

1.

**Year:** 2006

**Patient number:** 74

**Author:** Gordon, K.; Eddy, D.

**Reference:** Journal of Radiotherapy in Practice, 5, 1, 17-28, 2006

**Title:** The efficacy of stereotactic radiosurgery in the management of Vestibular Schwannomas - A retrospective analysis

**Abstract:** Vestibular Schwannomas (VS) are benign tumours arising from the neural sheath of the vestibular nerve, located near the auditory canal and cerebello-pontine angle adjacent to the brainstem making tumours "malignant by position". With high complication rates following surgery for tumour resection it is essential that alternative yet comparable management options such as Stereotactic Radiosurgery (SRS) be more fully evaluated in order to attain its efficacy and provide patients with alternative treatment modalities. The aim of this study was to critically evaluate the treatment outcomes of patients treated with SRS for Vestibular Schwannomas at the Cromwell Hospital's Gamma Knife Centre between 1998 and 2002. To facilitate this, information regarding patient's clinical history and SRS treatment parameters was collated and analysed via departmental on-line systems. In total the study provided a representative sample size of 74 patients with follow up data ranging from 6 months to 4 years post SRS (with a median of 12 months). At the maximum point of follow up attained by each patient 43% had an overall smaller tumour volume than at the time of treatment whilst 18% demonstrated a volume increase and 39% remained unchanged. In total 67% demonstrated evidence of decreased central tumour contrast enhancement (necrosis). 27% of patients suffered some form of immediate complication post SRS, all of which had resolved within 6 months. No correlation was found between the severity of the complication, prescription dose and tumour volume. Results are comparable with those from other published series highlighting a positive response from the tumour (decrease in volume) with few immediate complications, largely unchanged severity of symptoms post SRS and no negative impact on the patients quality of life. Although a number of significant papers have been published regarding the role of SRS in the management of VS there remains no definitive answer as to the best management option. Tumour control rates are comparable in both options and whilst both have their limitations, complication rates are generally much lower in the SRS group. Even so it is yet to be widely accepted as the treatment of choice in suitable cases. Nonetheless broadening the knowledge base with more research and education regarding the benefits of SRS will allow it to be promoted as a primary, contemporary treatment option in the management of VS. © 2006 Cambridge University Press.

2.

**Year:** 2006

**Patient number:** 254

**Author:** Hasegawa, Toshinori; Kida, Yoshihisa; Yoshimoto, Masayuki; Koike, Joji; Goto, Kishiko

**Reference:** Neurosurgery, 58, 6, 1119-28, 2006

**Title:** Evaluation of tumor expansion after stereotactic radiosurgery in patients harboring vestibular schwannomas

**Abstract:**OBJECTIVE: Stereotactic radiosurgery has been accepted as a safe and effective treatment in patients harboring a vestibular schwannoma. However, during follow-up, tumor expansion induced by high-dose irradiation can occur. Tumor expansion is more likely to be transient, but this phenomenon causes some confusion regarding whether further treatment should be performed. Our purpose was to clarify what type of tumor expansion requires additional treatment. METHODS: Between May 1991 and December 1998, 346 patients with a vestibular schwannoma, excluding two with neurofibromatosis, were treated using gamma knife radiosurgery. Of these, serial follow-up images to evaluate tumor expansion were available for 254 patients. Tumor expansion was classified into three types: central necrosis (Type A), solid expansion (Type B), and cyst enlargement or formation (Type C). RESULTS: Forty-two patients (17%) had tumor expansion during follow-up. Seventeen patients required additional treatment and 25 did not have any treatments after gamma knife radiosurgery. Type A, B, and C expansion was found in 14, 16, and 12 patients, respectively. Of these, three Type A patients, seven Type B patients, and seven Type C patients underwent salvage treatments. All patients in whom cyst formation developed eventually required craniotomy. CONCLUSION: Although tumor expansion was more likely to be transient, additional treatments should be considered in patients who experience neurological deterioration. We strongly recommend simply waiting and obtaining frequent follow-up images until the patients experience neurological deterioration, even when tumor expansion is developing, excluding cyst formation, which tends to continue.

3.

**Year:** 2006

**Patient number:** 123

**Author:** Hempel, J. M.; Hempel, E.; Wowra, B.; Schichor, Ch; Muacevic, A.; Riederer, A.

**Reference:** European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) :affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery, 263, 8, 714-8, 2006

**Title:** Functional outcome after gamma knife treatment in vestibular schwannoma

**Abstract:**Radiosurgery (RS) is a noninvasive, ambulatory special neurosurgical procedure for the treatment of vestibular schwannoma (VS). We treated 123 patients with unilateral schwannomas between 1994 and 2000 at the gamma knife (GK) center in Munich using a primary stereotactic procedure. These patients were followed up until June 2004 in respect to audiological, neurological, neurootological and radiological features before and after radiosurgical intervention. The actual tumor control rate of 8.2 years (mean) after GK surgery for all patients and a single treatment was calculated to be 96.7%. The impairment of hearing was on average 18% after GK, ranking from 0% gain of hearing loss up to 90%. Facial nerve function, graded according to the House-Brackmann scale, deteriorated in none of the patients; 5.8% reported a trigeminal neuralgia. Tinnitus developed in 4.1% of the patients after RS; 13.3% had vertigo for the

first time after the treatment, age apparently being a predisposing factor. Radiosurgical treatment for VS is an alternative to microsurgery (MS). It is associated with a lower rate of facial and trigeminal neuropathy, postoperative complications and hospital stay. The hearing preservation rate is equivalent to MS.

4.

**Year:** 2006

**Patient number:** 10

**Author:** Lee, Kuan J.; Barber, David C.; Walton, Lee

**Reference:** Medical physics, 33, 7, 2532-40, 2006

**Title:** Automated gamma knife radiosurgery treatment planning with image registration, data-mining, and Nelder-Mead simplex optimization

**Abstract:**Gamma knife treatments are usually planned manually, requiring much expertise and time. We describe a new, fully automatic method of treatment planning. The treatment volume to be planned is first compared with a database of past treatments to find volumes closely matching in size and shape. The treatment parameters of the closest matches are used as starting points for the new treatment plan. Further optimization is performed with the Nelder-Mead simplex method: the coordinates and weight of the isocenters are allowed to vary until a maximally conformal plan specific to the new treatment volume is found. The method was tested on a randomly selected set of 10 acoustic neuromas and 10 meningiomas. Typically, matching a new volume took under 30 seconds. The time for simplex optimization, on a 3 GHz Xeon processor, ranged from under a minute for small volumes (<1000 cubic mm, 2-3 isocenters), to several tens of hours for large volumes (>30,000 cubic mm, >20 isocenters). In 8/10 acoustic neuromas and 8/10 meningiomas, the automatic method found plans with conformation number equal or better than that of the manual plan. In 4/10 acoustic neuromas and 5/10 meningiomas, both overtreatment and undertreatment ratios were equal or better in automated plans. In conclusion, data-mining of past treatments can be used to derive starting parameters for treatment planning. These parameters can then be computer optimized to give good plans automatically.

5.

**Year:** 2006

**Patient number:** 82

**Author:** Massager, Nicolas; Nissim, Ouzi; Delbrouck, Carine; Devriendt, Daniel; David, Philippe; Desmedt, Françoise; Wikler, David; Hassid, Sergio; Brotchi, Jacques; Levivier, Marc

**Reference:** International journal of radiation oncology biology physics, 64, 5, 1331-40, 2006

**Title:** Role of intracanalicular volumetric and dosimetric parameters on hearing preservation after vestibular schwannoma radiosurgery

**Abstract:**PURPOSE: To analyze the relationship between hearing preservation after

gamma knife radiosurgery (GKR) for vestibular schwannoma (VS) and some volumetric and dosimetric parameters of the intracanalicular components of VS. **METHODS AND MATERIALS:** This study included 82 patients with a VS treated by GKR; all patients had no NF2 disease, a Gardner-Robertson hearing class 1-4 before treatment, a marginal dose of 12 Gy, and a radiologic and audiologic follow-up  $>$  or  $=1$  year post- GKR. The volume of both the entire tumor and the intracanalicular part of the tumor and the mean and integrated dose of these two volumes were correlated to the auditory outcomes of patients. **RESULTS:** At last hearing follow-up, 52 patients had no hearing worsening, and 30 patients had an increase of  $>$  or  $=1$  class on Gardner-Robertson classification. We found that hearing preservation after GKR is significantly correlated with the intracanalicular tumor volume, as well as with the integrated dose delivered to the intracanalicular tumor volume. **CONCLUSIONS:** Some volumetric and dosimetric parameters of the intracanalicular part of the tumor influence hearing preservation after GKR of VS. Consequently, we advise the direct treatment of patients with preserved functional hearing and a VS including a small intracanalicular volume.

6.

**Year:** 2006

**Patient number:** 208

**Author:** Pollock, Bruce E.

**Reference:** Neurosurgery, 58, 2, 241-8, 2006

**Title:** Management of vestibular schwannomas that enlarge after stereotactic radiosurgery: treatment recommendations based on a 15 year experience

**Abstract:** **OBJECTIVE:** Stereotactic radiosurgery is an effective alternative to surgical resection for the majority of patients with vestibular schwannomas (VS). However, after radiosurgery, the imaging characteristics of VSs are variable, and correct interpretation is critical to prevent unnecessary surgery for these patients. **METHODS:** A retrospective study of 208 consecutive patients with unilateral VS having radiosurgery between March 1990 and December 2001. Thirty (14%) patients had tumors that enlarged at least 2 mm after radiosurgery. The median follow-up after radiosurgery was 56 months (range 24-132 mo). **RESULTS:** The median time to tumor enlargement was 9 months (5-60 mo). The median volume increase was 75%. A loss of central enhancement was noted in 28 (93%) patients. Six (20%) patients had new symptoms noted at the time of tumor enlargement including hemifacial spasm ( $n = 2$ ), ataxia ( $n = 2$ ), trigeminal neuralgia ( $n = 1$ ), and facial numbness ( $n = 1$ ). Additional treatment was performed at the time of initial enlargement in 3 patients (resection,  $n = 2$ ; ventriculoperitoneal shunt,  $n = 1$ ). In the 28 patients who did not undergo resection at the time of initial enlargement, three patterns were identified on later imaging. Sixteen (57%) patients showed eventual tumor regression (type 1), and eight (29%) patients had tumors that increased and remained larger but did not show progressive enlargement (type 2). Four (14%) patients showed progressive enlargement on serial imaging (type 3) and underwent additional treatment (resection,  $n = 3$ ; stereotactic radiation therapy,  $n = 1$ ). **CONCLUSION:** Tumor expansion after VS radiosurgery rarely denotes a failed procedure, and the majority of patients only require further imaging. Approximately one third of tumors that enlarge will remain increased in

size compared with the time of radiosurgery but will not show sequential growth. Additional tumor treatment should be reserved only for patients who demonstrate progressive tumor enlargement on serial imaging (2% in this series).

7.

**Year:** 2006

**Patient number:** 82

**Author:** Pollock, Bruce E.; Driscoll, Colin L. W.; Foote, Robert L.; Link, Michael J.; Gorman, Deborah A.; Bauch, Christopher D.; Mandrekar, Jayawant N.; Krecke, Karl N.; Johnson, Craig H.

**Reference:** Neurosurgery, 59, 1, 77-85, 2006

**Title:** Patient outcomes after vestibular schwannoma management: a prospective comparison of microsurgical resection and stereotactic radiosurgery

**Abstract:** **OBJECTIVE:** The best management for patients with small- to medium- sized vestibular schwannomas (VS) is controversial. **METHODS:** A prospective cohort study of 82 patients with unilateral, unoperated VS less than 3 cm undergoing surgical resection (n = 36) or radiosurgery (n = 46). Patients undergoing resection were younger (48.2 yr versus 53.9 yr, P = 0.03). The groups were similar with regard to hearing loss, associated symptoms, and tumor size. The mean follow-up period was 42 months (range, 12-62 mo). **RESULTS:** Normal facial movement and preservation of serviceable hearing was more frequent in the radiosurgical group at 3 months (P < 0.001), 1 year (P < 0.001), and at the last follow-up examination (P < 0.01) compared with the surgical resection group. Patients undergoing surgical resection had a significant decline in the following subscales of the Health Status Questionnaire 3 months after surgery: physical functioning (P = 0.006), role-physical (P < 0.001), energy/fatigue (P = 0.02), and overall physical component (P = 0.004). Patients in the surgical resection group continued to have a significant decline in the physical functioning (P = 0.04) and bodily pain (P = 0.04) subscales at 1 year and in bodily pain (P = 0.02) at the last follow-up examination. The radiosurgical group had no decline on any component of the Health Status Questionnaire after the procedure. The radiosurgical group had lower mean Dizziness Handicap Inventory scores (16.5 versus 8.4, P = 0.02) at the last follow-up examination. There was no difference in tumor control (100 versus 96%, P = 0.50). **CONCLUSION:** Early outcomes were better for VS patients undergoing stereotactic radiosurgery compared with surgical resection (Level 2 evidence). Unless long-term follow-up evaluation shows frequent tumor progression at currently used radiation doses, radiosurgery should be considered the best management strategy for the majority of VS patients.

8.

**Year:** 2005

**Patient number:** 195

**Author:** Chung, Wen Yuh; Liu, Kang Du; Shiao, Cheng Ying; Wu, Hsiu Mei; Wang, Ling Wei; Guo, Wan Yuo; Ho, Donald Ming Tak; Pan, David Hung Chi

**Reference:** Journal of neurosurgery, 102, 87-96, 2005

**Title:** Gamma knife surgery for vestibular schwannoma: 10-year experience of 195 cases

**Abstract:**OBJECT: The authors conducted a study to determine the optimal radiation dose for vestibular schwannoma (VS) and to examine the histopathology in cases of treatment failure for better understanding of the effects of irradiation. METHODS: A retrospective study was performed of 195 patients with VS; there were 113 female and 82 male patients whose mean age was 51 years (range 11-82 years). Seventy-two patients (37%) had undergone partial or total excision of their tumor prior to gamma knife surgery (GKS). The mean tumor volume was 4.1 cm<sup>3</sup> (range 0.04-23.1 cm<sup>3</sup>). Multiisocenter dose planning placed a prescription dose of 11 to 18.2 Gy on the 50 to 94% isodose located at the tumor margin. Clinical and magnetic resonance (MR) imaging follow-up evaluations were performed every 6 months. A loss of central enhancement was demonstrated on MR imaging in 69.5% of the patients. At the latest MR imaging assessment decreased or stable tumor volume was demonstrated in 93.6% of the patients. During a median follow-up period of 31 months resection was avoided in 96.8% of cases. Uncontrolled tumor swelling was noted in five patients at 3.5, 17, 24, 33, and 62 months after GKS, respectively. Twelve of 20 patients retained serviceable hearing. Two patients experienced a temporary facial palsy. Two patients developed a new trigeminal neuralgia. There was no treatment-related death. Histopathological examination of specimens in three cases (one at 62 months after GKS) revealed a long-lasting radiation effect on vessels inside the tumor. CONCLUSIONS: Radiosurgery had a long-term radiation effect on VSs for up to 5 years. A margin 12-Gy dose with homogeneous distribution is effective in preventing tumor progression, while posing no serious threat to normal cranial nerve function.

9.

**Year:** 2005

**Patient number:** 288

**Author:** Hasegawa, Toshinori; Fujitani, Shigeru; Katsumata, Shun; Kida, Yoshihisa; Yoshimoto, Masayuki; Koike, Joji

**Reference:** Neurosurgery, 57, 2, 257-65, 2005

**Title:** Stereotactic radiosurgery for vestibular schwannomas: analysis of 317 patients followed more than 5 years

**Abstract:**OBJECTIVE: Many investigators have reported successful treatment of vestibular schwannomas with gamma knife radiosurgery (GKRS). However, long-term outcomes should be evaluated before concluding that GKRS is truly safe and effective for the treatment of vestibular schwannomas. METHODS: Between May 1991 and December 1998, 346 consecutive patients (excluding those presenting with neurofibromatosis Type 2) were treated with GKRS. Of these, 317 patients were assessed. Twenty-nine patients were lost to follow-up within 5 years. RESULTS: The median follow-up period was 7.8 years. Of 301 patients who underwent serial follow-up imaging, two (1%) experienced complete remission, 184 (61%) experienced partial remission, 93 (31%) had stable tumors, and 22 (7%) experienced treatment failure. The actuarial 5- or 10-year progression-free survival (PFS) rate was 93 and 92%, respectively.

