially may be at a higher risk of retreatment-related complications. There appears to be a dose-response relationship for both pain control and development of new side effects. It is important to counsel and treat patients individually based on this dose-response relationship.

Target Considerations

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Gamma Knife surgery for tumor-related trigeminal neuralgia: targeting both the tumor and the trigeminal root exit zone in a single session

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OBJECTIVE Gamma Knife surgery (GKS) represents an alternative treatment for patients with tumor-related trigeminal neuralgia (TRTN). However, in previous studies, the primary GKS target was limited to mass lesions. The authors evaluated whether GKS could target both the tumor and the trigeminal root exit zone (REZ) in a single session while providing durable pain relief and minimizing radiation dose-related complications for TRTN patients. METHODS The authors' institutional review board approved the retrospective analysis of data from 15 consecutive patients (6 men and 9 women, median age 67 years, range 45-79 years) with TRTN who had undergone GKS. In all cases, the radiation was delivered in a single session targeting both the tumor and trigeminal REZ. The authors assessed the clinical outcomes, including the extent of pain relief, durability of the treatment response, and complications. Radiation doses to organs at risk (OARs), including the brainstem and the cranial nerve VII-VIII complex, were analyzed as doses received by 2% or 50% of the tissue volume and the tissue volume covered by a dose of 12 Gy (V12Gy). RESULTS The median length of clinical follow-up was 38 months (range 12-78 months). Pain relief with GKS was initially achieved in 14 patients (93.3%) and at the last follow-up in 13 patients (86.7%). The actuarial recurrence-free survival rates were 93%, 83%, and 69% at 1, 3, and 5 years after GKS, respectively. Persistent facial numbness was observed in 3 patients (20.0%). There were no complications such as facial weakness, altered taste function, hearing impairment, and balance difficulties indicating impaired function of the cranial nerve VII-VIII complex. The V12Gy in the brainstem was less than or equal to 0.24 cm3 in all patients. There were no significant differences in any OAR values in the brainstem between patients with and without facial numbness after GKS. CONCLUSIONS The strategy of performing GKS for both tumor and trigeminal REZ in a single session is a safe and effective radiosurgical approach that achieves durable pain control for TRTN patients.

J Neurosurg. 2014 Dec;121 Suppl:203-9.

Radiosurgery target location and individual anatomical variation in trigeminal nerves.

Hung YC1, Lee CC, Liu KD, Chung WY, Pan DH, Yang HC.

OBJECT:

The authors evaluated individual anatomical variations in the trigeminal nerves of patients with medically intractable trigeminal neuralgia and clarified the relationships among the variations, radiosurgical target locations, and the clinical outcomes after high-dose Gamma Knife surgery (GKS).

METHODS:

From 2006 through 2011, the authors conducted a retrospective review of 106 cases of primary or secondary trigeminal neuralgia consecutively treated with GKS targeting the dorsal root entry zone (DREZ)

for which a maximal dose of 90 Gy and a 20% isodose line to the brainstem were used. A questionnaire was used to evaluate patients' pre- and post-GKS clinical conditions. To evaluate individual anatomical variations among trigeminal nerves, the authors used 3 parameters: the length of the trigeminal nerve in the cistern (nerve length), the length of the target between the radiation shot and the brainstem (targeting length), and the ratio between nerve length and targeting length (targeting ratio).
RESULTS:
The median length of the trigeminal nerves in the 106 patients was 9.6 mm (range 6.04-20.74 mm), the median targeting length was 3.8 mm (range 1.81-10.84 mm), and the median targeting ratio was 38% (range 13%- 80%). No statistically significant differences in pain relief and pain recurrence were detected among patients with these various nerve characteristics. However, radiation-induced facial hypesthesia correlated with nerve length and targeting ratio ($p < 0.05$) but not with absolute distance from the brainstem (targeting length).
CONCLUSIONS:
In trigeminal neuralgia patients who received DREZ-targeted GKS, the rate of pain relief did not differ according to anatomical nerve variations. However, the frequency of facial hypesthesia was higher among patients in whom the nerve was longer (> 11 mm) or the targeting ratio was lower (< 36%). Adjusting the target according to the targeting ratio, especially for patients with longer nerves, can reduce facial hypesthesia and enable maintenance of effective pain control.

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Impact of target location on the response of trigeminal neuralgia to stereotactic radiosurgery
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Object 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.

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Long-term outcome of gamma knife surgery using a retrogasserian petrous bone target for classic trigeminal neuralgia
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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.

Neurosurgery.2010;67(3):633-8 discussion 638-9. Epub 2010/07/22

Prospective comparison of posterior fossa exploration and stereotactic radiosurgery dorsal root entry zone target as primary surgery for patients with idiopathic trigeminal neuralgia

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BACKGROUND: Trigeminal neuralgia (TN) is the most common facial pain syndrome, with an incidence of approximately 27 per 100,000 patient-years. OBJECTIVE: To prospectively compare facial pain outcomes for patients having either a posterior fossa exploration (PFE) or stereotactic radiosurgery (SRS) as their first surgery for idiopathic TN. METHODS: Prospective cohort study of 140 patients with idiopathic TN who had either PFE (n = 91) or SRS (n = 49) from June 2001 until September 2007. The groups were similar with regard to sex, pain location, and pain duration. Patients who had SRS were older (67.1 vs 58.2 years P < .001). The median follow-up after surgery was 38 months. RESULTS: Patients who had PFE more commonly were pain free off medications (84% at 1 year, 77% at 4 years) compared with the SRS patients (66% at 1 year, 56% at 4 years hazard ratio = 2.5 95% confidence interval, 1.4-4.6 P = .003). Additional surgery for persistent or recurrent face pain was performed in 14 patients after PFE (15%) compared with 17 patients after SRS (35% P = .009). Nonbothersome facial numbness occurred more frequently in the SRS group (33% vs 18% P = .04). No difference was noted in other complications between patients who had PFE (12%) (dysesthetic facial pain, n = 3 cerebrospinal fluid leakage, n = 3 hearing loss, n = 2 wound infection, n = 1 pneumonia, n = 1 deep vein thrombosis, n = 1) and patients who had SRS (8%) (dysesthetic facial pain, n = 4 P = .47). CONCLUSION: PFE is more effective than SRS as a primary surgical option for patients with idiopathic TN.