Tumors less than 15 cm<sup>3</sup> in volume (10-yr PFS, 96%; P < 0.001) or which did not compress the brainstem and deviate the fourth ventricle (10-yr PFS, 97%; P = 0.008) resulted in significantly better PFS rates. Failure of treatment usually occurred within 3 years. When the tumor was treated with a marginal dose of 13 Gy or less, the hearing preservation rate was 68%, transient facial palsy developed at a rate of 1%, and facial numbness developed at a rate of 2%. **CONCLUSION:** GKRS proved to be a safe and effective treatment for patients followed longer than 5 years who presented with tumors with a volume of less than 15 cm<sup>3</sup> and who did not have significant fourth ventricle deviation. Good functional outcomes were observed in this group of patients.

10.

**Year:** 2005

**Patient number:** 73

**Author:** Hasegawa, Toshinori; Kida, Yoshihisa; Kobayashi, Tatsuya; Yoshimoto, Masayuki; Mori, Yoshimasa; Yoshida, Jun

**Reference:** Journal of neurosurgery, 102, 1, 10-6, 2005

**Title:** Long-term outcomes in patients with vestibular schwannomas treated using gamma knife surgery: 10-year follow up

**Abstract:** **OBJECT:** Gamma knife surgery (GKS) has been a safe and effective treatment for vestibular schwannomas in both the short and long term, although less is known about long-term outcomes in the past 10 years. The aim of this study was to clarify long-term outcomes in patients with vestibular schwannomas treated using GKS based on techniques in place in the early 1990s. **METHODS:** Eighty patients harboring a vestibular schwannoma (excluding neurofibromatosis Type 2) were treated using GKS between May 1991 and December 1993. Among these, 73 patients were assessed; seven were lost to follow up. The median duration of follow up was 135 months. The mean patient age at the time of GKS was 56 years old. The mean tumor volume was 6.3 cm<sup>3</sup>, and the mean maximal and marginal radiation doses applied to the tumor were 28.4 and 14.6 Gy, respectively. Follow-up magnetic resonance images were obtained in 71 patients. Forty-eight patients demonstrated partial tumor remission, 14 had tumors that remained stable, and nine demonstrated tumor enlargement or radiation-induced edema requiring resection. Patients with larger tumors did not fare as well as those with smaller lesions. The actuarial 10-year progression-free survival rate was 87% overall, and 93% in patients with tumor volumes less than 10 cm<sup>3</sup>. No patient experienced malignant transformation. **CONCLUSIONS:** Gamma knife surgery remained an effective treatment for vestibular schwannomas for longer than 10 years. Although treatment failures usually occurred within 3 years after GKS, it is necessary to continue follow up in patients to reveal delayed tumor recurrence.

11.

**Year:** 2005

**Patient number:** 45

**Author:** Huang, C. F.; Tu, H. T.; Lo, H. K.; Wang, K. L.; Liu, W. S.

**Reference:** Journal of the Chinese Medical Association, 68, 7, 315-320, 2005

**Title:** Radiosurgery for vestibular schwannomas

**Abstract:**Background: Radiosurgery has been established as an important alternative to microsurgery. We report our experience with radiosurgery for tumor control and the complications of unilateral vestibular schwannomas. Methods: We reviewed our early experience regarding clinical presentation, management and outcomes in 45 patients with acoustic schwannomas who underwent gamma knife stereotactic radiosurgery. The median follow-up period was 25 months (range, 6-48 months). Thirteen patients had undergone 1 or more previous resections before radiosurgery; 32 underwent radiosurgery as the first procedure. Median tumor volume was 4.5 mL (range, 0.5-30.0), and median radiotherapy dose was 11.5 Gy (range, 10.5-14.0 Gy). Results: Tumor control was achieved in 43 patients (95.6%). Loss of central contrast enhancement was a characteristic change and was noted in 29 patients (64.4%). Reduction in tumor size was shown in 15 patients (33.3%). Thirteen patients (28.9%) had good or serviceable hearing preoperatively, and in all of these, the preoperative status was retained immediately after radiosurgery. At follow-up, however, 10 patients (76.9%) had preserved hearing and 3 (23.1%) had reduced hearing on the treated side. Hearing in 1 patient that was not serviceable preoperatively later improved to a serviceable level. No patients had delayed facial palsy or lower cranial nerve dysfunction, but one had delayed trigeminal sensory loss. Conclusion: Radiosurgery achieved a high tumor control rate and a relatively low post- radiosurgical complication rate for acoustic neuromas. © 2005 Elsevier. All rights reserved.

12.

**Year:** 2005

**Patient number:** 18

**Author:** Inoue, Hiroshi K.

**Reference:** Journal of neurosurgery, 102, 111-3, 2005

**Title:** Low-dose radiosurgery for large vestibular schwannomas: long-term results of functional preservation

**Abstract:**OBJECT: The author conducted a study to assess the long-term results obtained in patients who underwent GKS for large vestibular schwannomas (> 3 cm in diameter). Facial and cochlear nerve functions were evaluated. METHODS: Twenty consecutive large tumors in 18 patients (including two cases of neurofibromatosis Type 2 (NF2)) were followed for more than 6 years. There were eight tumors that were more than 4 cm in maximum diameter. Microsurgery had already been performed prior to GKS in 11 patients (nine recurrent and two residual tumors). Four patients (including one with NF2) died during the follow-up period of other diseases or by accident. Fourteen of 15 tumors were stable or decreased in size. Microsurgery was performed in one patient 2 years after radiosurgery. Facial nerve function was preserved in all patients and hearing preserved in four of five patients with cochlear nerve function prior to radiosurgery. No adverse effects of radiosurgery have been observed to date. CONCLUSIONS: Gamma knife surgery seems to have a place in the low-dose treatment of selected large vestibular

schwannoma in patients with a reasonable chance of retaining facial function and pretreatment hearing level. Patients with severe brainstem compression should first be undergo microsurgery.

13.

**Year:** 2005

**Patient number:** 829

**Author:** Lunsford, L. Dade; Niranjan, Ajay; Flickinger, John C.; Maitz, Ann; Kondziolka, Douglas

**Reference:** Journal of neurosurgery, 102, 195-9, 2005

**Title:** Radiosurgery of vestibular schwannomas: summary of experience in 829 cases

**Abstract:**OBJECT: Management options for vestibular schwannomas (VSs) have greatly expanded since the introduction of stereotactic radiosurgery. Optimal outcomes reflect long-term tumor control, preservation of cranial nerve function, and retention of quality of life. The authors review their 15-year experience. METHODS: Between 1987 and 2002, some 829 patients with VSs underwent gamma knife surgery (GKS). Dose selection, imaging, and dose planning techniques evolved between 1987 and 1992 but thereafter remained stable for 10 years. The average tumor volume was 2.5 cm<sup>3</sup>. The median margin dose to the tumor was 13 Gy (range 10-20 Gy). No patient sustained significant perioperative morbidity. The average duration of hospital stay was less than 1 day. Unchanged hearing preservation was possible in 50 to 77% of patients (up to 90% in those with intracanalicular tumors). Facial neuropathy risks were reduced to less than 1%. Trigeminal symptoms were detected in less than 3% of patients whose tumors reached the level of the trigeminal nerve. Tumor control rates at 10 years were 97% (no additional treatment needed). CONCLUSIONS: Superior imaging, multiple isocenter volumetric conformal dose planning, and optimal precision and dose delivery contributed to the long-term success of GKS, including in those patients in whom initial microsurgery had failed. Gamma knife surgery provides a low risk, minimally invasive treatment option for patients with newly diagnosed or residual VS. Cranial nerve preservation and quality of life maintenance are possible in long-term follow up.

14.

**Year:** 2005

**Patient number:** 103

**Author:** Myrseth, Erling; Møller, Per; Pedersen, Paal Henning; Vassbotn, Flemming S.; Wentzel, Larsen Tore; Lund, Johansen Morten

**Reference:** Neurosurgery, 56, 5, 927-35, 2005

**Title:** Vestibular schwannomas: clinical results and quality of life after microsurgery or gamma knife radiosurgery

**Abstract:**OBJECTIVE: The aim of the present study was to evaluate the overall treatment efficacy (tumor control, facial nerve function, complications) and quality of life for patients treated primarily for unilateral vestibular schwannomas of 30 mm or less,

either by microsurgery or by gamma knife (GK) radiosurgery. The results for the two treatment groups are compared with each other, with main emphasis on the long-term quality of life. **METHODS:** This is a retrospective study of 189 consecutive patients, 86 treated by microsurgery and 103 by gamma knife. The mean observation time was 5.9 years. All patients had a magnetic resonance imaging scan and clinical evaluation performed toward the end of the study. To evaluate the quality of life, we used two standardized questionnaires, the Glasgow Benefit Inventory and Short-Form 36. The questionnaires were sent to the 168 living patients. The reply rate was 83.3%. **RESULTS:** A total of 79.8% of the patients in the microsurgery group and 94.8% of the GK patients had a good facial nerve function (House-Brackmann Grade 1-2). Hearing was usually lost after microsurgery, whereas the GK patients had preserved hearing, which often became reduced over the years after the treatment. The treatment efficacy, defined as no need for additional treatment, was similar for the two treatment modalities. Quality of life was reduced compared with normative data, being most reduced in the microsurgery group. Some of the quality of life questions showed an association with facial nerve function and sex. **CONCLUSION:** Posttreatment facial nerve function, hearing, complication rates, and quality of life were all significantly in favor of GK radiosurgery.

15.

**Year:** 2005

**Patient number:** 25

**Author:** Paek, Sun Ha; Chung, Hyun Tai; Jeong, Sang Soon; Park, Chul Kee; Kim, Chae Yong; Kim, Jeong Eun; Kim, Dong Gyu; Jung, Hee Won

**Reference:** Cancer, 104, 3, 580-590, 2005

**Title:** Hearing preservation after gamma knife stereotactic radiosurgery of vestibular schwannoma

**Abstract:**BACKGROUND. To evaluate the hearing preservation rate and to determine its prognostic factors after gamma knife (GK) stereotactic radiosurgery (SRS) in patients with vestibular schwannoma, the authors used a prospective study design to analyze these patients.METHODS. Between December 1997 and January 2002, 25 patients with vestibular schwannoma with serviceable hearing were enrolled in the current study. The median tumor volume was 3.0 cc (0.16-9.1 cc). The prescription dose was 12.0 +/- 0.7 gray at an isodose line of 49.8 +/- 1.1%. The tumor control rate and complications were evaluated by focusing on hearing preservation and its prognostic factors.RESULTS. Based on radiologic Study, the tumor control rate was 92% during the median follow-up period of 45 months. The trigeminal and facial nerve preservation rates were 95% and 100%, respectively. Thirteen (52%) of the 25 patients preserved serviceable hearing and 9 (36%) patients retained their pre-GK G-R grade levels after GK SRS. However, 16 patients showed hearing deterioration > 20 dB within 3-6 months and this trend continued for 24 months after the treatment. The maximum radiotherapy dose delivered to the cochlear nucleus was the single, significant prognostic factor of hearing deterioration.CONCLUSIONS. The authors concluded that a more sophisticated strategy to prevent hearing deterioration during the first 6 months post-GK SRS is necessary to improve long-term hearing preservation. Cancer 2005; 104:580-90. (c) 2005 American

Cancer Society.

16.

**Year:** 2005

**Patient number:** 23

**Author:** Poetker, David M.; Jursinic, Paul A.; Runge, Samuelson Christina L.; Wackym, P. Ashley

**Reference:** Otology & neurotology : official publication of the American Otological Society American Neurotology Society (and) European Academy of Otology and Neurotology, 26, 6, 1220-8, 2005

**Title:** Distortion of magnetic resonance images used in gamma knife radiosurgery treatment planning: implications for acoustic neuroma outcomes

**Abstract:** **OBJECTIVE:** To quantify the image distortion of our series of acoustic neuromas treated with gamma knife radiosurgery. **STUDY DESIGN:** Retrospective chart and digital radiographic file review with quantitative assessment of gamma knife treatment plans. **SETTING:** Tertiary referral center. **PATIENTS:** Patients undergoing gamma knife radiosurgery for the treatment of acoustic neuromas. **INTERVENTION:** Gamma knife radiosurgery. **MAIN OUTCOME MEASURES:** Gamma knife treatment plans containing magnetic resonance images were reviewed at each axial, sagittal, and coronal slice. The length of the greatest displacement of the treatment plan was measured and the volume of the treatment plan that fell outside of the internal auditory canal calculated. Known clinical measurements of audiometric, vestibular, facial, and trigeminal nerve functions were then compared with current measurements of tumor size. **RESULTS:** Twenty-two of the 23 patients had measurable image shifts on the axial images. The range of the image shift was 0 to 5.8 mm, with a mean shift of 1.92 +/- 1.29 mm (+/- standard deviation). Tumor volumes of the treatment plan that fell outside of the internal auditory canal ranged from 0 to 414 mm, with a mean of 90.5 mm. The mean percentage that fell outside of the internal auditory canal was 16.7% of total tumor volume (range, 2.4-77.6%). We could not draw any consistent correlations between degree of image shift and continued tumor growth or objective examination values. **CONCLUSION:** We have demonstrated a small but potentially significant shift in the treatment plan of gamma knife radiosurgery when based on magnetic resonance images. Although the image shift does not seem to affect the growth of the acoustic neuromas or auditory or facial nerve function, longer term follow-up is required to fully appreciate the true impact of this image shift.

17.

**Year:** 2005

**Patient number:** 78

**Author:** van, Eck Albertus T. C. J.; Horstmann, Gerhard A.

**Reference:** Journal of neurosurgery, 102, 204-6, 2005

**Title:** Increased preservation of functional hearing after gamma knife surgery for

vestibular schwannoma

**Abstract:**OBJECT: Gamma knife surgery (GKS) for vestibular schwannoma is still associated with an additional hearing loss of approximately 30%. The purpose of this study was to record the effect on hearing preservation of maintaining a margin dose of 13 Gy while reducing the maximum dose to 20 Gy. METHODS: Seventy-eight of 95 patients who entered a prospective protocol with a follow up of at least 12 months (mean 22 months) were evaluated. The mean tumor volume was 2.28 cm<sup>3</sup>. After a mean follow-up duration of 22 months, the magnetic resonance imaging- based tumor control rate was 87%. In two cases a second procedure (surgery) was necessary. Thus, the clinical control rate was 97.5%. In two cases there was an increase in trigeminal dysesthesia. One patient suffered transient facial nerve impairment. Functional hearing was preserved in 83.4% of the patients with functional hearing preoperatively. CONCLUSIONS: Reducing the maximum dose to 20 Gy seems to be an effective treatment, which probably increases preservation of functional hearing without sacrificing the high tumor control rates achieved in radiosurgery. Postradiosurgery tumor swelling occurred in 25% of the cases and was not correlated with hearing deterioration.

18.

**Year:** 2005

**Patient number:** 111

**Author:** Wowra, Berndt; Muacevic, Alexander; Jess, Hempten Anja; Hempel, John Martin; Müller, Schunk Stefanie; Tonn, Jörg Christian

**Reference:** Journal of neurosurgery, 102, 114-8, 2005

**Title:** Outpatient gamma knife surgery for vestibular schwannoma: definition of the therapeutic profile based on a 10-year experience

**Abstract:**OBJECT: The purpose of the study was to define the therapeutic profile of outpatient gamma knife surgery (GKS) for vestibular schwannoma (VS) by using sequential tumor volumetry to quantify changes following treatment. METHODS: A total of 111 patients met the inclusion criteria. The median follow-up duration was 7 years (range 5-9.6 years). Thirty-seven patients (33%) had undergone surgery before GKS and 10 (9%) had neurofibromatosis Type 2 (NF2). The median VS volume was 1.6 cm<sup>3</sup> (range 0.08-8.7 cm<sup>3</sup>). The actuarial 6-year tumor control rate after a single GKS treatment was 95%. Tumor swelling was observed in 43 patients (38.7%). Recurrence was significantly associated with NF2 ( $p < 0.003$ ) and the reduced dose ( $p < 0.03$ ) delivered to these tumors. The incidence of facial nerve neuropathy was mainly determined by surgery prior to GKS ( $p < 0.0001$ ). Facial nerve radiation toxicity was mild and transient. No permanent facial nerve toxicity was observed. Trigeminal neuropathy occurred in 13 patients, and this was correlated with the VS volume ( $p < 0.02$ ). The median hearing loss was -10 dB (range +20 dB to -70 dB). The risk of hearing loss was correlated with age and transient tumor swelling ( $p < 0.05$ ) but not with dose parameters or NF2. CONCLUSIONS: Outpatient GKS is feasible, effective, and safe. Its therapeutic profile compares favorably with that of microsurgery.

19.