Acta Neurochirurgica.2010;152(7):1165-70. Epub 2010/03/06

The retrogasserian zone versus dorsal root entry zone: comparison of two targeting techniques of gamma knife radiosurgery for trigeminal neuralgia

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BACKGROUND: We performed a comparative study of the retrogasserian zone (RGZ) with the dorsal root entry zone (DREZ) target to determine effective gamma knife radiosurgery (GKRS) technique in patients with medically refractory trigeminal neuralgia (TN). METHODS: We retrospectively reviewed the records of 39 patients with refractory TN undergoing GKRS between April 2005 and October 2008. Until October 2007, DREZ was used as the primary target point. Since November 2007, RGZ has been targeted, located anterior to DREZ. The pain outcome of patient, pain recurrence, and treatment-related complications were evaluated. FINDINGS: Using the Barrow Neurologic Index (BNI) pain score, 15 (93.8%) RGZ and 20 (87.0%) DREZ cases achieved treatment success (BNI pain score I-IIIb) (p = 0.631). Seven (43.8%) RGZ and four (17.4%) DREZ patients reported complete pain relief without medications (BNI pain score I). The time to a response after the GKRS was significantly shorter in the RGZ group (mean 4.1 weeks) than in the DREZ group (mean 6.4 weeks) (p = 0.044). The total complication rate (25.0%) in the RGZ group was similar to the DREZ group (26.1%) however, frequency of bothersome facial numbness and dry eye syndrome was lower in the RGZ group (0%, 0%) compared to the DREZ group (13.1%, 8.7%) (p = 0.255 and 0.503). CONCLUSIONS: The RGZ targeting technique in the GKRS for TN had a better treatment success, with fewer bothersome complications compared to the DREZ target.

General/Other

J Pain Res.2016;9(535-42.Epub 2016/08/25

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

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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.

American Family Physician.2016;94(2):133-5.Epub 2016/07/16

Trigeminal Neuralgia

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Neurology India.2016;64(4):624-9.Epub 2016/07/07

Radiosurgery for the management of refractory trigeminal neuralgia

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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.

Neurosurgery Clinics of North America.2016;27(3):297-304.Epub 2016/06/22

Gamma Knife Surgery in Trigeminal Neuralgia

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Gamma knife surgery (GKS) represents a safe, effective, and relatively durable noninvasive treatment option for patients with trigeminal neuralgia (TN) and recurrent TN. By one year's time, 75% to 90% of patients will have obtained pain relief, defined as Barrow Neurological Institute grades I to IIIB. Similar rates have been demonstrated for patients undergoing a second GKS for recurrent TN. Predictors of durability of GKS in TN include type I TN, post-GKS Barrow Neurological Institute score, and the presence of post-Gamma Knife facial numbness.

Neurosurgery Clinics of North America.2016;27(3):327-36.Epub 2016/06/22

Measurement of Trigeminal Neuralgia Pain: Penn Facial Pain Scale

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Pain is a subjective experience that cannot be directly measured. Therefore, patient-reported outcome is one of the currently accepted methods to capture pain intensity and its impact on activities of daily living. This article focuses on five patient-reported outcomes that have been used to measure trigeminal neuralgia pain-Visual Analog Scale, numeric rating scale, Barrow Neurological Institute Pain Intensity Score, McGill Pain Questionnaire, and Penn Facial Pain Scale. Each scale is evaluated for its practicality, applicability, comprehensiveness, reliability, validity, and sensitivity to measuring trigeminal neuralgia pain.

Headache.2016;2016/04/05

Gamma knife radiosurgery for trigeminal neuralgia secondary to benign lesions

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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.

Journal of Craniofacial Surgery.2016;27(1):e55-7.Epub 2015/12/18

Trigeminal Neuralgia Caused by Cerebellopontine Angle Arteriovenous Malformation Treated With Gamma Knife Radiosurgery

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Trigeminal neuralgia is a facial pain syndrome characterized as sudden onset and lightening-like sensation over somatosensorial branch(es) of fifth cranial nerve. Rarely, some underlying diseases or disorders could be diagnosed, such as multiple sclerosis, brain tumors, and vascular malformations. The authors present a 47-year-old man with trigeminal neuralgia over left V2 and V3 dermatomes. He had a previous transarterial embolization and long use of carbamazepine with partial response to treatment. Gamma knife radiosurgery (GKR) was planned. A marginal dose of 15 Gy was given to 50% isodose line. His pain was relieved by GKR in 1.5 years. Treatment of posterior fossa arteriovenous malformations causing trigeminal neuralgia, with GKR has a very limited use in the literature. It, however, is obvious that success rate as pain relief, in a very challenging field of functional neurosurgery, is satisfactory. Large series, however, are in need to make a more comprehensive statement about efficacy and safety of the procedure in these pathologies.

Journal of Neurosurgery.2016;124(4):1079-87.Epub 2015/09/05
Long-term safety and efficacy of Gamma Knife surgery in classical trigeminal neuralgia: a 497-patient historical cohort study
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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.

J Neurol Surg B Skull Base. 2016 Feb;77(1):47-53. 2015/08/03.
Management of Recurrent Trigeminal Neuralgia Associated with Petroclival Meningioma.
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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.

Oncology (Williston Park).2015;29(4 Suppl 1):Epub 2015/05/02
(P041) Clinical Outcomes of Gamma Knife Stereotactic Radiosurgery (GK-SRS) for Painful Trigeminal Neuropathy (TNP)

J Clin Neurosci.2015;22(5):818-22. Epub 2015/03/15
Long term efficacy and patient satisfaction of microvascular decompression and gamma knife radiosurgery for trigeminal neuralgia
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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.

Neurosurgery.2015;Epub2015/03/27
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
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Publique-Hopitaux de Marseille, Universite de la Mediterranee, INSERM U 751, Marseille, France; double daggerSignal Processing Laboratory (LTS 5), Swiss Federal Institute of Technology, Marseille, France; section signMedical Image Analysis Laboratory, Centre Hospitalier Universitaire Vaudois, Marseille, France; paragraph signCentre Hospitalier Universitaire Vaudois, Department of Clinical Neurosciences, Neurosurgery Service and Gamma Knife Center, Lausanne, Switzerland; ||University of Lausanne, Faculty of Biology and Medicine, Lausanne, Switzerland; #Department of Public Health and Medical Information, Centre Hospitalier Universitaire La Timone Assistance Publique-Hopitaux de Marseille, UMR 912 (INSERM-IRD-Universite de la Mediterranee), Marseille, France; **Department of Neurology, Clinical Neuroscience Federation, Centre Hospitalier Universitaire La Timone Assistance Publique-Hopitaux de Marseille, Marseille, France.
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). ABBREVIATIONS: BNI, Barrow Neurological InstituteCI, confidence intervalCTN, classic trigeminal neuralgiaGKS, Gamma Knife surgeryHR, hazard ratioMVD, microvascular decompressionTN, trigeminal neuralgia.

Stereotact Funct Neurosurg.2015;93(2):110-113. Epub 2015/02/28
Gamma Knife Stereotactic Radiosurgery for Trigeminal Neuralgia Caused by a Developmental Venous Anomaly
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Background: Trigeminal neuralgia (TN) is mostly caused by vascular compression of the nerve's root entry zone due to an ectatic artery. Rarer causes include compression from tumors, vascular malformations or multiple sclerosis plaques. Developmental venous anomalies (DVAs) are benign, aberrantly appearing venous structures that drain normal cerebral tissue. DVAs are a rare etiology of TN. The management of TN caused by a DVA is controversial as disruption of the DVA can be catastrophic. Methods: We report a case of a young man with severe medically refractory TN related to a brachium pontis DVA who was successfully treated by gamma knife stereotactic radiosurgery (GKSR) to the trigeminal nerve. Results: Within 2 weeks of GKSR, the patient reported experiencing 60% pain relief; 5 years postoperatively, he remains completely pain free with some mild sensory loss in the V2 and V3 areas. Conclusions: GKSR has an established role in the management of TN. This is the first reported case of using GKSR to treat TN caused by a DVA. In the setting of a DVA, GKSR should be an initial consideration for TN therapy after medical failure because of the high surgical risk related to disrupting the DVA. (c) 2015 S. Karger AG, Basel.

Surg Neurol Int. 2014 Nov 21;5:160. eCollection 2014.
Salvage Gamma Knife Radiosurgery after failed management of bilateral trigeminal neuralgia.
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BACKGROUND:
The incidence of bilateral trigeminal neuralgia (TN) is 1-6% of total number of TN cases. Gamma Knife Radiosurgery (GKRS) is effective in treating unilateral TN; however, outcomes of bilateral TN treated by GKRS have not been well evaluated. The purpose of this study is to evaluate the long-term GKRS outcomes of bilateral TN at our institution and compare with our published treatment outcomes of unilateral TN.
METHODS:
Between 2000 and 2006, eight patients with bilateral TN were treated with GKRS. Data available on seven patients were collected. Facial pain outcomes were defined using the Barrow Neurological Institute pain intensity scale. Outcomes and toxicities were compared to published outcomes of unilateral TN patients treated with GKRS at our institution.
RESULTS:
The incidence of bilateral TN in our series is 2.3%. Treatment outcomes were excellent in 5/14, good in 1/14, and poor in 8/14. Median follow-up time was 58 months. Median time-to-failure was 38 months. Pain control rate was 80% at 12 months and 65% at 36 months. Bothersome side effects were seen in 4/14 nerves treated. Compared with our long-term unilateral TN cohort, there was no statistically significant difference in outcome, time-to-failure, or rate of toxicity.
CONCLUSION:
Bilateral TN is rare, and effective treatment is crucial to improve the quality of life of those afflicted. Salvage GKRS is a reasonable treatment modality for individuals with bilateral TN.

Stereotact Funct Neurosurg.2014;92(3):170-177. Epub 2014/06/20
Trigeminal Neuralgia Related to Megadolichobasilar Artery Compression: A Prospective Series of Twenty-Nine Patients Treated with Gamma Knife Surgery, with More Than One Year of Follow-Up
Tuleasca, C., Carron, R., Resseguier, N., Donnet, A., Roussel, P., Gaudart, J., Levivier, M. and Regis, J.,Functional and Stereotactic Neurosurgery Unit, INSERM U751, Centre Hospitalier Universitaire La Timone Assistance Publique-Hopitaux de Marseille, Marseille, France.
Background: Trigeminal neuralgia (TN) secondary to megadolichobasilar artery (MBA) compression is considerably difficult to manage surgically. Objective: This study aims to evaluate the safety/efficacy of Gamma Knife surgery (GKS) in this special group of patients. Methods: Between July 1992 and November 2010, 29 patients with >1 year of follow-up presenting with MBA compression were treated with GKS at Timone University Hospital. Radiosurgery was performed using a Gamma Knife (model B, C or Perfexion). A single 4-mm isocenter was positioned in the cisternal portion of the trigeminal nerve at a median distance of 9.1 mm (range: 6-18.2 mm) from the emergence. Results: The median follow-up period was 46.1 months (range: 12.9-157.9 months). Initially, all patients (100%) were pain free; the average time to complete pain relief was 13.5 days (range: 0-240 days). Their actuarial probability of remaining pain free without medication at 0.5, 1 and 2 years was 93.1, 79.3 and 75.7%, respectively, and remained stable until 13 years after treatment. The actuarial probability of hypoesthesia onset at 6 months was 4.3%; at 1 year it reached 13% and remained stable until 13 years after treatment. Conclusions: GKS proved to be reasonably safe and effective on a long-term basis as a first- and/or second-line surgical treatment for TN due to MBA compression. (c) 2014 S. Karger AG, Basel.

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Trigeminal neuralgia pain relief after gamma knife stereotactic radiosurgery
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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.

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Results of radiosurgery for trigeminal neuralgia: Ankara experience

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Object. 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.

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[Gamma knife radiosurgery for trigeminal neuralgia: analysis of a multi institutional study]

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A multi-institutional study was conducted to evaluate the results of gamma knife radiosurgery(GKRS)for the treatment of trigeminal neuralgia. Eleven hundred and thirty-five patients at 39 centers were analyzed. Three hundred and sixty-nine patients had undergone percutaneous nerve block and 173 patients had undergone microvascular decompression(MVD)prior to GKRS. GKRS was performed for 69.4% of patients targeted at the nerve root entry zone(REZ)and for 20.4% of patients targeted at the retrogasserian region(RGR). The target dose of the GKRS used in the current study varied from 70 to 90 Gy(mean:77.8Gy). The median follow-up period after GKRS was 21.1 months(range 1 to 125 months). Six hundred and eighty-nine patients(66%)responded with excellent or good control(pain free), 157(15%)obtained fair control(more than 50% relief), and 192(19%)experienced treatment failure. After 3 years, 64% of cases were pain free and 80% had more than 50% pain relief. After 4 years, 37 patients underwent additional GKRS, 36 MVD and 36 percutaneous nerve block. Tolerable hypoesthesia or paresthesia occurred in 129 patients(11%), whereas bothersome symptoms developed in 8 patients(1%). But no patient developed

deafferentation pain. Nine patients(1%)complained of dry eye, but no other abnormalities of the cornea and conjunctiva were found on ophthalmological examination. Higher maximum radiosurgical dose was associated with a significantly greater factor of complete pain relief(p=0.0101). GKRS is a safe and effective alternative treatment for trigeminal neuralgia, and is a minimally invasive treatment. In addition it provided benefit to a patient population unwilling or unable to undergo more invasive surgical approaches.