**Year:** 2004

**Patient number:** 54

**Author:** Delsanti, C.; Régis, J.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 401-6, 2004

**Title:** Cystic vestibular schwannomas

**Abstract:** RATIONALE: Patients with cystic vestibular schwannomas (VS) are a radiologically well-defined subgroup of patients who classically have poor outcome after microsurgical resection. Since Pendl's report of a high rate of failures, they are also considered as poor candidates for radiosurgery. MATERIAL AND METHOD: Among the 1000 consecutive patients who underwent Gamma Knife surgery in Marseilles, France between July 1992 and January 2002, we have collected and studied 54 patients with cystic VS at the time of treatment. RESULTS: The median follow-up of this group was 26 Months (mean: 33, range: 6-90). Failure (6.4%) led to microsurgical removal in 2 patients and a radiosurgery in 1 patient with a delay of 2 Years for 2 of them and 3 Years for the third. No facial palsy has been reported. Two patients developed transient hypesthesia. Among the 32 patients with functional hearing at the time of treatment, 53% preserved their hearing function at 3 Years. CONCLUSIONS: We found an increased risk of failure in this group compared to patients with no cyst at time of radiosurgery (93.6% instead of 98%). But this is also a group where we observe most dramatic shrinkage. Prudent radiosurgical treatment of cystic vestibular schwannomas remains mandatory: strict follow-up is specially important.

20.

**Year:** 2004

**Patient number:** 1000

**Author:** Delsanti, C.; Tamura, M.; Galanaud, D.; Régis, J.

**Reference:** Neurochirurgie, 50, 2-3 II, 312-319, 2004

**Title:** Changing radiological results, pitfalls and criteria of failure

**Abstract:** Rationale. - To evaluate the morphological changes occurring during the years following radiosurgery in order to better define the cure- failure parameters. Material and methods. - Between July 1992 and January 2002 the otoneurosurgical group of the Timone Hospital in Marseille have operated 1000 vestibular schwannomas. The MR imaging performed before (at diagnosis) during and after radiosurgery (6 months, 1 year, 2 years, 3 years, 5 years, 7 years and 10 years) was carefully studied. Systematically six lengths measurements were obtained for each lesion. Results. - Preoperatively 129 patients were had progressive tumors. At time of radiosurgery, median tumor volume was 732mm<sup>3</sup> (3) (mean: 1346, range: 20-14405). According to the Koos topographical classification, lesions were stage I in 80 patients, stage II in 538 patients, stage III in 322 patients and stage IV in 56 patients. A clear loss of the central enhancement was visible on the postoperative MR control at 6 months and/or 1 year in 45.5% of patients. In 64% of these patients, this loss of the central contrast enhancement have disappeared. A significant increase of the tumor size was recorded in 15% of the patients. The median

increase was 62% (mean: 78%, range: 30-350%). Progression led to salvage surgery (either resection or radiosurgery), in only 3% of the patients. Conclusion. - The specificity of the morphological changes after radiosurgery, when ignored, can lead to misinterpretation and eventually to inappropriate decisions, dangerous for the patient. The analysis of our results had led us to consider continuous progression after 3 years as mandatory to retain the diagnosis of failure.

21.

**Year:** 2004

**Patient number:** 313

**Author:** Flickinger, John C.; Kondziolka, Douglas; Niranjan, Ajay; Maitz, Ann; Voynov, George; Lunsford, L. Dade

**Reference:** International journal of radiation oncology biology physics, 60, 1, 225-30, 2004

**Title:** Acoustic neuroma radiosurgery with marginal tumor doses of 12 to 13 Gy

**Abstract:** **PURPOSE:** To define tumor control and clinical outcomes of radiosurgery to marginal tumor doses of 12-13 Gy for unilateral acoustic neuroma patients. **METHODS AND MATERIALS:** Three hundred thirteen patients with previously untreated unilateral acoustic neuromas (vestibular schwannomas) underwent gamma knife radiosurgery between February 1991 and February 2001 with marginal tumor doses of 12-13 Gy (median, 13 Gy). Median follow-up was 24 months (maximum, 115 months; 36 patients with > or =60 months). Maximum doses were 20-26 Gy (median, 26 Gy), and treatment volumes were 0.04-21.4 mL (median, 1.1 mL). **RESULTS:** The actuarial 6-year clinical tumor control rate (no requirement for surgical intervention) for the entire series was 98.6 +/- 1.1%. Two patients required tumor resection; one had a complete resection for solid tumor growth and one required partial resection for an enlarging adjacent subarachnoid cyst. Six-year actuarial rates for preservation of facial nerve function, normal trigeminal nerve function, unchanged hearing level, and useful hearing were 100%, 95.6 +/- 1.8%, 70.3 +/- 5.8%, and 78.6 +/- 5.1%, respectively. The risk of developing trigeminal neuropathy correlated with increasing tumor volume ( $p = 0.038$ ). **CONCLUSIONS:** Acoustic neuroma radiosurgery with doses of 12-13 Gy provides high rates of tumor control and cranial nerve preservation.

22.

**Year:** 2004

**Patient number:** 175

**Author:** Gabert, K.; Régis, J.; Delsanti, C.; Roche, P. H.; Facon, F.; Tamura, M.; Pellet, W.; Thomassin, J. M.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 350-7, 2004

**Title:** Preserving hearing function after Gamma Knife radiosurgery for unilateral vestibular schwannoma

**Abstract:** **OBJECTIVE:** The majority of the patients still lose hearing function in spite of

the technical advances in microsurgery. We wanted to evaluate preservation of hearing function potential after Gamma Knife Surgery. **MATERIAL AND METHOD:** In Marseille, we performed 1000 Gamma-Knife procedures for vestibular schwannomas between July 1992 and January 2002. This population included 175 patients undergoing first intention surgery for a unilateral schwannoma with functional preoperative hearing (Gardner and Robertson 1 or 2) who were studied with a follow- up longer than 3 Years. Univariate and multivariate analysis was performed. **RESULTS:** Numerous parameters significantly influenced the probability of functional hearing preservation at 3 years. The overall rate of preservation was 60%. The main parameters of predictability were limited hearing loss (Gardner and Robertson stage 1 versus 2) before radiosurgery, presence of tinnitus as the initial symptom, young age and the small tumor size. Preservation of functional hearing at 3 years was 77.8% when the patient was initially in stage I, 80% when the patient's first symptom was tinnitus, and 95% when the patient had both. In these patients, the probability of functional preservation at 5 years was 84%. **CONCLUSION:** We report a large population of patients treated by radiosurgery with initial functional hearing. These results demonstrate that a large percentage of selected patients can preserve functional hearing after Gamma Knife Surgery, their chances of functional preservation being greater than after microsurgery or simple surveillance.

23.

**Year:** 2004

**Patient number:** 17

**Author:** Iwai, Y.; Yamanaka, K.; Uyama, T.; Morikawa, T.; Honda, Y.; Matsusaka, Y.; Komiyama, M.; Yasui, T.

**Reference:** Japanese Journal of Neurosurgery, 13, 7, 508-514, 2004

**Title:** The treatment for acoustic neuromas: Indication and results of gamma knife radiosurgery and surgery

**Abstract:** We evaluated the treatment results of acoustic neuromas in the era of radiosurgery. We treated acoustic neuromas using the following strategy. Small to medium size tumors (below 3 cm) were treated by gamma knife radiosurgery and large tumors (above 3 cm) were treated using a combination of surgery and radiosurgery. Using gamma knife radiosurgery, we were able to achieve 96.4% of clinical tumor growth control with 0.7% incidence of trigeminal neuropathy (without new facial neuropathy). We used low dose radiosurgery (average tumor marginal dose 11.8 Gy) with a follow-up of an average of 54 months. For the 17 patients with large tumors treated by the combination of surgery and radiosurgery who could be followed up for over 24 months after radiosurgery, we were able to preserve normal facial function (House-Brackmann grade I-II) in 70.6% of the patients after subtotal removal. High clinical tumor growth control for residual tumor was achieved in 94.1% of subjects with an average of 40 months follow-up. By using this strategy, the treatment outcome for acoustic neuroma is improved from the standpoint of functional outcome and maintaining the patient's quality of life.

24.

**Year:** 2004

**Patient number:** 52

**Author:** Landy, Howard J.; Markoe, Arnold M.; Wu, Xiaodong; Patchen, Sherri J.; Reis, Isildinha M.; Takita, Cristiane; Abdel, Wahab May M.; Wen, B. Chen; Wolfson, Aaron H.; Huang, David T.

**Reference:** Stereotactic and functional neurosurgery, {Stereotact-Funct-Neurosurg }, 2004 (epub: 04 Oct 2004), vol. 82, no. 4, p. 147-52, ISSN: 1011-6125.

**Title:** Safety and efficacy of tiered limited-dose gamma knife stereotactic radiosurgery for unilateral acoustic neuroma

**Abstract:** Stereotactic radiosurgery has become a more widely employed modality of treatment for acoustic neuromas, but controversy still arises regarding the safety and efficacy of the technique. In general, radiation doses have been reduced over time. Since beginning treatments of acoustic neuromas with the Gamma Knife at the University of Miami/Jackson Memorial Medical Center in 1994, a dose regimen was adopted by the first author employing limited doses selected on the basis of tumor size with the anterior and medial regions of the prescription isodose surface kept just inside the gadolinium-enhanced limit of the tumor, in order to protect the facial nerve and brainstem. The records of patients treated for unilateral tumors were retrospectively reviewed. Fifty-two patients, aged 23-83 years, were treated with peripheral tumor doses of 10-14 Gy at the 45-70% isodoses. No patient developed new facial weakness or sensory loss; 3 patients had minor transient facial twitching within a few months of treatment. Of 34 patients followed more than 1 year (range 14-100 months, mean 43.4 months, median 37 months), 17 tumors reduced in size, 16 remained unchanged, and 1 increased in size. One patient, who had radiosurgery as planned postoperative adjuvant treatment after partial resection of a large tumor, developed an enlarging peritumoral arachnoid cyst that required surgical resection 79 months after radiosurgery. Patients with good pretreatment hearing retained approximately the same subjective level of hearing. Very good control of unilateral acoustic neuroma has been achieved by a limited-dose scheme that produces minimal complications, but due to the frequently indolent course of these tumors, continued long-term monitoring will be necessary. 2004 S. Karger AG, Basel.

25.

**Year:** 2004

**Patient number:** 219

**Author:** Muacevic, A.; Jess, Hempten A.; Tonn, J. C.; Wowra, B.

**Reference:** Acta neurochirurgica. Supplement, 91, 75-8, 2004

**Title:** Results of outpatient gamma knife radiosurgery for primary therapy of acoustic neuromas

**Abstract:** Stereotactic radiosurgery (SRS) has been recognized as a non-invasive alternative to surgery for the treatment of acoustic neuromas. Purpose of the current study was to define the impact of outpatient gamma knife radiosurgery (GKS) for patients with unilateral sporadic acoustic neuromas treated within ten years. Follow-up images were analyzed using tumor volume measurements. 219 patients with sporadic acoustic neuromas were treated by GKS as primary therapy. Patients with NF-2 tumors were

excluded. Patients were eligible for GKS up to a size limit of 12.5 cm<sup>3</sup>. The median follow up time was 6 years after radiosurgery. The local tumor control rate was high (97%). Cranial nerve morbidities were comparably low. 10% of the patients developed hearing loss after radiosurgery and one patient experienced a transient facial neuropathy (0.5%). Transient trigeminal neuropathy developed in 12 patients (5%) and was found to be dependent on the tumor size before treatment. Outpatient gamma knife radiosurgery is a safe and effective treatment method for selected patients with sporadic vestibular schwannomas.

26.

**Year:** 2004

**Patient number:** 218

**Author:** Ouaknine, M.; Hugon, M.; Roman, S.; Thomassin, J. M.; Sarabian, N.; Régis, J.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 358-66, 2004

**Title:** Improvement in postural orientation and stability after stereotactic gamma irradiation of acoustic neurinomas

**Abstract:** Non-surgical stereotactic gamma ionizing irradiation was developed in order to produce a lethal effect on unilateral acoustic neurinomas (vestibular schwannomas). We present a study of postural vestibular dependent performances in 218 patients before and after curative irradiation. Subjects were asked to stand at ease on a static dynamometric foot-plate, gazing at a fixed point in front of them (EO condition) or to stand eyes closed (EC condition). Statokinesigrams were registered during two consecutive sessions of 51.2 sec, under EO and EC conditions. These sessions were first managed the days before (d-1), and after (d+1) irradiation; others were performed later (d+1 to 5 Years; n=37). Center of pressure (CofP) mediolateral (X) and sagittal (Y) positions were quantified every 100 msec. Mean Xm session value (with SD) was taken as a personal parameter for left or right body inclination. Area S for 90% of the XY successive placements of the CofP observed during a session was taken as an index for 2D postural way. Before irradiation the overall average of the 218 personal Xm mean values demonstrated a statistically significant body inclination toward the affected side, however under EC condition only. The day after irradiation, a significant reduction of the overall mean value of body inclination was observed. Paired Xm statistics confirmed this trend toward usual symmetry. The day after stereo- irradiation, averaging areas S of ellipses indicated a shift of instability toward normality. For the two parameters, the pseudo-Romberg ratios (performance EC/performance EO) indicated that a special visual contribution to balance control is present in patients with a neurinoma tumor (here I and II grades). The relative importance of this visual support declined shortly after ionizing treatment. Because the radiation is neither noxious nor excitatory we think such a rapid recovery is due to some recovery of vestibular nerve afferent conduction, and a rapid neural reprogramming of the balance control. These attractive results call for deeper investigations of both vestibular and auditory functions.

27.

**Year:** 2004

**Patient number:** 51

**Author:** Pogodzinski, Matthew S.; Harner, Stephen G.; Link, Michael J.

**Reference:** Otolaryngology--head and neck surgery, 130, 5, 611-6, 2004

**Title:** Patient choice in treatment of vestibular schwannoma

**Abstract:**OBJECTIVES: There are options available to patients newly diagnosed with vestibular schwannoma. Our institution employs stereotactic radiosurgery, microsurgical removal, and watchful waiting. There are no studies in the literature examining which of these treatment options patients are choosing. STUDY DESIGN AND SETTING: Using retrospective chart review from January 2000 through December 2001, we noted several variables and patients' initial treatment choices. RESULTS: During the 24-month study period, 139 patients were seen at our institution with a new diagnosis of vestibular schwannoma and made a clear initial treatment choice. Of these, 32 (23%) patients elected watchful waiting; 51 (36%) underwent stereotactic radiosurgery, and 56 (40%) underwent surgical removal. Surgical excision correlated with younger age and larger tumor size. CONCLUSIONS: Our initial hypothesis, that patients choosing treatment would choose stereotactic radiosurgery more than 50% of the time, was untrue for the time course studied. SIGNIFICANCE: This is the first study to examine patient choice in treatment of vestibular schwannoma.

28.

**Year:** 2004

**Patient number:** 1000

**Author:** Régis, J.; Delsanti, C.; Roche, P. H.; Thomassin, J. M.; Pellet, W.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 301-11, 2004

**Title:** Functional outcomes of radiosurgical treatment of vestibular schwannomas: 1000 successive cases and review of the literature

**Abstract:**RATIONALE: To evaluate the functional results of Gamma Knife surgery of vestibular schwannomas relying on a large and prospective series of consecutive cases. MATERIAL AND METHOD: The first 1000 patients with cerebello-pontine angle schwannomas were consecutively treated by Gamma Knife in Marseille Timone University Hospital between July 1992 and March 2001. Patients without NF2 and or clinico-radiological arguments in favor of a facial origin accounted for a population of 927 patients (414 males, for 513 females) including 843 treated in first intention. In this series the Koos classification was: stage I 77 patients, stage II 520 patients, stage III 287 patients and stage IV 42 patients. The average Volume was 12.7mm<sup>3</sup>. Hearing was useful (Gardner and Robertson) before radiosurgery in 47% of the patients (subnormal in 20.3%). RESULTS: Tumor control at last follow-up was 97%. Globally, a clinical trigeminal injury was observed in 0.6% of the patients and a facial palsy in 1.3%. There was clearly a decrease of the incidence of neuropathies with time; no facial palsy being reported among the last 258 patients. The rate of functional hearing preservation (Gardner) for patients initially in class I was 77.8% (47.6% for class II) at 3 Years. This rate of functional preservation reached 95% among patients with tinnitus as a first

symptom. **CONCLUSION:** Today, strong evidence supports the superiority of Gamma Knife surgery in term of functional preservation and equal efficacy compared with microsurgical removal. Consequently, radiosurgery must be preferred as a first intention choice for young patients with few symptoms presenting with a small to middle size vestibular schwannomas (Koos I-III).

29.