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Trigeminal Neuralgia Caused by Nerve Compression by Dilated Superior Cerebellar Artery Associated with Cerebellar Arteriovenous Malformation: Case Report

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Intracranial arteriovenous malformation (AVM) is a rare cause of trigeminal neuralgia (TGN). In this presented case, successful resolution of AVM-related TGN following embolization and gamma knife stereotactic radiosurgery (GKRS) was obtained. A patient suffered from TGN on the left side, which was thought to be caused by root entry zone compression by dilated superior cerebellar artery (SCA) associated with cerebellar AVM. The cerebellar vermis AVM was embolized in endovascular surgery. The AVM was reduced in size and TGN was partially relieved. The patient subsequently underwent GKRS for the residual nidus. TGN was completely resolved within one year and a half. GKRS following embolization of the nidus improved the flow-related dilation of the SCA and completely relieved TGN.

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Gamma knife radiosurgery for typical trigeminal neuralgia: An institutional review of 108 patients

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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.

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Constant Face Pain in Typical Trigeminal Neuralgia and Response to Gamma Knife Radiosurgery

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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.

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

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Object 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).

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Do Carbamazepine, Gabapentin, or Other Anticonvulsants Exert Sufficient Radioprotective Effects to Alter Responses From Trigeminal Neuralgia Radiosurgery?

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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.

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Trigeminal Neuralgia: Radiosurgery Before Microvascular Decompression Perspective Statement
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Prospective study of the short-term adverse effects of gamma knife radiosurgery
Chao, S. T., Thakkar, V. V., Barnett, G. H., Vogelbaum, M. A., Angelov, L., Weil, R. J., Rasmussen, P., Reuther, A. M., Jamison, B., Neyman, G. and Suh, J. H.,Rose Ella Burkhardt Brain Tumor and Neuro-oncology Center, Neurological Institute, Cleveland Clinic, Cleveland, Ohio. chaos@ccf.org.
Purpose of this study is to determine the types, incidence, and severity of acute complications of intracranial stereotactic radiosurgery (SRS), specifically Gamma Knife (GK). Patients who had never had previous SRS were eligible for this prospective IRB-approved study. The questionnaire used applicable questions from CTCAE v.3.0, the Brief Pain Questionnaire (Short Form), Brief Fatigue Inventory, and the Tinnitus Handicap Inventory. Questionnaires were obtained prior to Gamma Knife (GK), 1 week, 1 month, and 2 months to assess complications. Seventy-six eligible patients (median age of 62 years) had complete data and were analyzed. Diagnoses included: 26 (34%) with brain metastases, 15 (20%) with trigeminal neuralgia, 12 (16%) with schwannoma, 10 (13%) with meningioma, 7 (9%) with arteriovenous malformation, 3 (4%) with pituitary adenoma, and 3 (4%) with other. At 1 week, 24% developed minimal scalp numbness (p = 0.0004 baseline compared to 1 week). Only 13% had minimal scalp numbness at 1 month and 2% at 2 months (both p 5 NS compared to baseline). There was no difference in scalp tingling between baseline and the various time points. Thirteen percent developed pin site pain at 1 week with a median intensity level of 2 out of 10. By one month, only 3% had pin site pain with a median intensity level of 3 out of 10. Four percent developed pin-site infection at 1 week and none at 1 and 2 months. There was no significant difference in nausea from baseline at 1 week, but there was worsening nausea at 1 month (p = 0.0114). By 1 month, 10% reported new local hair loss. 23%, 16%, and 15% complained of new/worsening fatigue at 1 week, 1 month, and 2

months, respectively, but 40% reported fatigue at baseline. Balance improved following SRS over all time periods (for all comparisons, p < 0.009). 1%, 6%, and 3% developed new tinnitus at 1 week, 1 month, and 2 months, respectively, which was significant when comparing baseline to non-baseline (p = 0.0269). Thirty-two patients were employed prior to SRS. Three (9%) patients did not return to work. Twenty-seven (84%) patients returned to work a median of 4 days after SRS. Two people did not report their employment status after SRS. There was no significant difference in face swelling, headache, eye pain, vomiting, seizures, or passing out at any intervals compared to baseline. This prospective study demonstrates that GK is well tolerated with few patients developing major acute effects. Many patients are able to return to work shortly after GK.

Expert Rev Med Devices.2011;8(6):709-21. Epub 2011/10/28

Gamma Knife((R)) radiosurgery for trigeminal neuralgia

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Trigeminal neuralgia is characterized by a temporary paroxysmal lancinating facial pain in the trigeminal nerve distribution. The prevalence is four to five per 100,000. Local pressure on nerve fibers from vascular loops results in painful afferent discharge from an injured segment of the fifth cranial nerve. Microvascular decompression addresses the underlying pathophysiology of the disease, making this treatment the gold standard for medically refractory trigeminal neuralgia. In patients who cannot tolerate a surgical procedure, those in whom a vascular etiology cannot be identified, or those unwilling to undergo an open surgery, stereotactic radiosurgery is an appropriate alternative. The majority of patients with typical facial pain will achieve relief following radiosurgical treatment. Long-term follow-up for recurrence as well as for radiation-induced complications is required in all patients undergoing stereotactic radiosurgery for trigeminal neuralgia.

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Outcomes of Gamma Knife surgery for trigeminal neuralgia secondary to vertebrobasilar ectasia

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Object Vertebrobasilar ectasia (VBE) is an unusual cause of trigeminal neuralgia (TN). The surgical options for patients with medically refractory pain include percutaneous or microsurgical rhizotomy and microvascular decompression (MVD). All such procedures can be technically challenging. This report evaluates the response to a minimally invasive procedure, Gamma Knife surgery (GKS), in patients with TN associated with severe vascular compression caused by VBE. Methods Twenty patients underwent GKS for medically refractory TN associated with VBE. The median patient age was 74 years (range 48-95 years). Prior surgical procedures had failed in 11 patients (55%). In 9 patients (45%), GKS was the first procedure they had undergone. The median target dose for GKS was 80 Gy (range 75-85 Gy). The median follow-up was 29 months (range 8-123 months) after GKS. The treatment outcomes were compared with 80 case-matched controls who underwent GKS for TN not associated with VBE. Results Intraoperative MR imaging or CT scanning revealed VBE that deformed the brainstem in 50% of patients. The trigeminal nerve was displaced in cephalad or lateral planes in 60%. In 4 patients (20%), the authors could identify only the distal cisternal component of the trigeminal nerve as it entered into the Meckel cave. After GKS, 15 patients (75%) achieved initial pain relief that was adequate or better, with or without medication (Barrow Neurological Institute [BNI] pain scale, Grades I-IIIb). The median time until pain relief was 5 weeks (range 1 day-6 months). Twelve patients (60%) with initial pain relief reported recurrent pain between 3 and 43 months after GKS (median 12 months). Pain relief was maintained in 53% at 1 year, 38% at 2 years, and 10% at 5 years. Some degree of facial sensory dysfunction occurred in 10% of patients. Eventually, 14 (70%) of the 20 patients underwent an additional surgical procedure including repeat GKS, percutaneous procedure, or MVD at a median of 14 months (range 5-50 months) after the initial GKS. At the last follow-up, 15 patients (75%) had satisfactory pain control (BNI Grades I-IIIb), but 5 patients (25%) continued to have unsatisfactory pain control (BNI Grade IV or V). Compared with patients without VBE, patients with VBE were much less likely to have initial (p = 0.025) or lasting (p = 0.006) pain relief. Conclusions Pain control rates of GKS in patients with TN associated with VBE were inferior to those of patients without VBE. Multimodality surgical or medical management strategies were required in most patients with VBE.