**Year:** 2004

**Patient number:** 43

**Author:** Roche, P. H.; Ribeiro, T.; Soumare, O.; Robitail, S.; Pellet, W.; Régis, J.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 345-9, 2004

**Title:** Hydrocephalus and vestibular schwannomas treated by Gamma Knife radiosurgery

**Abstract:** The occurrence of hydrocephalus in association with a vestibular schwannoma (VS) is a well-known phenomenon. It is usually supported, albeit never demonstrated, that radiosurgery increases the risk of hydrocephalus. The purpose of this study is to investigate this issue in our own series of patients in order to provide more data. Between July 1992 and January 2002, among the 1000 VS that have been treated at the Timone hospital using a Gamma knife, 43 patients displayed a hydrocephalus, 32 of them before the treatment (group A) and 11 of them only after the treatment (group B). It is of note that in both groups, age at the time of treatment (median age of 70 in A & B) and Volume of tumor were comparable and significantly higher than for the whole treated population. Following radiosurgery, 75% of the patients from the group A did not require a shunt whereas all the patients from the group B did, including 3 who also had significant tumor progression requiring surgery. Occurrence of a de novo hydrocephalus was a rare event (1%) that required a shunt early after radiosurgery, at a mean interval of 14.8 Months (4-31). Results from this study suggest that radiosurgery does not significantly increase the risk of hydrocephalus during the natural history of a VS. We can postulate that Gamma Knife radiosurgery might provide a protective influence on hydrocephalus decompensation since the number of preexisting hydrocephalus that necessitated a shunt after the treatment was small. More investigations involving more patients will bring more arguments in the near future.

30.

**Year:** 2004

**Patient number:** 60

**Author:** Roche, P. H.; Robitail, S.; Delsanti, C.; Marouf, R.; Pellet, W.; Régis, J.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 394-400, 2004

**Title:** Radiosurgery of vestibular schwannomas after microsurgery and combined radio-microsurgery

**Abstract:** Significant morbidity is expected after microsurgery for recurrent or growing residual vestibular schwannoma (VS). In order to avoid this procedure, radiosurgery appeared as an interesting alternative. The purpose of this study is to analyze the results

of Gamma Knife radiosurgery in this indication. Between July 1992 and January 2002, 60 patients (including 12 NF2 patients) underwent radiosurgical treatment after one or more attempts of surgical resection (including 27 growing remnant VS and 19 recurrent VS) and could be followed with enough informations, out of 103 patients (10% of the VS population treated during the same period). Mean interval between surgical removal and radiosurgery was 71.5 Months (1.8-127.8 Months). Technical difficulties during the procedure were observed in the 12 cases, mainly due to problems in identifying the target. Median follow-up was 51.6 Months. Four out of 58 patients (7%, confidence interval: 1.9-16.7) were diagnosed as failure. Statistical study failed to find significant parameters influencing failure. Facial and trigeminal nerves were not impaired while one case of severe bulbopontine radio- induced injury leading to a lower cranial nerve deficit was observed. These results show that, in spite of additional difficulties to treat these patients with radiosurgery, this treatment is efficient with acceptable morbidity and can avoid another microsurgical procedure. The strategy of planned combined micro-and radiosurgical treatment of large VS deserves additional investigations to be validated.

31.

**Year:** 2004

**Patient number:** 44

**Author:** Roche, P. H.; Robitail, S.; Pellet, W.; Devèze, A.; Thomassin, J. M.; Régis, J.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 377-82, 2004

**Title:** Results and indications of gamma knife radiosurgery for large vestibular schwannomas

**Abstract:** Regular treatment of large vestibular schwannomas (VS) is surgical resection of the tumor with attempt of facial nerve preservation. In a very reduced number of tumors, microsurgery is not warranted mainly because of contralateral deafness or the risk of life-threatening open surgery. The purpose of this study was to analyze the results of Gamma Knife radiosurgery delivered for large VS. Between July 1992 and January 2002, we treated 50 patients harboring a large VS defined as a Koos grade IV tumor. Data and follow-up were available for 45 tumors involving 44 patients, including 12 neurofibromatosis type 2. Mean age at the time of treatment was 43,5 (range: 14-84), mean diameter of the tumor in the CPA was 18mm (range: 12-30) and the mean Volume was 4301 mm<sup>3</sup> (range: 1340-11405). Gamma knife treatment was undertaken using on average 13.4 isocenters (range: 4-48) and 10.2 Gy at the tumor margin (range: 8-14). Median follow-up was 45.5 Months (from 24 to 108 Months). Tumor control was 69% (interval confidence: 52-83%) and 3 patients had to be operated because of continuous tumor growth. Statistical analysis showed that tumor Volume was correlated to Gamma Knife failure in a uni-and multivariate model ( $p=0.027$ ). No brain stem complication was observed. No facial nerve deterioration was found and hearing preservation could be obtained at a useful level in 12 out of 20 patients (60%). These results suggest that in a highly selected subgroup of patients with large VS, radiosurgery can be an interesting alternative to open surgery, particularly if hearing preservation is required. Information should be given to the patients that the risk of failure is greater than for small and medium sized VS.

32.

**Year:** 2004

**Patient number:** 37

**Author:** Roche, P. H.; Robitail, S.; Thomassin, J. M.; Pellet, W.; Régis, J.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 367-76, 2004

**Title:** Surgical management of vestibular schwannomas secondary to type 2 neurofibromatosis

**Abstract:** To evaluate the results of Gamma Knife radiosurgery treating vestibular schwannomas (VS) secondary to type 2 neurofibromatosis (NF2) we reviewed our clinical experience. Among the VS that have been treated between July 1992 and January 2002, we could analyze retrospectively the data of 50 VS from 37 patients. Fourteen patients had the mild phenotype while 23 were affected by the severe form. Before radiosurgery, one or two microsurgery attempts had been undertaken in 16 VS. Tumor Volume ranged from 120 to 14405 mm<sup>3</sup> (mean: 3468 mm<sup>3</sup>) at the time of treatment; 12 tumors were Koos stade 4. Median clinical and radiological follow-up was 62 Months and ranged from 27 to 123 Months. The 5-Year and 10-Year actuarial survival rates without failure justifying tumor removal were 90 and 85% respectively. The 5-Year actuarial survival rate without hearing decreasing was 36% when selecting the cases of useful hearing (Gardner I & II) at the time of treatment. Severe phenotype ( $p=0.05$ ) and dose ( $>12$  Gy) delivered at the tumor margin ( $p=0.032$ ) were correlated to hearing deterioration at univariate analysis. Permanent facial neuropathy occurred in 2%. Even though the level of tumor control and hearing preservation is not the same as for sporadic VS, these results show that Gamma Knife radiosurgery is a valuable alternative treatment for

33.

**Year:** 2004

**Patient number:** 47

**Author:** Saito, K.; Yoshida, J.

**Reference:** Japanese Journal of Neurosurgery, 13, 6, 427-432, 2004

**Title:** Treatment of acoustic schwannomas associated with neurofibromatosis type 2

**Abstract:** Seventy-four patients with bilateral acoustic schwannomas (AS) registered in a nationwide study from 1986 to 1987 were studied. Kaplan-Meier analysis indicated that overall 10- and 20-year survival rates following diagnosis of NF2 patients were 67% and 38%, respectively. Early onset of the initial symptom significantly compromised survival. The AS volume was measured on CT or MRI and retrospectively studied in 27 patients (54 AS). In natural course, it was difficult to predict tumor growth. After treatments, clinical factors that significantly contributed to the tumor growth were younger symptom onset, association of intracranial meningioma, and larger tumor volume before the treatment. Regrowth rate was low after gamma-knife treatment and no recurrence after total tumor removal. Large AS in patients with earlier symptom onset or intracranial meningioma require total removal. During the past 5 years, 243 NF2 patients were followed in 78

institutes: 49 without treatment, 125 with surgical resection, 47 with radiosurgery, and 22 with resection and radiosurgery. Opinions about treatment of NF2 patients from 67 institutions were analyzed. Strategies for AS were divergent. Large AS or AS showing tumor growth on serial MRI require treatment. Total removal is desirable. Gamma-knife radiosurgery is effective for small AS. The first side of bilateral AS need early treatment. The second side of AS should be treated after hearing deterioration occurs in this side. With brainstem or cerebellar signs present, however, the second side requires early resection as well.

34.

**Year:** 2004

**Patient number:** 17

**Author:** Szeifert, G. T.; Figarella, Branger D.; Roche, P. H.; Régis, J.

**Reference:** Neuro-Chirurgie, 50, 2-3 Pt 2, 327-37, 2004

**Title:** Histopathological observations on vestibular schwannomas after Gamma Knife radiosurgery: the Marseille experience

**Abstract:**BACKGROUND AND PURPOSE: Radiosurgery has become a successful treatment modality in the management of vestibular schwannomas (VS) during the past four decades. Although the number of treated cases has been increasing continuously we know relatively little about the pathological effect of high dose irradiation on VS following radiosurgery. The purpose of this study was to analyze histopathological changes in VS after Leksell Gamma Knife (LGK) radiosurgery. METHODS: Out of a series of 1350 VS cases treated with LGK surgery 22 patients underwent craniotomy for tumor removal in 6-92 Months interval after radiosurgery. Surgical pathology material was available in 17 cases. Routine histological and immunohistochemical investigations were performed on the tissue samples. Histopathological findings were compared with clinical and radiological follow-up data. RESULTS: Coagulation necrosis in the central part of the schwannomas surrounded with a transitional zone containing loosened tissue structure of shrunken tumor cells covered with an outer capsule of vigorous neoplastic cells was the basic histopathological lesion. Granulation tissue proliferation with inflammatory cell infiltration, different extent of hemorrhages and scar tissue development was usually present. Endothelial destruction or wall damage of vascular channels was a common finding. Analyzing the follow-up data it turned out that 7 patients out of the 22 were operated on because of radiological progression only without clinical deterioration and 4 of them was removed during the latency period after radiosurgery. CONCLUSION: Results of the present histopathological study suggest that radiosurgery works with double effect on VS: it seems to destroy directly tumor cells (with necrosis or inducing apoptosis), and causes vascular damages as well. The loss of central contrast enhancement on

35.

**Year:** 2004

**Patient number:** 100

**Author:** Tamura, M.; Murata, N.; Hayashi, M.; Régis, J.

**Reference:** Neurochirurgie, 50, 2-3 II, 338-344, 2004

**Title:** Injury of the lacrimal component of the nervus intermedius function after radiosurgery versus microsurgery

**Abstract:** Rationale. - Due to the synergetic role of the facial nerve and the nervus intermedius in the mechanical protection of the eye, vestibular schwannomas (VS) and/or their treatment are dangerous for the visual function. Our goal was to evaluate and compare the impact of the tumor itself, and the microsurgery (MS) or radiosurgery (RS). Material and method. - A functional questionnaire evaluating among other items the patient's complaints related to the eye was addressed to a series of 100 patients, 3 years after GKS of a previously unresected unilateral VS. Answers were compared with those of a group of 100 patients operated microsurgically. A Shirmer test was additionally performed before radiosurgery, and more than 2 years after radiosurgery in 46 patients. Results. - The risk of dry eye and burning eye was much higher in patients operated by MS compared to patients operated by GKS due to the high incidence of facial palsy in the former (57/99) and the its absence in the later (0/80). In the population operated microsurgically, the presence of a permanent facial palsy (57 patients among 99 responding to the questionnaire) was, of course, associated with a high rate of complaints about burning eye (n=18) and crying eye (n=23). Among patients from the two arms with no facial palsy, a dry eye was reported by 8/64 after GKS and 7/42 after MS (NS) and a burning eye by 9/64 after GKS and 9/42 after MS (NS). Thus patients with no clinical signs of impairment of the VII motor nerve accounted for 14% of the cases signs indicating injury of the intermedius nerve with the same probability whatever the kind of surgery. When no permanent facial palsy was observed a crocodile tear syndrome was more frequently observed after MS (4/42 versus 1/64,  $p=0.07$ ). This suggests an early lesion of the VII motor and intermedius, and a subsequent abnormal regrowth. The only patient reporting a crocodile tear syndrome after GKS turned out to have presented transiently a discret deficit of orbicular muscle signaling transient partial facial nerve injury. In absence of facial palsy, a "crying eye" was reported more frequently after MS (16/42 versus 9/64,  $p=0.01$ ), leading us to suspect frequent infraclinical VII nerve injury in patients with no obvious facial palsy operated by MS. Patients tested with Shirmer test, before and more than 2 years after, were improved in 28.3%, stable in 56.5%, and worse in 15.2%. Conclusions. - This study is the first demonstrating that radiosurgery can induce nervus intermedius injury in a small percentage of cases (14%). These patients had been treated 11 years ago with what we can consider as "archo GKS technology" compared to today's refinements. The impact of modern GKS on the nervus intermedius is currently under evaluation in our group. However, symptoms related to the eye either due to the injury of the nervus intermedius or of the VII motor or both are much more frequent after MS than after RS.

36.

**Year:** 2004

**Patient number:** 33

**Author:** Wackym, P. Ashley; Runge, Samuelson Christina L.; Poetker, David M.; Michel,

Michelle A.; Alkaf, Farah Mohd; Burg, Linda S.; Firszt, Jill B.

**Reference:** *Otology & neurotology*, 25, 5, 752-61, 2004

**Title:** Gamma knife radiosurgery for acoustic neuromas performed by a neurotologist: early experiences and outcomes

**Abstract:** **OBJECTIVE:** To assess early outcomes after Gamma knife radiosurgery of acoustic neuromas and other skull base tumors. **BACKGROUND:** Gamma knife radiosurgery is one of the available methods to treat acoustic neuromas, in addition to micro-surgical resection. Neuro-otologists have long been associated with microsurgical resection of these tumors; however, the application of Gamma knife radiosurgery to the treatment of these tumors by neuro-otologists has not been previously described. **SETTING:** Acoustic Neuroma and Skull Base Surgery Program / Tertiary Referral Center. **STUDY DESIGN/PATIENTS/INTERVENTION:** Prospective clinical study of all patients treated by the senior author and our gamma knife team beginning in June 2000. **MAIN OUTCOME MEASURES:** Preoperative MRI, audiometry, vestibular testing and facial nerve electromyography were completed. At six-month intervals postoperatively, audiometry, caloric testing and MRI were performed to determine thresholds and speech discrimination ability, vestibular function, and the size of the tumor. **RESULTS:** From June 2000 until March 2004, 38 patients were treated, and these included 33 acoustic neuromas, two meningiomas, one glomus jugulare tumor, and two facial neuromas. Greater than 36 month follow-up was available in 7 patients, > 24 months in 24, > 12 months in 31, and > 6 months in 34 patients. Statistically significant reduction in tumor size was seen over time, and tumor control was achieved in all but two patients. Various patterns of changes in auditory function, both in threshold and speech discrimination were observed in either positive or negative directions. **CONCLUSIONS:** Preliminary experience with Gamma knife radiosurgery indicates that this treatment method represents another option for neuro-otologists to use in managing patients with skull base tumors.

37.

**Year:** 2003

**Patient number:** 95

**Author:** Delbrouck, C.; Hassid, S.; Massager, N.; Choufani, G.; David, Ph; Devriendt, D.; Levivier, M.

**Reference:** *Acta oto-rhino-laryngologica belgica*, 57, 3, 197-204, 2003

**Title:** Preservation of hearing in vestibular schwannomas treated by radiosurgery using Leksell Gamma Knife: preliminary report of a prospective Belgian clinical study

**Abstract:** **INTRODUCTION:** Radiosurgery is an alternative to the microsurgical resection of vestibular schwannoma (VS). Since its introduction, radiosurgery has been used in more than 8000 patients with VS worldwide and the long term tumor control rates are reported to be 86 to 100%. The aim of this study is to report our experience with Leksell Gamma Knife (LGK) radiosurgery in the management of VS and to evaluate the serviceable hearing preservation rate after one-year follow-up. **MATERIAL AND METHODS:** Between January 2000 and October 2002, 95 patients with unilateral VS

underwent LGK radiosurgery at the University Erasmus Hospital of Brussels with the first worldwide installed LGK C. All patients in our series underwent evaluation with high resolution neurodiagnostic imaging including computed tomography and MRI, and clinical evaluation as well as audiological tests that included tonal and vocal audiometries. The Gardner Robertson (GR) classification is used to report the results of this study. We identified 48 patients treated for VS with LGK, tested and retested with vocal and tonal audiometries by the same team, and followed for a minimum of one year. There were 38 patients with previously untreated VS (9 grade I, 9 grade II, 20 grade III according to Koos) and 10 patients with postoperative evolutive residual tumor. **RESULTS:** Before LGK, 24 patients had serviceable (17 GR class I and 7 GR class II) hearing; 16 (67%) of these patients had preservation of serviceable hearing (Pure tone average < 50 db and Speech discrimination > 50%) at the one-year audiological follow-up. It was observed that 9 of the 17 GR class I patients (52.9%) maintained their level of audition and 14 of these (82.3%) preserved serviceable hearing. No deterioration of hearing occurred in the 7 patients with preradiosurgery radiosurgery nonserviceable hearing (GR class III) at the one-year follow-up. One patient improved from GR class V to III after LGK. No patient developed trigeminal neuropathy and only one patient who had preradiosurgery facial nerve dysfunction experienced deterioration at one-year follow-up. **CONCLUSIONS:** In view of the high tumor control rate and excellent long-term cranial nerve preservation rates, LGK radiosurgery should now be considered as an excellent alternative strategy to microsurgery for the management of VS grade I to III as well as in cases of residual tumor after microsurgery. Compared to results obtained in centers with long-term experience, our data suggest that LGK radiosurgery is an efficient reproducible therapeutic approach that offers high rate of hearing preservation. This justifies the choice of radiosurgery as the first treatment option in VS.