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Fitting radiosurgery into the trigeminal neuralgia management puzzle
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Outcomes of gamma knife radiosurgery for trigeminal neuralgia after a minimum 3-year follow-up
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We conducted a retrospective study of the outcomes of 17 patients who underwent gamma knife radiosurgery (GKRS) for idiopathic trigeminal neuralgia (TN) with a minimum 3-year follow-up. The median interval from GKRS to pain improvement was 4 weeks (range, 1-16 weeks). At the last follow-up, a good treatment outcome was verified in 16 (94.1%) patients (Barrow Neurologic Index pain score, I-IIIb). One patient (5.9%) had treatment failure. On follow up, six patients (35.3%) had a recurrence of pain following some initial relief. Mean time to pain recurrence was 20 months (range, 3-36 months). Four patients (23.5%) experienced treatment-related complications. Three patients reported some degree of post-treatment facial numbness. One patient reported decreased corneal sensation (dry eye syndrome). GKRS is a safe and effective long-term treatment method for TN and should be considered as an alternative option for medically intractable TN.

Stereotactic and Functional Neurosurgery.2011;89(1):17-24. Epub 2010/12/03
Stereotactic radiosurgery for patients with trigeminal neuralgia associated with petroclival meningiomas
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BACKGROUND: The management of trigeminal neuralgia in patients with associated skull base meningiomas is complex. OBJECTIVE: We evaluated the pain management needs and outcomes in patients with petroclival meningiomas associated with medically refractory trigeminal neuralgia. METHODS: During a 21-year period, 168 patients underwent stereotactic radiosurgery (SRS) for meningiomas involving the petroclival region. We identified 12 patients (10 females median age 54 years) who had trigeminal neuralgia in association with an ipsilateral petroclival meningioma. The median tumor volume was 3.8 cm(3) (1.0-15.9 cm(3)). The median prescription dose for tumor margins was 13 Gy (11-16 Gy). RESULTS: Initial pain control [Barrow Neurological Institute (BNI) grades I-IIIb] was obtained in 10 of 12 patients (83%). However, 3 patients with initial adequate relief later developed pain. Follow-up imaging revealed control of tumor growth in all patients at a median follow-up of 68 months. No patient developed any new sensory dysfunction. The tumor shrinkage was not associated with pain relief. At the final follow-up, 5 patients had pain of BNI grade I (2 after surgery), 4 had grade IIIb and 3 had grade IV. CONCLUSIONS: SRS provided effective tumor control, but trigeminal neuralgia persisted to varying degrees in most patients. Multimodality pain management strategies were required in most patients with skull base meningiomas associated with trigeminal neuralgia.

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Trigeminal nerve dysfunction after Gamma Knife surgery for trigeminal neuralgia: a detailed analysis
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OBJECT: Gamma Knife surgery (GKS) is an effective treatment option for intractable trigeminal neuralgia (TN). The incidence of trigeminal nerve dysfunction, such as facial numbness or dysesthesia, has been reported to be higher than previously published, and the degree and prognosis of trigeminal nerve dysfunction has not been well evaluated. The authors evaluated the incidence, timing, degree, and outcome of trigeminal nerve dysfunction after GKS for TN. METHODS: One hundred four patients with medically refractory TN were treated by GKS. Thirty-nine patients were men and 65 were women their median age at GKS was 74 years. Using a single isocenter and a 4-mm collimator, 80 or 90 Gy was directed to the trigeminal nerve root. Follow-up data were obtained at clinical examinations every 3-6 months after GKS. Each patient's pain-control status and degree of trigeminal nerve dysfunction were recorded. The incidence,

timing, and degree of dysfunction (assessed using the Barrow Neurological Institute facial numbness scale [BNI-N]) and the prognosis and factors related to trigeminal nerve dysfunction were analyzed. RESULTS: The median duration of follow-up in these patients was 37 months (range 6-121 months). At the final clinical visit, a pain-free status was still observed in 71 patients (68.3%). In 51 patients (49.0%), new or increased trigeminal nerve dysfunction developed at a median of 10.5 months (range 4-68 months) after GKS. In 24 patients (23.1%), this dysfunction was categorized as BNI-N Score II, in 20 patients (19.2%) as BNI-N Score III, and in 7 patients (6.7%) as BNI-N Score IV. Among those patients, 18 patients, including 3 patients with BNI-N Score IV, experienced improvement in nerve dysfunction between 24 and 108 months after GKS (median 52.5 months). At the final clinical visit, 43 patients (41.3%) reported having some trigeminal nerve dysfunction: in 26 patients (25.0%) this was categorized as BNI-N Score II, in 13 patients (12.5%) as BNI-N Score III, and in 4 patients (3.8%) as BNI-N Score IV. The only independent factor that was correlated to all trigeminal nerve dysfunction and also specifically to bothersome trigeminal nerve dysfunction was pain-free status at the final clinic visit. CONCLUSIONS: The incidence of trigeminal nerve dysfunction after GKS for TN was 49%. The severity of the dysfunction improved in one-third of the afflicted patients, even in those with severe dysesthesia at long-term follow-up. A strong relationship between TN and good pain control was identified.

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Gamma Knife surgery for trigeminal neuralgia: a review of 450 consecutive cases

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OBJECT: The success rates and side effects of Gamma Knife surgery (GKS) in patients with trigeminal neuralgia (TN) are not fully clear. A comparison of data across previous reports is hampered by differences in treatment protocols, lengths of follow-up, and outcome criteria. The purpose of this paper is to contribute to knowledge of the efficacy of GKS in TN by reviewing data in a large group of patients with this disorder, who were treated with a uniform treatment protocol and evaluated using a well-established pain scale and Kaplan-Meier analysis. METHODS: The authors reviewed 450 treatments in 365 patents with medically refractory TN who were treated between June 2002 and October 2009 at the Gamma Knife Center Tilburg. In all patients 80 Gy was prescribed, with a single 4-mm isocenter located at the root entry zone (REZ). In 79 patients repeated GKS was performed using a uniform dose of 80 Gy, which was delivered, in a highly standardized manner, to a spot anterior to the position of the first treatment. Follow-up was obtained by reviewing the patients' medical records and conducting telephone interviews. Outcome was assessed using the Barrow Neurological Institute (BNI) pain scale and the BNI facial numbness scale. RESULTS: The median follow-up period was 28 months. In the idiopathic TN group, rates of adequate pain relief, defined as BNI Pain Scores I-IIIB, were 75%, 60%, and 58% at 1, 3, and 5 years, respectively. In the multiple sclerosis (MS)-related TN group the rates of adequate pain relief were 56%, 30%, and 20% at 1, 3, and 5 years, respectively. Repeated GKS was as successful as the first. An analysis of our treatment strategy of repeated GKS showed rates of adequate pain relief of 75% at 5 years in the idiopathic TN and 46% in the MS-related TN group. Somewhat bothersome numbness was reported by 6% of patients after the first treatment and by 24% after repeated GKS. Very bothersome numbness was reported in 0.5% after the first GKS and in 2% after the second treatment. CONCLUSIONS: In this study the authors analyzed outcomes of GKS in a large cohort of patients with TN uniform treatment consisted of 80 Gy delivered to the REZ. The initial and long-term outcomes of pain relief and sensory dysfunction are comparable to recently published results at other institutions, where similar outcome criteria were used. These data should prove helpful to assist patients and clinicians in their TN management decisions.

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Gamma Knife irradiation-induced histopathological changes in the trigeminal nerves of rhesus monkeys

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OBJECT: The authors' goal was to observe histopathological changes in the trigeminal nerve after Gamma Knife surgery (GKS) in rhesus monkeys, and to investigate the radiobiological mechanism of GKS for primary trigeminal neuralgia. The nerve length-dosage effect of irradiation is also discussed. METHODS: One of 5 rhesus monkeys randomly served as a control, and the other 4 monkeys were randomly administered a

target radiation dose of 60, 70, 80, or 100 Gy (a different dose in each animal). The size of the collimator was 4 mm, and the target point was the trigeminal nerve root. In each experimental monkey, one side was exposed to single-target-point irradiation, and the contralateral side was exposed to double-target-point irradiation. After 6 months, the trigeminal nerve root was examined using light microscopy, transmission electron microscopy, and immunohistochemistry. RESULTS: At each radiation dose, the damage to the nerve tissue by single-target-point irradiation was identical to that caused by double-target-point irradiation. In the trigeminal nerve tissues of the monkeys irradiated with 60 and 70 Gy, there was limited nerve demyelination and degeneration, fragmentation, or loss of axons. In the trigeminal nerve tissue of the monkey irradiated with 80 Gy, the nerve tissue showed a disordered structure. In the trigeminal nerve tissue of the monkey irradiated with 100 Gy, there was severe derangement in the structure of the nerve tissue, and extensive demyelination, fragmentation, and loss of axons. CONCLUSIONS: The target doses of 60 and 70 Gy have very little impact on the structure of the trigeminal nerve. Irradiation at 80 Gy can cause partial degeneration and loss of axons and demyelination. A 100-Gy dose can cause some necrosis of neurons. Comparing the single-target-point with the double-target-point irradiation, the extent of damage to the nerve tissue is identical, and no difference in the nerve length-dosage effect was found.

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Microvascular decompression after failed Gamma Knife surgery for trigeminal neuralgia: a safe and effective rescue therapy?

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OBJECT: Stereotactic radiosurgical rhizolysis using Gamma Knife surgery (GKS) is an increasingly popular treatment for medically refractory trigeminal neuralgia. Because of the increasing use of GKS for trigeminal neuralgia, clinicians are faced with the problem of choosing a subsequent treatment plan if GKS fails. This study was conducted to identify whether microvascular decompression (MVD) is a safe and effective treatment for patients who experience trigeminal neuralgia symptoms after GKS. METHODS: From their records, the authors identified 29 consecutive patients who, over a 2-year period, underwent MVD following failed GKS. During MVD, data regarding thickened arachnoid, adhesions between vessels and the trigeminal nerve, and trigeminal nerve atrophy/discoloration were noted. Outcome and complication data were also recorded. RESULTS: The MVD procedure was completed in 28 patients (97%). Trigeminal nerve atrophy was noted in 14 patients (48%). A thickened arachnoid was noted in 1 patient (3%). Adhesions between vessels and the trigeminal nerve were noted in 6 patients (21%) and prevented MVD in 1 patient. At last follow-up, 15 patients (54%) reported an excellent outcome after MVD, 1 (4%) reported a good outcome, 2 (7%) reported a fair outcome, and 10 patients (36%) reported a poor outcome. After MVD, new or worsened facial numbness occurred in 6 patients (21%). Additionally, 3 patients (11%) developed new or worsened troubling dysesthesias. CONCLUSIONS: Thickened arachnoid, adhesions between vessels and the trigeminal nerve, and trigeminal nerve atrophy/discoloration due to GKS did not prevent completion of MVD. An MVD is an appropriate and safe "rescue" therapy following GKS, although the risks of numbness and troubling dysesthesias appear to be higher than with MVD alone.

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Outcomes following single-treatment Gamma Knife surgery for trigeminal neuralgia with a minimum 3-year follow-up

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OBJECT: Gamma Knife surgery (GKS) has been shown to be effective in treating trigeminal neuralgia (TN). Existing studies have demonstrated success rates of 69.1-85% with median follow-up intervals of 19-60 months. However, series with uniform long-term follow-up data for all patients have been lacking. In the present study the authors examined outcomes in a series of patients with TN who underwent a single GKS treatment followed by a minimum follow-up of 36 months. They used a clinical scale that simplifies the reporting of outcome data for patients with TN. METHODS: Fifty-three consecutive patients with typical, intractable TN received a median maximum radiation dose of 80 Gy applied with a single 4-mm isocenter

to the affected trigeminal nerve. Follow-up data were obtained by clinical examination and questionnaire. Outcome results were categorized into the following classes (in order of decreasing success): Class 1A, complete pain relief without medications 1B, complete pain relief with either a decrease or no change in medications 1C, > or = 50% pain relief without medications 1D, > or = 50% pain relief with either a decrease or no change in medications and Class 2, < 50% pain relief and/or increase in medications. Patients with Class 1A-1D outcome (equivalent to Barrow Neurological Institute Grades I-IIIb) were considered to have a good treatment outcome, whereas in patients with Class 2 outcome (equivalent to Barrow Neurological Institute Grades IV and V) treatment was considered to have failed. RESULTS: A good treatment outcome from initial GKS was achieved in 31 (58.5%) patients for whom the mean follow-up period was 48 months (range 36-66 months). Outcomes at last follow-up were reflected by class status: Class 1A, 32.1% of patients 1B, 1.9% 1C, 3.8% 1D, 20.8% and Class 2, 41.5%. Statistical analysis showed no difference in outcomes between patients previously treated with microvascular decompression or rhizotomy compared with patients with no previous surgical treatments. Thirty-six percent of patients reported some degree of posttreatment facial numbness. Anesthesia dolorosa did not develop in any patient. CONCLUSIONS: Despite a time-dependent deterioration in the success rate of GKS for medically intractable TN, the authors' study showed that > 50% of patients can be expected to have a good outcome based on their scoring system, with approximately 33% having an ideal outcome (pain free with no need for medications). Long-term data, as those presented here, are important when counseling patients on their treatment options.