38.

**Year:** 2003

**Patient number:** 183

**Author:** Fukuoka, S.; Takanashi, M.; Hojo, A.; Konishi, M.; Nakamura, H.

**Reference:** Japanese Journal of Neurosurgery, 12, 8, 527-533, 2003

**Title:** Gamma knife radiosurgery for acoustic schwannomas: An analysis of the method of low dose and conformal multiple shots with smaller collimator

**Abstract:** The purpose of this study was to analyze tumor control and possible complications of gamma knife radiosurgery (GKRS) in patients with acoustic schwannomas treated using low marginal dose and conformal multiple shots with smaller collimators to fit irregular tumor shapes. The authors evaluated 183 patients with follow-up periods ranging from 3 to 11 years. Marginal doses were 9 to 15 Gy (median 12 Gy), with corresponding treatment volumes being between 0.1 and 18.7 ml (median 1.8 ml). The number of isocenter varied from 2 to 24 shots (median 9 shots). The actuarial tumor control rate (resection-free survival) was 96.5%. Useful hearing, trigeminal and facial functions were preserved at 75%, 97.4%, and 100%, respectively. Hydrocephalus was recognized in 5.7% of all patients, and seems to occur in cases with medium sized tumors where mild ventricular enlargement is evident prior to treatment. GKRS proves to

be a safe and effective therapy for small to medium sized tumors. However, the indication for larger sized tumors (diameter 3+cm) should be carefully considered, larger tumors being less easy to control and liable to cause ataxia due to transient expansion.

39.

**Year:** 2003

**Patient number:** 14

**Author:** Iwai, Yoshiyasu; Yamanaka, Kazuhiro; Ishiguro, Tomoya

**Reference:** Surgical neurology, 59, 4, 283-9, 2003

**Title:** Surgery combined with radiosurgery of large acoustic neuromas

**Abstract:**The treatment of acoustic neuromas has been improved by advancements in microsurgical techniques and in radiosurgery. To further elucidate the degree of clinical improvement, we evaluated the treatment results of a combination of surgery and radiosurgery for large acoustic neuromas. **METHODS:** From January 1994 through December 2000, we treated 14 patients with large acoustic neuromas using a combination of surgery and radiosurgery. Of these, 8 were male and 6 were female patients, with an average age of 47 years (range, 18-64). The average maximum diameter of the tumor was 42 mm (range, 30-58 mm). All patients underwent operations using the retrosigmoid approach, and one patient was retreated using the transpetrosal transtentorial approach. The tumors were removed subtotally in thirteen patients and partially in one who had a very large hypervascular acoustic neuroma. There were no mortality and no surgical complications, such as hemorrhage or CSF leakage. Postoperative facial palsy was avoided in 10 patients (71%). Radiosurgery was performed 1 to 6 months (mean, 2.9 months) after surgery. At the time of radiosurgery, the treatment size (mean diameter) became 19.2 mm (range, 9.8-36.1 mm). The average tumor marginal dose was 12.1Gy (range, from 10-14 Gy). The mean follow-up period was 32 months after radiosurgery. **RESULTS:** The tumor size decreased in 6 patients, unchanged in 5 patients, and increased in 3 patients. Only 1 patient (7%) with extra large tumor needed surgical resection 1 year after radiosurgery. Excellent facial nerve function (House & Brackmann Grade I or II) was preserved in 12 patients (85.7%) in the final follow-up. **CONCLUSIONS:** In the case of large acoustic neuromas, subtotal removal and subsequent radiosurgery is one option for maintaining cranial nerve function and long-term tumor growth control.

40.

**Year:** 2003

**Patient number:** 51

**Author:** Iwai, Yoshiyasu; Yamanaka, Kazuhiro; Shiotani, Masato; Uyama, Taichi

**Reference:** Neurosurgery, 53, 2, 282-87, 2003

**Title:** Radiosurgery for acoustic neuromas: results of low-dose treatment

**Abstract:****OBJECTIVE:** The results of radiosurgical treatment of acoustic neuromas have improved by reducing the tumor marginal doses. We report relatively long-term follow-up

results (>5 yr) for patients who underwent low-dose radiosurgery. **METHODS:** We treated and followed 51 consecutive patients with unilateral acoustic neuromas who were treated from January 1994 to December 1996 by gamma knife radiosurgery at low doses ( $\leq 12$  Gy to the tumor margin). The average age of the patients was 55 years (range, 32-76 yr). The treatment volume was 0.7 to 24.9 cm<sup>3</sup> (median, 3.6 cm<sup>3</sup>). The marginal radiation dose was 8 to 12 Gy (median, 12 Gy), and the follow-up period ranged from 18 to 96 months (median, 60 mo). **RESULTS:** Clinical tumor growth control (without tumor resection) was achieved in 96% of patients, and the 5-year tumor growth control rate was 92%. Hearing was preserved in 59% of those with preradiosurgical hearing preservation (Gardner-Robertson Classes 1-4), and improvements (>20 dB of improvement) were noted in 9% of the patients with any hearing. Hearing was preserved at a useful level (Gardner-Robertson Classes 1 and 2) in 56% of patients. Although preexisting trigeminal neuropathy worsened in 4% of the patients, our patients did not experience new facial palsies or trigeminal neuropathies after radiosurgery. Facial spasm occurred in 6% of the patients, and intratumoral bleeding occurred in 4% of patients. **CONCLUSION:** Low-dose radiosurgery ( $\leq 12$  Gy at the tumor margin) can achieve a high tumor growth control rate and maintain low postradiosurgical morbidity (including hearing preservation) for acoustic neuromas.

41.

**Year:** 2003

**Patient number:** 12

**Author:** Kaplan, Daniel M.; Hehar, Sukhminderjit S.; Tator, Charles; Guha, Ab; Laperriere, Normand; Bance, Manohar; Rutka, John A.

**Reference:** The Journal of otolaryngology, 32, 1, 23-32, 2003

**Title:** Hearing loss in acoustic neuromas following stereotactic radiotherapy

**Abstract:** **BACKGROUND:** Hearing preservation is a major concern in the management of acoustic neuroma (AN), whether treated by surgery or radiation or followed conservatively. **OBJECTIVE:** To assess the change in hearing in patients who underwent radiotherapy for ANs and to compare it with data from conservatively managed patients. **DESIGN:** Prospective case series. **SETTING:** Neuro-otology, neurosurgery, and radiation oncology practices in tertiary care hospitals of the University Health Network, University of Toronto. **PATIENTS AND METHODS:** Between 1991 and 1999, 32 patients who underwent radiotherapy were followed prospectively. Seventeen patients had pretreatment measurable hearing and a minimum 1-year follow-up. Twelve of these patients underwent Gamma Knife radiation and five had fractionated radiation therapy with a linear accelerator. Pre- and post-treatment hearing was classified according to the Gardner-Robertson (GR) classification and according to the 1995 guidelines of the American Academy of Otolaryngology-Head and Neck Surgery Committee on Hearing and Equilibrium (AAO-HNS CHE). **OUTCOME MEASURE:** Change in hearing post-treatment. **RESULTS:** Mean follow-up was 48 months. Deterioration in the level of hearing was observed in 8 and 11 of the patients using the AAO-HNS CHE and the GR classifications, respectively. Forty-four to 70% of the patients had lost their pretreatment serviceable hearing, depending on the classification of hearing used and how serviceable

hearing was defined. Compared with series of patients followed conservatively in our institution and in other studies, patients who receive stereotactic radiation appear to lose hearing at least at the same rate. **CONCLUSION:** Our data suggest that hearing loss continues to occur despite radiotherapy, and patients should be advised accordingly.

42.

**Year:** 2003

**Patient number:** 157

**Author:** Kondziolka, D.; Nathoo, N.; Flickinger, J. C.; Niranjan, A.; Maitz, A. H.; Lunsford, L. D.; Piepmeyer, J. M.; Berger, M. S.; Loeffler, J. S.; Gutin, P. H.

**Reference:** Neurosurgery, 53, 4, 815-822, 2003

**Title:** Long-term results after radiosurgery for benign intracranial tumors

**Abstract:****BACKGROUND:** Stereotactic radiosurgery is the principal therapeutic alternative to resecting benign intracranial tumors. The goals of radiosurgery are the long-term prevention of tumor growth, the maintenance of patient function, and the prevention of new neurological deficits or adverse radiation effects. Evaluation of long-term outcomes more than 10 years after radiosurgery is needed. **METHODS:** We evaluated 285 consecutive patients who underwent radiosurgery for benign intracranial tumors between 1987 and 1992. Serial imaging studies were obtained, and clinical evaluations were performed. Our series included 157 patients with vestibular schwannomas, 85 patients with meningiomas, 28 patients with pituitary adenomas, 10 patients with other cranial nerve schwannomas, and 5 patients with craniopharyngiomas. Prior surgical resection had been performed in 44% of these patients, and prior radiotherapy had been administered in 5%. The median follow-up period was 10 years. **RESULTS:** Overall, 95% of the 285 patients in this series had imaging-defined local tumor control (63% had tumor regression, and 32% had no further tumor growth). The actuarial tumor control rate at 15 years was 93.7%. In 5% of the patients, delayed tumor growth was identified. Resection was performed after radiosurgery in 13 patients (5%). No patient developed a radiation-induced tumor. Eighty-one percent of the patients were still alive at the time of this analysis. Normal facial nerve function was maintained in 95% of patients who had normal function before undergoing treatment for acoustic neuromas. **CONCLUSION:** Stereotactic radiosurgery provided high rates of tumor growth control, often with tumor regression, and low morbidity rates in patients with benign intracranial tumors when evaluated over the long term. This study supports radiosurgery as a reliable alternative to surgical resection for selected patients with benign intracranial tumors.

43.

**Year:** 2003

**Patient number:** 101

**Author:** Levivier, Marc; Lorenzoni, Jose; Massager, Nicolas; Ruiz, Salvador; Devriendt, Daniel; Brotchi, Jacques

**Reference:** Neurosurgical focus, {Neurosurg-Focus}, 15 May 2003 (epub), vol. 14, no. 5, p. e8, ISSN: 1092-0684.

**Title:** Use of the Leksell gamma knife C with automatic positioning system for the treatment of meningioma and vestibular schwannoma

**Abstract:** OBJECT: The authors report their experience using the Leksell gamma knife C (GK-C) for the treatment of meningioma and vestibular schwannoma (VS). METHODS: In December 1999, the first commercially available clinical GK-C was installed at the Université Libre de Bruxelles (Erasme Hospital, Brussels, Belgium). In January 2000, the system was upgraded and equipped with the automatic positioning system (APS). Between February 2000 and February 2003, the APS-equipped GK-C was used to perform 532 radiosurgical treatments, including those in 97 meningiomas and 101 VSs. Meningioma and VS represent 18 and 19%, respectively, of lesions in patients treated with GK-C at the authors' center. The mean number of isocenters per lesion was 9.5 (range 1-36): 18.1 (range 1-36) for meningioma and 12.8 (range 1-27) for VS. In 77.6% of the cases, the authors used a single helmet of collimators (55.5% in meningioma and 74.3% in VS). The most frequently used collimator size was 4 mm (46.7%). Whereas it was 4 mm in cases of VS (64.3%), it was 8 mm in cases of meningioma (41.6%). The APS could be used in 86% of the cases, either alone (79%) or in combination with trunnions (7%). There was a difference in the APS-based treatment success rate in meningiomas (85%) and VSs (94%). A significant difference was also noted in the conformity of the radiosurgical treatments between the two lesions. CONCLUSIONS: The APS-equipped GK-C represents an evolutionary step in radiosurgery. It requires adjustments by the treating team for its specific limitations, which vary among indications, as exemplified by the differences inherent between meningioma and VS in this series.

44.

**Year:** 2003

**Patient number:** 54

**Author:** Linskey, Mark E.; Johnstone, Peter A. S.; O'Leary, Michael; Goetsch, Steven

**Reference:** Journal of neurosurgery, 98, 4, 800-6, 2003

**Title:** Radiation exposure of normal temporal bone structures during stereotactically guided gamma knife surgery for vestibular schwannomas

**Abstract:** OBJECT: The dosimetry of radiation exposure of healthy inner, middle, and external ear structures that leads to hearing loss, tinnitus, facial weakness, dizziness, vertigo, and imbalance after gamma knife surgery (GKS) for vestibular schwannomas (VSs) is unknown. The authors quantified the dose of radiation received by these structures after GKS for VS to assess the likelihood that these doses contributed to postradiosurgery complications. METHODS: A retrospective study was performed using a prospectively acquired database of a consecutive series of 54 patients with VS who were treated with GKS during a 3.5- year period at an open unit gamma knife center. Point doses were measured for 18 healthy temporal bone structures in each patient, with the anatomical position of each sampling point confirmed by a fellowship-trained neurotologist. These values were compared against single-dose equivalents for the 5-year tolerance dose for a 5% risk of complications and the 5-year tolerance dose for a 50% risk of complications, which were calculated using known 2-Gy/fraction thresholds for chronic otitis, chondromalacia, and osseous necrosis, as well as the tumor margin

dose and typical tumor margin prescription doses for patients in whom hearing preservation was attempted. External and middle ear doses were uniformly low. The intratemporal facial nerve is susceptible to unintentionally high radiation exposure at the fundus of the internal auditory canal, with higher than tumor margin doses detected in 26% of cases. In the cochlea, the basal turn near the modiolus and its inferior portion are most susceptible, with doses greater than 12 Gy detected in 10.8 and 14.8% of cases. In the vestibular labyrinth, the ampulated ends of the lateral and posterior semicircular canals are most susceptible, with doses greater than 12 Gy detected in 7.4 and 5.1% of cases. **CONCLUSIONS:** Doses delivered to middle and external ear structures are unlikely to contribute to post- GKS complications, but unexpectedly high doses may be delivered to sensitive areas of the intratemporal facial nerve and inner ear. Unintentional delivery of high doses to the stria vascularis, the sensory neuroepithelium of the inner ear organs and/or their ganglia, may play a role in the development of post-GKS tinnitus, hearing loss, dizziness, vertigo, and imbalance. Minimizing treatment complications post-GKS for VS requires precise dose planning conformality with the three-dimensional surface of the tumor.

45.

**Year:** 2003

**Patient number:** 134

**Author:** Litvack, Zachary N.; Norén, Georg; Chougule, Prakash B.; Zheng, Zhen

**Reference:**Neurosurgical focus (electronic resource), {Neurosurg-Focus}, 15 May 2003 (epub), vol. 14, no. 5, p. e3, ISSN: 1092-0684.

**Title:** Preservation of functional hearing after gamma knife surgery for vestibular schwannoma

**Abstract:** **OBJECT:** The goal of this retrospective study was to define the rates of preservation of functional hearing and growth control of vestibular schwannomas (VS) treated by gamma knife surgery (GKS) involving a consistent 12-Gy prescription dose. **METHODS:** One hundred thirty-four patients with unilateral VS underwent GKS between 1994 and 2000. The mean magnetic resonance (MR) imaging follow-up period was 31.7 months (maximum 72 months), and the mean audiometry follow-up interval was 26.3 months (maximum 60 months). The mean marginal dose was 12 +/- 0.6 Gy. The mean maximum dose delivered to the tumor center was 25.4 Gy (range 17.4-34.3 Gy). The tumor control rate, defined as no change or a reduction in size at last follow up, was 96.7%. Of the patients studied, 97.7% remained free from the need to undergo tumor resection. Overall functional hearing preservation was 61.7%; the preservation rate for intracanalicular tumors was 63.6%, for those with an intracranial diameter less than 1.5 cm it was 54.5%, for those between 1.5 and 3 cm it was 68.2%, and for those larger than 3 cm it was 33.3%. Early in the series, three patients (2.2%) developed temporary facial weakness (House-Brackmann Grade II-III) in the posttreatment period, but this resolved within a few weeks. No case of facial weakness occurred after 1996. **CONCLUSIONS:** The authors demonstrated the efficacy, safety, and in many ways, the advantage of GKS over microsurgery for VS. Patients harboring tumors 3 cm or smaller in intracranial diameter, regardless of their age and medical condition, should be given the option of

undergoing GKS as primary treatment.