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Glossopharyngeal neuralgia treated with gamma knife radiosurgery

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BACKGROUND: Although gamma knife radiosurgery is an established treatment option for trigeminal neuralgia, its role in the management of glossopharyngeal neuralgia is unclear. We report a case of glosspharyngeal neuralgia treated effectively with gamma knife radiosurgery, review the literature, and discuss the rationale supporting dose and target selection. CASE DESCRIPTION: A 47-year-old woman presented with persistent lancinating pain to the left throat, which was refractory to medical therapy. She declined a microvascular decompression and instead chose stereotactic radiosurgery. Gamma knife radiosurgery to the glossopharyngeal nerve at the glossopharyngeal meatus was used, and a maximum dose 80 Gy was delivered. She was pain-free off medications 1 month after the procedure and remains pain-free 11 months. There were no adverse neurologic effects attributable to the procedure. CONCLUSIONS: This clinical response provides encouraging evidence for the treatment of glossopharyngeal neuralgia with stereotactic radiosurgery and is consistent with previous reports. Further investigation is needed to define the role of stereotactic radiosurgery in the management of glossopharyngeal neuralgia.

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Trigeminal neuralgia: outcomes after gamma knife radiosurgery

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BACKGROUND: Trigeminal neuralgia (TN) often remains difficult to treat despite multiple available medications, and can severely impact on the quality of life of affected patients. Gamma knife radiosurgery has recently emerged as a minimally-invasive alternative to surgery for patients suffering from drug-resistant TN. The goal of this study was to report the short-term efficacy of gamma knife radiosurgery for TN and assess its impact on the quality of life of patients treated in the first 18 months of our experience. METHODS: Patients with medically-refractory TN or with unacceptable drug side effects were considered for radiosurgery. A maximum dose of 80 Gy was administered to the affected nerve using a single 4-mm isocenter. Follow-up assessments were made at 2,4 and 6 months, with evaluation of pain relief, drug reduction and quality of life. Factors impacting treatment response were assessed using Cox regression analysis. RESULTS: A total of 67 patients were treated. Significant pain relief was seen in 77.6% of patients, including 32.6% who became pain-free. Patients were able to discontinue all medications in 34.3% or reduce drug intake by more than 50% in an additional 28.4% of cases. No variable was found to predict pain relief although older age (>66 years) approached statistical significance. Sensory side effects were seen in 14.9% of patients. Quality of life improved in the majority of patients after radiosurgery. CONCLUSIONS:

Gamma knife radiosurgery is a safe and effective management alternative for trigeminal neuralgia, providing good or excellent pain relief and improvement in quality of life in the majority of patients with few side effects.

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Trigeminal neuralgia: historical notes and current concepts

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BACKGROUND: Trigeminal neuralgia is a syndrome of paroxysmal excruciating, lancinating unilateral facial pain. REVIEW SUMMARY: There are several clinical features that are characteristic of trigeminal neuralgia, but there may be red flags that should suggest alternative diagnoses. There is convincing evidence that the idiopathic form develops from focal demyelination at the trigeminal root entry zone with subsequent ephaptic cross-talk between axons. Vascular compression of the nerve root causes this demyelination in most patients. Medical management of this condition, using anticonvulsant therapy and other agents, aims to dampen the abnormal electrical signals and to ameliorate symptoms. In refractory cases, a number of surgical interventions can be considered, the most common of which is microvascular decompression of the trigeminal nerve. Gamma knife therapy is emerging as an alternative treatment for the patient with medically refractive trigeminal neuralgia, particularly in the elderly patient with comorbid conditions. CONCLUSION: Knowledge of the proper diagnosis and management of trigeminal neuralgia is essential to the successful management of these patients.

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Long-term outcome of gamma knife radiosurgery for treatment of typical trigeminal neuralgia

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PURPOSE: To analyze the long-term outcomes of patients with typical trigeminal neuralgia treated with gamma knife radiosurgery (GKRS). PATIENTS AND METHODS: A total of 62 consecutive patients with typical trigeminal neuralgia were treated with GKRS between 1998 and 2004. Of the 62 patients, 2 were lost to follow-up the remaining 60 patients were followed for >12 months. The mean prescribed maximal dose was 79.7 Gy (range, 75-80), using a 4-mm shot. RESULTS: Of the 60 patients, 48 were followed for >4 years. An additional 3 patients, followed for <4 years, experienced recurrent pain after a favorable initial response and were incorporated into the long-term response analysis. Of these 51 patients (mean age, 61 +/- 11 years 37 women [72.5%] and mean follow-up duration, 58 +/- 14 months), 46 (90.2%) responded to GKRS, as demonstrated by an improvement in their Barrow Neurological Institute pain intensity score. Of the 46 patients, 24 (52.2%) had pain recurrence. The actuarial recurrence-free survival rate was 84.8%, 76.1%, 69.6%, 63.0%, and 45.8% at 1, 2, 3, 4, and 5 years after radiosurgery, respectively. Patient age >70 years correlated with a favorable outcome in terms of pain recurrence after radiosurgery (hazard ratio, 0.125 95% confidence interval, 0.016-0.975 p = .047) on multivariate analysis. CONCLUSION: GKRS seems to be an effective treatment modality for patients with typical trigeminal neuralgia considering the initial response rate however, fewer than one-half of patients might continue to benefit from GKRS after long-term follow-up. Elderly patients might be good candidates for radiosurgery considering the long-term durability of efficacy.