46.

**Year:** 2003

**Patient number:** 830

**Author:** Pellet, W.; Regis, J.; Roche, P. H.; Delsanti, C.

**Reference:** Advances and technical standards in neurosurgery, 28, 227-82, 2003

**Title:** Relative indications for radiosurgery and microsurgery for acoustic schwannoma

**Abstract:** The physical and biological principles underlying the use of radiosurgery for the treatment of vestibular schwannomas of up to 2.5 cm in diameter are reviewed together with the historical controversies that have surrounded its introduction. The results in terms of mortality, quality of life, preservation of facial movement and hearing, incidence of shunt-dependent hydrocephalus, cancer neogenesis and brain stem damage are compared in the Marseilles series of 600 microsurgical procedures and 830 Gamma knife procedures and with the peer-reviewed literature. The key principles of a steep profile to radiation exposure at the tumour margin, careful topographical planning of the radiation against the tumour shape to minimise the radiation dose to the cranial nerves and brain stem, early tumour swelling, tumour texture and national history of the tumour are analysed. Protocols for the management of unilateral schwannoma, Type

47.

**Year:** 2003

**Patient number:** 234

**Author:** Rowe, J. G.; Radatz, M. W. R.; Walton, L.; Hampshire, A.; Seaman, S.; Kemeny, A. A.

**Reference:** Neurology in Practice, 74, 11, 1536-1542, 2003

**Title:** Gamma knife stereotactic radiosurgery for unilateral acoustic neuromas

**Abstract:** Objective: To evaluate the clinical results achievable using current techniques of gamma knife stereotactic radiosurgery to treat sporadic unilateral acoustic neuromas. Methods: A retrospective review of 234 consecutive patients treated for unilateral acoustic neuromas between 1996 and 1999, with a mean (SD) follow up of 35 (16) months. Tumour control was assessed with serial radiological imaging and by the need for surgical intervention. Hearing preservation was assessed using Gardner-Robertson grades. Details of complications including cranial neuropathies and non-specific vestibulo-cochlear symptoms are included. Results: A tumour control rate in excess of 92% was achieved, with only 3% of patients undergoing surgery after radiosurgery. Results were less good for larger tumours, but control rates of 75% were achieved for 35-45 mm diameter lesions. Of patients with discernible hearing, Gardner-Robertson grades were unchanged in 75%. Facial nerve function was adversely affected in 4.5%, but fewer than 1% of patients had persistent weakness. Trigeminal symptoms improved in 3%, but developed in 5% of patients, being persistent in less than 1.5%. Transient non-specific vestibulo-cochlear symptoms were reported by 13% of patients. Conclusions: Tumour control rates, while difficult to define, are comparable after

radiosurgery with those experienced after surgery. The complications and morbidity after radiosurgery are far less frequent than those encountered after surgery. This, combined with its minimally invasive nature, may make radiosurgery increasingly the treatment of choice for small and medium sized acoustic neuromas.

48.

**Year:** 2003

**Patient number:** 96

**Author:** Rowe, J. G.; Radatz, M. W. R.; Walton, L.; Soanes, T.; Rodgers, J.; Kemeny, A. A.

**Reference:** Journal of neurology neurosurgery and psychiatry, 74, 9, 1288-93, 2003

**Title:** Clinical experience with gamma knife stereotactic radiosurgery in the management of vestibular schwannomas secondary to type 2 neurofibromatosis

**Abstract:** **OBJECTIVE:** To evaluate the results of stereotactic radiosurgery treating vestibular schwannomas secondary to type 2 neurofibromatosis. **METHODS:** A retrospective review of 122 type 2 neurofibromatosis vestibular schwannomas consecutively treated in 96 patients. Tumour control was assessed by recourse to surgical intervention, by serial radiological imaging, and by the calculation of relative growth ratios in patients (n=29) harbouring untreated contralateral tumours to act as internal controls. Hearing function was assessed with Gardner- Robertson grades and with averaged pure tone audiogram thresholds. Other complications are detailed. **RESULTS:** Applying current techniques, eight years after radiosurgery it was estimated that 20% of patients will have undergone surgery for their tumour, 50% will have radiologically controlled tumours, and in 30% there will be some variable concern about tumour control, but up to that time they will have been managed conservatively. Relative growth ratios one and two years after treatment indicate that radiosurgery confers a significant (p=0.01) advantage over the natural history of the disease. Analysis of these ratios beyond two years was precluded by the need to intervene and radiosurgically treat the contralateral control tumours in more than 50% of the cases. This growth control was achieved with 40% of patients retaining their Gardner-Robertson hearing grades three years after treatment, (40% having some deterioration in grade, 20% becoming deaf). Pure tone audiogram results suggest some progressive long term hearing loss, although interpretation of this is difficult. Facial and trigeminal neuropathy occurred in 5% and 2%. **CONCLUSIONS:** Radiosurgery is a valuable minimally invasive alternative treatment for these tumours. For most patients, it controls growth or defers the need for surgery, or both. There is a price in terms of hearing function, although this may compare favourably with the deafness associated with the natural history of the disease, and with surgery. In deciding on therapy, patients should be aware of this treatment option.

49.

**Year:** 2003

**Patient number:** Review of literature

**Author:** Shin, Young Je; Lapeyre, Mestre Maryse; Gafsi, Inthidar; Cognard, Christophe;

Deguine, Olivier; Tremoulet, Michel; Fraysse, Bernard  
**Reference:** Acta oto-laryngologica, 123, 1, 59-64, 2003

**Title:** Neurotological complications after radiosurgery versus conservative management in acoustic neuromas: a systematic review-based study

**Abstract:**OBJECTIVE: Treatment modalities for acoustic neuroma (AN) include surgery, observation and gamma-knife surgery. The aim of this study was to compare neurotological complications resulting from two treatment alternatives to microsurgery: radiosurgery and observation. MATERIAL AND METHODS: We conducted a systematic review of the literature dealing with radiosurgery for AN and compared the rate of neurotological complications in this population with that in a cohort of patients managed conservatively. RESULTS: We found that neurotological complications, namely facial hypoesthesia ( $p = 0.002$ ), hearing loss ( $p < 0.05$ ) and hydrocephalus ( $p = 0.02$ ), were more frequently encountered after radiosurgery than with conservative management. In contrast, we found that the risk of growth of AN is significantly higher with conservative management and that the rate of stability of the tumor did not differ significantly between the two treatments. CONCLUSION: We prefer a conservative management regimen for patients who cannot be operated on for their AN. However, there are some difficulties inherent in this conservative management policy, namely non-compliance and difficulties in establishing the evolution of the tumor.

50.

**Year:** 2003

**Patient number:** Review of literature

**Author:** Yamakami, Iwao; Uchino, Yoshio; Kobayashi, Eiichi; Yamaura, Akira

**Reference:** Neurological research, 25, 7, 682-90, 2003

**Title:** Conservative management, gamma-knife radiosurgery, and microsurgery for acoustic neurinomas: a systematic review of outcome and risk of three therapeutic options

**Abstract:**Conservative management, gamma-knife (GK) radiosurgery, and microsurgery are therapeutic options for acoustic neurinomas (ANs). To determine the outcomes and risks of these methods this systematic review analyzed data from 903 patients with conservative management, 1475 with GK radiosurgery, and 5005 with microsurgery from 38 studies identified in MEDLINE searches. Conservative management over a 3.1-year period showed that 51% of ANs showed a tumor growth, an average tumor growth rate was 1.87 mm year<sup>-1</sup>, 20% of ANs ultimately required surgical intervention, and a third of the patients lost useful hearing. GK radiosurgery significantly reduced the percentage of ANs that enlarged, to 8%, and reduced the percentage that underwent microsurgery to 4.6% over a 3.8-year period. Microsurgery removed 96% of ANs totally, with tumor recurrence, mortality, and major disability rates of 1.8%, 0.63%, and 2.9%, respectively. The majority of ANs grow slowly, but ultimately require intervention. Carrying the risk of hearing loss, conservative management should be supplemented with close follow-up. With a low rate of morbidity, GK radiosurgery suppresses tumor growth and provides good tumor control. Microsurgery provides the best tumor control, although mortality and

morbidity are not completely eliminated.

51.

**Year:** 2002

**Patient number:** 59

**Author:** Horstmann, Gerhard A.; Van, Eck Albertus T. C. J.

**Reference:** Journal of neurosurgery, 97, 5Suppl, 450-5, 2002

**Title:** Gamma knife model C with the automatic positioning system and its impact on the treatment of vestibular schwannomas

**Abstract:**OBJECT: The aim of this study was to assess the effects of the gamma knife automatic positioning system (APS) on the treatment of patients, particularly effects of this system on the treatment of patients with vestibular schwannomas (VSs), with a view to reducing loss of hearing. METHODS: The dose delivery with an increased number of shots was checked with GAFChromic Film for various numbers of shots (one to 129). The results in the first 549 patients were recorded. In addition a series of 59 patients with VSs treated with 13 Gy to the 65% isodose is presented. The authors have termed this the 13 on 65 concept. The film dosimetry showed that a large number of small shots did not materially affect the dose and dose distribution produced by gamma knife treatment. The APS was used alone in 72% of arteriovenous malformations, 71% of meningiomas, 94% of VSs, and 84% of pituitary adenomas. Metastatic tumors were accessible in a pure APS mode in 59% of all cases, glioma in 58%, and uveal melanoma in 10% of the cases. Thus two thirds of patients could be treated using APS alone. It was possible to use the APS and manual systems together for complex or very eccentrically placed targets. The APS resulted in the use of a larger number of isocenters. After a mean follow-up period of 15 months, the results in patients with the VSs in whom 13 Gy was delivered to the 65% isodose were similar to those in patients treated with the more conventional 50% margin isodose. There was no change in the incidence of hearing loss within the study period, and the incidence of trigeminal and facial neuropathies remained unchanged after treatment as well. CONCLUSIONS: The APS encourages the design of more conformal dose plans. The greater use of smaller collimators results in a steeper dose gradient with a smaller amount of radiation outside the target volume. Because the APS is able to apply a large number of smaller isocenters in an acceptable time, the number of isocenters used is increased. An increased number of isocenters can also be used to reduce the maximum radiation dose and increase the homogeneity in a given dose plan.

52.

**Year:** 2002

**Patient number:** 96

**Author:** Karpinos, Marianna; Teh, Bin S.; Zeck, Otto; Carpenter, L. Steven; Phan, Chris; Mai, Wei Yuan; Lu, Hsin H.; Chiu, J. Kam; Butler, E. Brian; Gormley, William B.; Woo, Shiao Y.

**Reference:** International journal of radiation oncology biology physics, 54, 5, 1410-21, 2002

**Title:** Treatment of acoustic neuroma: stereotactic radiosurgery vs microsurgery

**Abstract:** **PURPOSE:** Two major treatment options are available for patients with acoustic neuroma, microsurgery and radiosurgery. Our objective was to compare these two treatment modalities with respect to tumor growth control, hearing preservation, development of cranial neuropathies, complications, functional outcome, and patient satisfaction. **METHODS AND MATERIALS:** To compare radiosurgery with microsurgery, we analyzed 96 patients with unilateral acoustic neuromas treated with Leksell Gamma Knife or microsurgery at Memorial Hermann Hospital, Houston, Texas, between 1993 and 2000. Radiosurgery technique involved multiple isocenter (1-30 single fraction fixed-frame magnetic resonance imaging) image-based treatment with a mean dose prescription of 14.5 Gy. Microsurgery included translabyrinthine, suboccipital, and middle fossa approaches with intraoperative neurophysiologic monitoring. Preoperative patient characteristics were similar except for tumor size and age. Patients undergoing microsurgery were younger with larger tumors compared to the radiosurgical group. The tumors were divided into small <2.0 cm, medium 2.0-3.9 cm, or large >4.0 cm. Median follow-up of the radiosurgical group was longer than the microsurgical group, 48 months (3-84 months) vs. 24 months (3-72 months). **RESULTS:** There was no statistical significance in tumor growth control between the two groups, 100% in the microsurgery group vs. 91% in the radiosurgery group ( $p > 0.05$ ). Radiosurgery was more effective than microsurgery in measurable hearing preservation, 57.5% vs. 14.4% ( $p = 0.01$ ). There was no difference in serviceable hearing preservation between the two groups. Microsurgery was associated with a greater rate of facial and trigeminal neuropathy in the immediate postoperative period and at long-term follow-up. The rate of development of facial neuropathy was significantly higher in the microsurgical group than in the radiosurgical group (35% vs. 0%,  $p < 0.01$  in the immediate postsurgical period and 35.3% vs. 6.1%,  $p = 0.008$ , at long-term follow-up). Similarly, the rate of trigeminal neuropathy was significantly higher in the microsurgical group than in the radiosurgical group (17% vs. 0% in the immediate postoperative period,  $p < 0.01$ , and 22% vs. 12.2%,  $p = 0.009$ , at long-term follow-up). There was no significant difference in exacerbation of preoperative tinnitus, imbalance, dysarthria, dysphagia, and headache. Patients treated with microsurgery had a longer hospital stay (2-16 days vs. 1-2 days,  $p < 0.01$ ) and more perioperative complications (47.8% vs. 4.6%,  $p < 0.01$ ) than did patients treated with radiosurgery. There was no correlation between the microsurgical approach used and postoperative symptoms. There was no difference in the postoperative functioning level, employment, and overall patient satisfaction. There was no correlation between the radiation dose, tumor size, number of isocenters used, and postoperative symptoms in the radiosurgical group. **CONCLUSION:** Radiosurgical treatment for acoustic neuroma is an alternative to microsurgery. It is associated with a lower rate of immediate and long-term development of facial and trigeminal neuropathy, postoperative complications, and hospital stay. Radiosurgery yields better measurable hearing preservation than microsurgery and equivalent serviceable hearing preservation rate and tumor growth control.

**Year:** 2002

**Patient number:** 30

**Author:** Ottaviani, Francesco; Neglia, Cesare Bartolomeo; Ventrella, Laura; Giugni, Enrico; Motti, Enrico

**Reference:** Archives of otolaryngology--head & neck surgery, 128, 11, 1308-12, 2002

**Title:** Hearing loss and changes in transient evoked otoacoustic emissions after gamma knife radiosurgery for acoustic neurinomas

**Abstract:**OBJECTIVE: To evaluate the neuro-otological effects of gamma knife radiosurgery in patients with acoustic neurinoma. DESIGN: Prospective study. SETTING: University hospital in Milan, Italy. PATIENTS: Thirty consecutive patients with acoustic neurinoma who underwent gamma knife radiosurgery. INTERVENTION: Gamma knife radiosurgery. MAIN OUTCOME MEASURES: Results of neuro-otological tests, including pure-tone audiometry, auditory brainstem responses, and transient evoked otoacoustic emissions, during a 2-year follow-up. RESULTS: Three patients showed slight tumor growth, 1 complained of a transient facial disturbance, and 5 complained of mild trigeminal disturbances. Seven of the 26 patients with a measurable threshold before radiosurgery experienced a 2-year decrease of more than 20 dB in at least 1 hearing level, and 2 of these became deaf in the affected ear. The analysis of auditory brainstem responses showed no significant increase in mean wave V latency after radiosurgery, but intensity of transient evoked otoacoustic emissions worsened in 9 of the 12 patients who had them before treatment. A statistically significant correlation was found between the 2-year decrease in low-tone average, pure-tone average, and high-tone average hearing levels and the 2-year decrease in transient evoked oacoustic emissions ( $P < .001$ ,  $P = .008$ , and  $P < .001$ , respectively), and between the 2-year decrease in high-tone average hearing and the maximal cochlear dose ( $P = .03$ ). CONCLUSIONS: Although most patients had only a slight fluctuation of their hearing threshold after gamma knife radiosurgery, several experienced a remarkable hearing worsening. Hearing impairment was found to be mainly due to cochlear irradiation and maximal cochlear dose, which was correlated to hearing loss.

54.