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Long-term outcomes of Gamma Knife radiosurgery for classic trigeminal neuralgia: implications of treatment and critical review of the literature. Clinical article

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OBJECT: Few long-term studies of Gamma Knife surgery (GKS) for trigeminal neuralgia (TN) exist. The authors report their long-term experience with the use of GKS in a previously reported cohort of patients with TN that has now been followed since 1996. METHODS: One hundred twelve patients with TN were treated with GKS at the University of Maryland between June 1996 and July 2001. Of these, 67% had no

invasive operations for TN prior to GKS, 13% had 1, 4% had 2, and 16% had >or= 3. The right side was affected in 56% of cases, predominantly involving V2 (26%), V3 (24%), or a combination of both (18%) branches. The median age at diagnosis was 56 years, and median age at GKS was 64 years. The median prescription dose of 75 Gy (range 70-80 Gy) was delivered to the involved trigeminal nerve root entry zone. The authors assessed the degree of pain before and after GKS by using the Barrow Neurological Institute (BNI) pain scale. RESULTS: In total, 102 patients took the survey at least once, for a response rate of 91%. Although not found to alter the conclusions of this study, 7 cases of atypical TN were found and these patients were removed, for a total of 95 cases herein analyzed. The median follow-up was 5.6 years (range 13-115 months). Before GKS, 88% of patients categorized their pain as BNI IV or V (inadequate control or severe pain on medication), whereas the remainder described their pain as BNI III (some pain, but controlled on medication). After GKS, 64% reported a BNI score of I (no pain, no medications), 5% had BNI II (no pain, still on medication), 12% had BNI III, and 19% reported a BNI score of IV or V. The median time to response was 2 weeks (range 0-12 weeks) and the median response duration was 32 months (range 0-112 months). Eighty-one percent reported initial pain relief, and actuarial rates of freedom from treatment failure at 1, 3, 5, and 7 years were 60, 41, 34, and 22%, respectively. Response duration was significantly better for those who had no prior invasive treatment versus those in whom a previous surgical intervention had failed (32 vs 21 months, $p < 0.02$). New bothersome facial numbness was reported in 6% of cases. CONCLUSIONS: This study represents one of the longest reported median follow-up periods and actuarial results for a cohort of patients with classic TN treated with GKS. Although GKS achieves excellent rates of initial pain relief, these results suggest a steady rate of late failure, particularly among patients who had undergone prior invasive surgical treatment. Despite a higher than expected recurrence rate, GKS remains a viable treatment option, particularly for patients who have had no prior invasive procedures. Patients with recurrences can still be offered salvage therapy with either repeat GKS, microvascular decompression, or rhizotomy.

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[Malignant lymphoma presented as left trigeminal neuralgia]

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A male, 60 years of age, presented with transient left facial pain located within all three divisions of the trigeminal nerve. Magnetic resonance imaging (MRI) revealed a swollen left trigeminal nerve with gadolinium enhancement. Following schwannoma diagnosis, the patient received Gamma Knife radiosurgery, which proved effective against symptoms of neuralgia and enhanced lesions. A relapse of unsteadiness was noted 11 months after initial treatment. Furthermore, while MRI presented a normal trigeminal nerve, multiple enhanced white matter mass lesions around the lateral ventricles were observed. Lastly, pathological examinations revealed diffuse large B cell lymphomas. The administration of high-dose methotrexate followed with whole brain radiation therapy appeared to have remarkable effects. No recurrences were observed in a 30 month duration following secondary treatment. Malignant lymphoma may present as trigeminal neuralgia. The conclusions from our case report and another literature review follow a difficult to near impossible task of establishing a correct diagnosis without biopsy in the initial stages of trigeminal nerve tumors. Therefore, a careful MRI follow-up is necessary even if the tumors show a favorable response towards primary steroid treatment or Gamma Knife radiosurgery.

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Salvage gamma knife stereotactic radiosurgery for surgically refractory trigeminal neuralgia

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PURPOSE: To evaluate the clinical outcome of patients with surgically refractory trigeminal neuralgia (TN) treated with rescue gamma knife radiosurgery (GKRS). METHODS AND MATERIALS: Seventy-nine patients with typical TN received salvage GKRS between 1997 and 2002 at the Barrow Neurological Institute (BNI). All patients had recurrent pain following at least one prior surgical intervention. Prior surgical interventions included percutaneous destructive procedures, microvascular decompression (MVD), or GKRS. Thirty-one (39%) had undergone at least two prior procedures. The most common salvage dose was 80 Gy, although 40-50 Gy was typical in patients who had received prior radiosurgery. Pain outcome was assessed using the

BNI Pain Intensity Score, and quality of life was assessed using the Brief Pain Inventory. RESULTS: Median follow-up after salvage GKRS was 5.3 years. Actuarial analysis demonstrated that at 5 years, 20% of patients were pain-free and 50% had pain relief. Pain recurred in patients who had an initial response to GKRS at a median of 1.1 years. Twenty-eight (41%) required a subsequent surgical procedure for recurrence. A multivariate Cox proportional hazards model suggested that the strongest predictor of GKRS failure was a history of prior MVD (p=0.029). There were no instances of serious morbidity or mortality. Ten percent of patients developed worsening facial numbness and 8% described their numbness as "very bothersome." CONCLUSIONS: GKRS salvage for refractory TN is well tolerated and results in long-term pain relief in approximately half the patients treated. Clinicians may reconsider using GKRS to salvage patients who have failed prior MVD.

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Nerve atrophy and a small cerebellopontine angle cistern in patients with trigeminal neuralgia

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OBJECT: The aim of this study was to provide information to help confirm the diagnosis of trigeminal neuralgia (TN) using MR imaging. METHODS: The authors evaluated atrophy of the trigeminal nerve, the cross-sectional area of the cerebellopontine angle (CPA) cistern, and the length of the cisternal segment of the trigeminal nerve on the affected side in 26 consecutive patients with TN who were treated using Gamma Knife surgery. RESULTS: The mean volume of the trigeminal nerve on the affected side was significantly smaller than the mean volume of the trigeminal nerve on the unaffected side ($p < 0.001$). Nerve atrophy was present in 25 patients (96.2%) on the affected side and in 1 patient on the unaffected side. The mean cross-sectional area of the CPA cistern on the affected side (188.5 mm2) was significantly smaller than the mean volume on the unaffected side (232.8 mm2) in 25 of the 26 patients ($p = 0.001$). The mean length of the cisternal segment of the trigeminal nerve on the affected side (7.9 mm) was significantly shorter than the mean length on the unaffected side (9.6 mm) in 25 of the 26 patients ($p = 0.001$). CONCLUSIONS: Among the patients with TN, there was a statistically significant difference in the MR imaging findings of the affected side compared with the unaffected side of the trigeminal nerve. Atrophy of the trigeminal nerve and a small CPA cistern in patients with TN provides additional markers for the diagnosis of TN and helps confirm the diagnosis based on clinical examination.

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Trigeminal neuralgia

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We completed a retrospective study of 270 patients with essential trigeminal neuralgia treated by gamma knife surgery. The target was localized on the retro-Gasserian portion of the nerve with 90 Gy at maximum. Among them, 150 patients were followed up more than 2 years. They were divided into 2 groups: pre-APS (41 patients) and post-APS (109 patients) treated by model C-APS since 2003. In the post-APS group, initial electric discharge was observed in 98.2% and at the last follow-up of at least 2 years in 79.8%. Complete recurrence was observed in 4.7% and postoperative complications were observed in 29.4%. These results were much better than those of the pre-APS group. There is no doubt that precise dose planning, C-APS treatment, so-called 'robotized micro radiosurgery', is important for improved treatment results.