**Year:** 2002

**Patient number:** 43

**Author:** Qi, Shubin; Yu, Xin; Li, Shiyue; Zhou, Dongxue; Liu, Zonghui

**Reference:** Zhonghua yi xue za zhi, 82, 9, 637-9, 2002

**Title:** Neuropathy in nearby cranial nerves after acoustic schwannoma gamma knife radiosurgery, a follow-up study

**Abstract:**OBJECTIVE: To investigate the risks of facial, trigeminal and acoustic neuropathies after acoustic schwannoma gamma knife radiosurgery. METHODS: The clinical data of forty-three patients with 46 masses of acoustic schwannoma who underwent gamma knife radiosurgery with the dose of 12 approximately 15 Gy to the tumor margin between January 1997 and October 2000 and were followed up for 6 approximately 24 months (on average 16.9 months) were studied. The tumor diameter

was 10 approximately 20 mm in 12 cases, 21 approximately 30 mm in 23 cases,  $\geq 31$  mm in 11 cases, with the average value of 28 mm. RESULTS: The general tumor control rate was 91.3%. The useful hearing preservation rate was 100% immediately after radiosurgery, 87% 6 months later and 78% 2 years later. The hearing preservation rate was high for small tumors. The facial and trigeminal neuropathies began to appear after 6 months. The incidence rates of facial neuropathy was 15.3%, 7.6%, and 3.8% 6 months, 1 year and 2 years after radiosurgery respectively. The incidence rates of trigeminal neuropathy was 11.4%, 3.8%, and 3.8% respectively 6 months, 1 year, and 2 years after radiosurgery. The incidence of neuropathy was 3.8% for tumors with a diameter  $< 30$  mm for both facial and trigeminal nerves. The hearing in 2 out of 15 cases with dysaudia began to improve 6 months after radiosurgery. The incidence of neuropathy for tumors with the diameter  $> 30$  mm was 3.8% for both nerves 2 years after radiosurgery. The preservation rate of useful hearing for tumors with the diameter  $< 20$  mm was 100% after radiosurgery. CONCLUSION: Stereotactic radiosurgery using gamma knife with a dose of 12 approximately 15 Gy to the tumor margin succeeds in controlling acoustic schwannoma and preserving useful hearing. The incidence of facial and trigeminal neuropathies are low. The neuropathy caused by gamma knife radiosurgery is sub-lethal and can be recovered gradually.

55.

**Year:** 2002

**Patient number:** 211

**Author:** Regis, J.; Delsanti, Ch; Roche, Ph; Soumare, O.; Dufour, H.; Porcheron, D.; Peragut, J. C.; Thomassin, J. M.; Pellet, W.

**Reference:** Neuro-Chirurgie, 48, 6, 471-8, 2002

**Title:** Preservation of hearing function in the radiosurgical treatment of unilateral vestibular schwannomas Preliminary results

**Abstract:** INTRODUCTION: Preservation of functional hearing can be now attempted during the surgical treatment of a vestibular schwannomas. The probability of functional hearing preservation for each of the neurosurgical approaches is currently under evaluation. We report here a preliminary evaluation of our radiosurgical experience. MATERIAL AND METHOD: In Marseilles, we performed 800 gamma-knife procedures for cochleovestibular schwannomas by between July 1992 and December 2000. These patients were evaluated systematically according to a prospective methodology. We report here the study of the population of 211 patients with unilateral schwannoma and a functional preoperative hearing (Gardner and Robertson 1 or 2) treated as first intention, with a follow-up longer than two years. RESULTS: Hearing was improved with the radiosurgery in 3% of cases with a average gain of 10 decibels. Average loss in decibel on the four main frequencies (500, 1,000, 2,000, 4,000 Hz) was 17 dB. The probability of functional hearing preservation with radio surgery was high: 73%. However, this probability depended on numerous factors related to the patient and to the operative technique. The main parameters of predictability were limited preoperative tonal loss, Gardner and Robertson stage 1 (versus 2), multiisocentric planning, peripheral dose lower than 13 Gy. So a Gardner and Robertson stage 1 intracanalicular tumor treated in

accordance with the state of the art with a gamma-knife and a marginal dose inferior to 13 Gy has a probability of functional conservation at 2 years greater than 95%.

**CONCLUSION:** Our results are preliminary and they require the confirmation of a more extensive and more prolonged follow-up. However, the large size of this population and the systematic methodology should help us in determining more precisely the place of radiosurgery and especially to better inform the patients of their chances of hearing preservation according to their individual risk profile.

56.

**Year:** 2002

**Patient number:** 41

**Author:** Régis, Jean; Hayashi, Motohiro; Porcheron, Denis; Delsanti, Christine; Muracciole, Xavier; Peragut, Jean Claude

**Reference:** Journal of neurosurgery, 97, 5Suppl, 588-91, 2002

**Title:** Impact of the model C and Automatic Positioning System on gamma knife radiosurgery: an evaluation in vestibular schwannomas

**Abstract:** **OBJECT:** The technical advances associated with the model C gamma knife include a robotized system enabling automatic positioning of the stereotactic coordinates. The purpose of this study was to analyze the clinical impact of this technical modification. **METHODS:** The authors studied a sample of patients with vestibular schwannoma (VS). This sample included three groups treated using gamma knife radiosurgery. Group I comprised 21 patients with VS treated just before the installation of the Automatic Positioning System (APS). Group II included patients in Group I with new dose plans created using the APS (in other words, simulated dose plans). Group III consisted of a control group of 20 patients matched for tumor grade with the previous group and treated recently with the APS. Treatment times were calculated after correcting the time for each shot according to the age of the sources after reloading. The treatment times, including total time, irradiation time, and duration of the neurosurgical procedure, were analyzed. In addition, dose planning including number of isocenters, number of different collimators, malfunctions, and the conformity and selectivity indices were recorded. The trend was to reduce the mean number of collimator runs from 7.9 to 1.2 and to increase the mean number of shots from 7.9 to 15.6, mostly by using the 4-mm collimator exclusively. The APS-related conformity and selectivity were improved from 95 to 97% and from 78 to 84%, respectively. The total treatment time was reduced by 53%, and time required to interact with the patient in the room was considerably reduced (75%), giving the neurosurgeon greater freedom to perform other tasks during the treatment period. The reduction of the time spent by the neurosurgeon at work in the room was 84%. The total radiation time was increased by 54%. **CONCLUSIONS:** The preliminary results of this study indicate that the robotization of the gamma knife is likely a major advance in radiosurgery.

57.

**Year:** 2002

**Patient number:** 104

**Author:** Régis, Jean; Pellet, William; Delsanti, Christine; Dufour, Henry; Roche, Pierre Hughes; Thomassin, Jean Marc; Zanaret, Michel; Peragut, Jean Claude  
**Reference:** Journal of neurosurgery, 97, 5, 1091-100, 2002

**Title:** Functional outcome after gamma knife surgery or microsurgery for vestibular schwannomas

**Abstract:**OBJECT: Microsurgical excision is an established treatment for vestibular schwannoma (VS). In 1992 the authors used a patient questionnaire to evaluate the functional outcome and quality of life in a series of 224 consecutive patients. In addition, starting with gamma knife surgery (GKS) in 1992, the authors decided to use the same methodology to evaluate prospectively the results of this modality to compare the two alternatives. METHODS: Among the 500 patients who were included prospectively, the authors only evaluated patients in whom GKS was the primary treatment for unilateral VS. Four years of follow up was available for the first 104 consecutive patients. Statistical analysis of the GKS and microsurgery populations has shown that only a comparison of Stage II and III (according to the Koos classification) was meaningful in terms of group size and preoperative risk factor distribution. Objective results and questionnaire answers from the first 97 consecutive patients were compared with the 110 patients in the microsurgery group who fulfilled the inclusion criteria. Questionnaire answers indicated that 100% of patients who underwent GKS compared with 63% of patients who underwent microsurgery had no new facial motor disturbance. Forty-nine percent of patients who underwent GKS (17% in the microsurgery study) had no ocular symptoms, and 91% of patients treated with GKS (61% in the microsurgery study) had no functional deterioration after treatment. The mean hospitalization stay was 3 days after GKS and 23 days after microsurgery. All the patients who underwent GKS who had been employed, except one, had kept the same professional activity (56% in the microsurgery study). The mean time away from work was 7 days for GKS (130 days in the microsurgery study). Among patients whose preoperative hearing level was Class 1 according to the Gardner and Robertson scale, 70% preserved functional hearing after GKS (Class 1 or 2) compared with only 37.5% in the microsurgery group. CONCLUSIONS: Functional side effects happen during the first 2 years after radiosurgery. Findings after 4 years of follow up indicated that GKS provided better functional outcomes than microsurgery in this patient series.

58.

**Year:** 2002

**Patient number:** 114

**Author:** Rowe, Jeremy G.; Radatz, Matthias; Walton, Lee; Kemeny, Andras A.

**Reference:** Stereotactic and functional neurosurgery, 79, 2, 107-16, 2002

**Title:** Stereotactic radiosurgery for type 2 neurofibromatosis acoustic neuromas: patient selection and tumour size

**Abstract:**Acoustic neuromas which are secondary to type 2 neurofibromatosis (NF2) respond less well to radiosurgery than unilateral sporadic disease. To refine the selection of these patients, a regression analysis was performed examining the response to

radiosurgery of 114 NF2 tumours. The major determinant of outcome was tumour volume ( $p < 0.001$ ). Calculating sensitivity and specificity values for different tumour volume limits gives a sensitivity value of 0.96 for a volume limit of 10 cm<sup>3</sup>. This suggests that the size constraints that apply to the radiosurgical management of NF2 acoustic neuromas differ and are more restricted than those which are accepted for acoustic neuromas in general. Copyright 2002 S. Karger AG, Basel.

59.

**Year:** 2002

**Patient number:** 60

**Author:** Unger, F.; Walch, C.; Papaefthymiou, G.; Eustacchio, S.; Feichtinger, K.; Quehenberger, F.; Pendl, G.

**Reference:** Zentralblatt für Neurochirurgie, 63, 2, 52-8, 2002

**Title:** Long term results of radiosurgery for vestibular schwannomas

**Abstract:** Radiosurgery is either a primary or an adjunct management approach used to treat patients with vestibular schwannomas. The goals are long-term tumour growth control, maintenance of cranial nerve function and prevention of new neurologic deficiencies. We sought to determine long-term outcomes measuring the potential benefits against the neurological risks of radiosurgery. **METHODS:** 278 patients with vestibular schwannomas underwent Gamma Knife radiosurgery as a treatment modality for from April 1992 to November 2001. The long-term results of 60 patients were evaluated who received radiosurgery as primary treatment. 12 cases presented with previously performed subtotal microsurgical resection or recurrence of disease (12-96 months, median 39). The median treatment volume was 3.8 ccm and the median dose to the tumour margin was 12 Gy. The median patient follow-up time was 88 months (range 72-114 months). **RESULTS:** Four tumours progressed after primary radiosurgery. Tumour control rate was 93%. Useful hearing (Gardner-Robertson I/II) was preserved in 16 patients (55%). Clinical neurological improvement occurred in 36 patients (60%). Adverse effects comprised neurological symptoms (incomplete facial palsy (House-Brackman II/III) in five cases (three recovered completely), mild trigeminal neuropathy in three cases, and morphological changes displaying rapid enlargement of preexisting macrocysts in two patients and tumour growth in two other ones. Microsurgical resection was performed in three cases (5%) and one patient underwent a shunting procedure because of hydrocephalus formation. In patients who had undergone previous microsurgery, neither new cranial nerve deficit nor any tumour growth was observed. **CONCLUSIONS:** Radiosurgery performed with current techniques proved to be an effective method for growth control of vestibular schwannomas with both a low mortality rate and a good quality of life. An increasing percentage of patients will undergo radiosurgery as accessibility to this alternative increases, and more data regarding long-term follow-up are available. It is a post-operative complementary treatment for partially removed tumours. Accordingly, radiosurgery is a useful method for the management of properly selected patients.

60.

**Year:** 2002

**Patient number:** 50

**Author:** Unger, F.; Walch, C.; Papaefthymiou, G.; Feichtinger, K.; Trummer, M.; Pendl, G.

**Reference:** Acta neurochirurgica, 144, 7, 671-6, 2002

**Title:** Radiosurgery of residual and recurrent vestibular schwannomas

**Abstract:** Radiosurgery is either a primary or an adjunctive management approach used to treat patients with vestibular schwannomas. We sought to determine outcomes measuring the potential benefits against the neurological risks in patients who underwent radiosurgery after previous microsurgical subtotal resection or recurrence of the tumour after total resection. Gamma Knife radiosurgery was applied as an adjunctive treatment modality for 86 patients with vestibular schwannomas from April 1992 to August 2001. We evaluated the results of 50 patients who had a follow-up of at least 3.5 years (median 75 months, range 42-114 months). In 16 patients a recurrence of disease was observed after previous total resection. The median treatment volume was 3.4 ccm with a median dose to the tumour margin of 13 Gy. Tumour control rate was 96%. Two tumours progressed after adjunctive radiosurgery. Useful hearing (Gardner-Robertson II) (4 patients (8%)) and residual hearing (Gardner-Roberson III) (10 patients (20%)) remained unchanged in all patients, who presented with it before radiosurgery, respectively. Clinical neurological improvement was observed in 24 patients (46%). Adverse effects comprised transient neurological symptoms and signs (incomplete facial palsy, House- Brackman II/III) in five cases (recovered completely), mild trigeminal neuropathy in four cases, and morphological changes displaying rapid enlargement of a pre-existing macrocyst in one patient and tumour growth in another one. No permanent new cranial nerve deficit was observed. Radiosurgery appears to be an effective adjunctive method for growth control of vestibular schwannomas and is associated with both a low mortality rate and a good quality of life. Accordingly, radiosurgery is a rewarding therapeutic approach for the preservation of cranial nerve function in the management of patients with vestibular schwannoma in whom prior microsurgical resection failed.

61.

**Year:** 2002

**Patient number:** 100

**Author:** Unger, F.; Walch, C.; Schröttner, O.; Eustacchio, S.; Sutter, B.; Pendl, G.

**Reference:** Acta neurochirurgica. Supplement, 84, 77-83, 2002

**Title:** Cranial nerve preservation after radiosurgery of vestibular schwannomas

**Abstract:** Radiosurgery is a management approach used to treat patients with vestibular schwannomas. The goals are long-term tumour growth control, maintenance of cranial nerve function and prevention of new deficiencies. We sought to determine long-term outcomes measuring the potential benefits against the neurological risks of primary radiosurgery. Gamma Knife radiosurgery was applied as a treatment modality for 289 patients with vestibular schwannomas from April 1992 to April 2002. The long-term

results of 100 patients who underwent radiosurgery were evaluated. 60 patients received a primary treatment, 40 other cases presented with previously performed subtotal microsurgical resection or recurrence of disease (12-96 months, median 39). The median treatment volume was 3.4 ccm and the median dose to the tumour margin was 13 Gy. The median patient follow-up time was 76 months (range 60-120 months). Four tumours progressed after primary radiosurgery. Tumour control rate was 96%. Useful hearing (Gardner- Robertson I/II) was preserved in 16 patients (55%). Clinical neurological improvement occurred in 50%. Adverse effects comprised neurological symptoms (incomplete facial palsy) (House-Brackman II /III) in six cases (four recovered completely), mild transient trigeminal neuropathy in five cases, and morphological changes displaying rapid enlargement of preexisting macrocysts in two patients and tumour growth in two other patients. Microsurgical resection was performed in four cases (4%) and two patients underwent a shunting procedure because of hydrocephalus formation (2%). In patients who had undergone previous microsurgery, no new cranial nerve deficit was observed. Radiosurgery is an effective method for growth control of vestibular schwannomas and is associated with both a low mortality rate and a good quality of life. Accordingly, for the preservation of cranial nerve function radiosurgery is a useful method for the management of properly selected patients and is comparable to microsurgery.

62.

**Year:** 2001

**Patient number:** 69

**Author:** Andrews, D. W.; Suarez, O.; Goldman, H. W.; Downes, M. B.; Bednarz, G.; Corn, B. W.; Werner, Wasik M.; Rosenstock, J.; Curran, W. J., Jr.

**Reference:** International journal of radiation oncology biology physics, 50, 5, 1265-78, 2001

**Title:** Stereotactic radiosurgery and fractionated stereotactic radiotherapy for the treatment of acoustic schwannomas: comparative observations of 125 patients treated at one institution

**Abstract:**BACKGROUND: Stereotactic radiosurgery (SRS) and, more recently, fractionated stereotactic radiotherapy (SRT) have been recognized as noninvasive alternatives to surgery for the treatment of acoustic schwannomas. We review our experience of acoustic tumor treatments at one institution using a gamma knife for SRS and the first commercial world installation of a dedicated linac for SRT. METHODS: Patients were treated with SRS on the gamma knife or SRT on the linac from October 1994 through August 2000. Gamma knife technique involved a fixed-frame multiple shot/high conformality single treatment, whereas linac technique involved daily conventional fraction treatments involving a relocatable frame, fewer isocenters, and high conformality established by noncoplanar arc beam shaping and differential beam weighting. RESULTS: Sixty-nine patients were treated on the gamma knife, and 56 patients were treated on the linac, with 1 NF-2 patient common to both units. Three patients were lost to follow-up, and in the remaining 122 patients, mean follow-up was 119 +/- 67 weeks for SRS patients and 115 +/- 96 weeks for SRT patients. Tumor control rates were high (> or =97%) for sporadic tumors in both groups but lower for NF-2 tumors

in the SRT group. Cranial nerve morbidities were comparably low in both groups, with the exception of functional hearing preservation, which was 2.5-fold higher in patients who received conventional fraction SRT. **CONCLUSION:** SRS and SRT represent comparable noninvasive treatments for acoustic schwannomas in both sporadic and NF-2 patient groups. At 1-year follow-up, a significantly higher rate of serviceable hearing preservation was achieved in SRT sporadic tumor patients and may therefore be preferable to alternatives including surgery, SRS, or possibly observation in patients with serviceable hearing.

63.

**Year:** 2001

**Patient number:** 40

**Author:** Bertalanffy, A.; Dietrich, W.; Aichholzer, M.; Brix, R.; Ertl, A.; Heimberger, K.; Kitz, K.

**Reference:** Acta neurochirurgica, 143, 7, 689-95, 2001

**Title:** Gamma knife radiosurgery of acoustic neurinomas

**Abstract:** The authors report on their series of 40 patients with 41 acoustic neurinomas (ACNs), including one patient with bilateral acoustic neurinomas suffering from neurofibromatosis type 2 (NF II) who were treated with the gamma knife unit at their institution between August 1992 and October 1995. Of these 41 tumours, 21 ACNs had been operated on before (1 to 4 times), 20 ACNs were exclusively treated by gamma knife radiosurgery (GKRS). The maximal axial tumour diameter ranged from 6 to 33 mm (median: 25 mm), the maximal transverse tumour diameter ranged from 7 mm to 36 mm (median: 16 mm). The dose distributed to the tumour margin was 10 to 17 Gy (median: 12 Gy) by enclosing the tumour with the 40% to 95% isodose line (median: 50% isodose line) and using 1 to 12 isocenters (median: 5 isocenters). Central loss of contrast enhancement was observed in 78% of the patients within six to 12 months after radiosurgery. Thirty-two patients were observed over a minimum follow up period of at least 36 months, 9 patients were lost to follow up as they died of unrelated causes or refused further check-ups. Within the follow up period of up to seven years, magnetic resonance imaging (MRI) control scans revealed the tumour diameter stable or decreased in 29 cases and increased in three tumours. Of 14 patients with useful hearing before treatment, 9 patients were examined in addition to pure tone audiogram by measurement of brainstem auditory evoked potentials (BAEPs) one to four years after radiosurgery. None of these patients showed a postoperative loss of the cochlea function. According to slight alterations of the cochlea function (cochlea summing action potential), pure tone audiometry of those patients revealed only slight changes of the hearing level (HL) within a maximum range of  $\pm 15$  Decibel (dB). The hearing threshold improved in two, was stable in four and deteriorated in three patients, respectively. We observed postradiosurgical aggravation of a pre-existing facial weakness in two out of 13 patients, a new occurrence of facial palsy was seen in two cases (four years after treatment), one of them was previously operated on and both suffered from cystic degeneration with mass effect. Tinnitus improved in six out of 13 patients, deteriorated in two and never appeared as a new permanent sequela. Trigeminal hypaesthesia did also

not appear as a new permanent symptom, improved in three out of 9, and deteriorated in one out of 9 patients. Vertigo increased in six out of 23, was stable in 8 and decreased in nine out of 23 patients each. GKRS proves to be a safe and highly satisfactory therapeutical option or addition to open surgery, especially for radiologically verified regrowing residual ACNs, but also as primary treatment in selected patients. A high rate of tumour control can be achieved with an acceptable rate of neurological deficits.

64.

**Year:** 2001

**Patient number:** 190

**Author:** Flickinger, J. C.; Kondziolka, D.; Niranjan, A.; Lunsford, L. D.

**Reference:** Journal of neurosurgery, 94, 1, 1-6, 2001

**Title:** Results of acoustic neuroma radiosurgery: an analysis of 5 years' experience using current methods

**Abstract:**OBJECT: The goal of this study was to define tumor control and complications of radiosurgery encountered using current treatment methods for the initial management of patients with unilateral acoustic neuroma. METHODS: One hundred ninety patients with previously untreated unilateral acoustic neuromas (vestibular schwannomas) underwent gamma knife radiosurgery between 1992 and 1997. The median follow-up period in these patients was 30 months (maximum 85 months). The marginal radiation doses were 11 to 18 Gy (median 13 Gy), the maximum doses were 22 to 36 Gy (median 26 Gy), and the treatment volumes were 0.1 to 33 cm<sup>3</sup> (median 2.7 cm<sup>3</sup>). The actuarial 5-year clinical tumor-control rate (no requirement for surgical intervention) for the entire series was 97.1+/-1.9%. Five-year actuarial rates for any new facial weakness, facial numbness, hearing-level preservation, and preservation of testable speech discrimination were 1.1+/-0.8%, 2.6+/-1.2%, 71+/-4.7%, and 91+/-2.6%, respectively. Facial weakness did not develop in any patient who received a marginal dose of less than 15 Gy (163 patients). Hearing levels improved in 10 (7%) of 141 patients who exhibited decreased hearing (Gardner-Robertson Classes

65.

**Year:** 2001

**Patient number:** 556

**Author:** Niranjan, A.; Dade, Lunsford L.; Kondziolka, D.; Flickinger, J. C.

**Reference:** Operative Techniques in Neurosurgery, 4, 1, 36-42, 2001

**Title:** Gamma knife radiosurgery for acoustic tumors

**Abstract:**Stereotactic radiosurgery is a technique designed to produce a specific radiobiologic effect within a sharply defined target volume in a single session. Radiosurgery is a potentially effective alternative to surgical removal of small-sized to moderate-sized acoustic tumors. During a 12-year period, 556 patients with acoustic tumors underwent radiosurgery at the University of Pittsburgh, which represents 25% of all tumor radiosurgery cases. Our technique for acoustic tumor radiosurgery evolved

steadily in the 1990s. The current technique of radiosurgery includes MR imaging-based conformal dose planning and 13 Gy minimal tumor dose. Preservation of cochlear and facial nerve function is the main concern during radiosurgery dose planning. For moderate-sized tumors, preservation of trigeminal nerve and brain stem function is a consideration. In our recent analysis, the 5-year actuarial rates of preoperative hearing level preservation and speech preservation were 71% and 91% for 192 patients treated with 13 Gy as the median tumor margin dose. This dose was associated with 1.1% risk of new facial weakness and a 2.6% risk of facial numbness (5-year actuarial rates). The actuarial 5-year clinical tumor control rate (no requirement for surgical intervention) was 97%. All patients (100%) with intracanalicular tumors treated at 13 Gy margin dose maintained a serviceable level of hearing. The results after radiosurgery of acoustic tumors have established it as an important minimally invasive alternative to microsurgery. Copyright © 2001 W.B. Saunders Company.

66.

**Year:** 2001

**Patient number:** 45

**Author:** Petit, J. H.; Hudes, R. S.; Chen, T. T.; Eisenberg, H. M.; Simard, J. M.; Chin, L. S.

**Reference:** Neurosurgery, 49, 6, 1299-306, 2001

**Title:** Reduced-dose radiosurgery for vestibular schwannomas

**Abstract:** **OBJECTIVE:** To evaluate tumor control and complications associated with low-dose radiosurgery for vestibular schwannomas. **METHODS:** Between December 1993 and January 2000, 47 patients with vestibular schwannomas were treated at our center with gamma knife radiosurgery. The marginal tumor doses ranged from 7.5 to 14.0 Gy (median, 12.0 Gy) for patients treated after microsurgery and from 10.0 to 15.0 Gy (median, 12.0 Gy) for patients in whom radiosurgery was the primary treatment. The median maximum tumor diameter was 18 mm (range, 3-50 mm). Evaluation included audiometry, neurological examination, and serial imaging tests. A survey was conducted at the time of analysis. **RESULTS:** Follow-up data were available for 45 patients and ranged from 1 to 7 years (median, 3.6 yr). In 43 patients (96%), tumor control (no radiographic progression or surgical resection) was observed. All 33 previously untreated patients had tumor control. Transient facial weakness, experienced in two patients (4%), had resolved completely within 6 months. No patient developed trigeminal neuropathy. Hearing was diminished from baseline in 12% of patients with useful hearing (Gardner-Robertson Class III). However, all patients with pretreatment hearing Gardner-Robertson Class I or II maintained testable hearing (Class I to III) at the most recent examination. **CONCLUSION:** Low-dose radiosurgery in this series provided comparable local control and decreased incidences of complications in relation to other reports. Additional follow-up will allow more definitive conclusions to be reached regarding the ultimate rates of tumor control and hearing preservation. Nevertheless, the current dose used for vestibular schwannomas at the University of Maryland Medical Center is 12.0 Gy to the tumor periphery.

67.

**Year:** 2001

**Patient number:** 12

**Author:** Walch, C.; Unger, F.; Anderhuber, W.; Feichtinger, K.

**Reference:** Laryngo- rhino- otologie, 80, 7, 385-8, 2001

**Title:** Radiosurgery of recurrent acoustic neurinoma or: the elegant solution of a surgical problem?

**Abstract:**BACKGROUND: Stereotactic radiosurgery has proved to be an effective alternative to microsurgical resection in treatment of acoustic neuroma. Still, microsurgery is considered by many to be the therapy of choice. In case of recurrence microsurgical resection is much more difficult because of scarring and has a higher risk of complications. Therefore in cases of recurrence the role of radiosurgery needed to be evaluated.

PATIENTS AND METHODS: From April 1992 to July 1997 135 patients suffering from acoustic neuroma were treated at the Neurosurgical Department of the University Medical School of Graz by means of the gamma-Knife. 12 patients had recurrence after a single or several microsurgical resections. The age distribution was between 38 and 71 years with a mean of 57 years. The diameter of the tumors varied between 10.5 and 31.2 mm.

RESULTS: In all 12 cases the tumors could be inactivated biologically in a mean follow-up period of 58.8 months by means of stereotactic radiosurgery. Tumor shrinkage was achieved in 3 cases (25%), central necrotic areas were observed in 8 cases (67%). No additional cranial nerve palsies occurred. CONCLUSIONS: Stereotactic radiosurgery has proven to be a safe and effective treatment option instead of repeated microsurgery. Stereotactic radiosurgery should be considered as the therapy of choice in cases of recurrent acoustic neuromas.

68.

**Year:** 2000

**Patient number:** 125

**Author:** Ito, K.; Shin, M.; Matsuzaki, M.; Sugasawa, K.; Sasaki, T.

**Reference:** International journal of radiation oncology biology physics, 48, 1, 75-80, 2000

**Title:** Risk factors for neurological complications after acoustic neurinoma radiosurgery: refinement from further experiences

**Abstract:**Purpose: Further actuarial analyses of neurological complications were performed on a larger population treated by stereotactic radiosurgery at our institution, to establish the optimal treatment parameters. METHODS AND MATERIALS: Between June 1990 and September 1998, 138 patients with acoustic neurinomas underwent stereotactic radiosurgery at Tokyo University Hospital. Of these, 125 patients who received medical follow-up for 6 months or more entered the present study. Patient ages ranged from 13 to 77 years (median, 53 years). Average tumor diameter ranged from 6.7 to 25.4 mm (mean, 13.9 mm). Maximum tumor doses ranged from 20 to 40 Gy (mean, 29.8 Gy) and peripheral doses from 12 to 25 Gy (mean, 15.4 Gy). One to 12 isocenters were used (median, 4). Follow-up period ranged from 6 to 104 months (median, 37 months). The potential risk factors for neurological complications were analyzed by two

univariate and one multivariate actuarial analyses. Neurological complications examined include hearing loss, facial palsy, and trigeminal nerve dysfunction. Variables included in the analyses were four demographic variables, two variables concerning tumor dimensions, and four variables concerning treatment parameters. A variable with significant p values ( $p < 0.05$ ) on all three actuarial analyses was considered a risk factor. **RESULTS:** The variables that had significant correlation to increasing the risk for each neurological complication were: Neurofibromatosis Type 2 (NF2) for both total hearing loss and pure tone threshold (PTA) elevation; history of prior surgical resection, tumor size, and the peripheral tumor dose for facial palsy; and the peripheral tumor dose and gender (being female) for trigeminal neuropathy. In facial palsies caused by radiosurgery, discrepancy between the course of palsy and electrophysiological responses was noted. **CONCLUSION:** Risk factors for neurological complications seem to have been almost established, without large differences between institutions treating a large number of patients by radiosurgery. Radiosurgical doses and tumor dimensions were considered the two important risk factors for the 7th and 5th nerve injuries. Neurofibromatosis Type 2 was an important factor for hearing loss.

69.

**Year:** 2000

**Patient number:** 20

**Author:** Kida, Y.; Kobayashi, T.; Tanaka, T.; Mori, Y.

**Reference:** Surgical neurology, 53, 4, 383-89, 2000

**Title:** Radiosurgery for bilateral neurinomas associated with neurofibromatosis type 2

**Abstract:** **OBJECTIVE:** The clinical course of bilateral acoustic tumors associated with neurofibromatosis (NF2) is generally troublesome, and no definite treatment strategy has been established. Follow-up results of bilateral acoustic tumors after radiosurgery are reported herein. **METHODS:** The current indications for radiosurgery are 1) a growing tumor less than 30 mm in mean diameter, 2) the ipsilateral ear has no serviceable hearing, and 3) there is risk of brain stem compression or brain stem dysfunction. Twenty cases of bilateral acoustic tumors were treated with the gamma knife, including 7 males and 13 females. The mean age was 38.2 years and the mean tumor size 24.4 mm. The tumors were treated with mean maximum and marginal doses of 26.8 Gy and 13.0 Gy, respectively. Among them, 12 patients had profound hearing loss in the ipsilateral (treated) ear, but the other 8 had serviceable hearing. **RESULTS:** Tumors treated with radiosurgery showed central necrosis in 60% of the cases at 6 months and in 70% at 9 months after radiosurgery. Thereafter, the tumors often demonstrated slow regression. The rate of tumor shrinkage was 20% at 12 months, 35% at 24 months, and almost 60% at 36 months. At the last follow-up (mean 33.6 months), the tumors demonstrated shrinkage in 50% and tumor control in 100%. The contralateral tumors were stable in 12 (60%) and enlarged in 8 (40%). Preservation of serviceable hearing ipsilaterally was obtained in 33.3%. Deterioration of ipsilateral facial nerve function, either in the natural course or as a complication, occurred in 10%. **CONCLUSIONS:** Because of good tumor control and tumor shrinkage as well as an acceptable complication rate, radiosurgery should be incorporated in the treatment strategy for bilateral acoustic tumors associated

with NF2.

70.

**Year:** 2000

**Patient number:** 69

**Author:** Møller, P.; Myrseth, E.; Pedersen, P. H.; Larsen, J. L.; Krakenes, J.; Moen, G.

**Reference:** Acta oto-laryngologica. Supplementum, 543, 34-7, 2000

**Title:** Acoustic neuroma--treatment modalities Surgery, gamma-knife or observation?

**Abstract:** We present our results of 211 patients with acoustic neuroma over a period of 10 years, 1988-97. We operated on 100 and 111 had Gamma-knife (GK) treatment (69 were available to follow-up). The results are excellent for surgery on small and intracanalicular tumours. In tumours of the same size, surgery and GK treatment give comparable, but somewhat different, results. In the GK group of 54 primary treated patients, 3 patients had to be operated on and another 4 developed hydrocephalus. A group of 35 acoustic tumours was observed for more than 3 years. Nineteen did grow (54%). Hearing was unchanged in 23%. We performed surgery in 11 patients and gave 2 patients GK treatment because of tumour growth of > 2 mm in diameter a year. We conclude that either treatment is effective for small and medium-sized acoustic neuromas. Hearing preservation was best in the GK-treated group (80%), compared to only 12.5% in the group operated via the suboccipital route. Larger tumours and most medium-sized tumours should be operated, as should smaller tumours with persistent symptoms of vertigo and pain. Medical contraindications to surgery or reluctance to undergo surgery make GK treatment a good alternative. Treatment of residual tumours with the GK could also be a solution to a difficult problem.

71.

**Year:** 2000

**Patient number:** 78

**Author:** Nakamura, H.; Jokura, H.; Takahashi, K.; Boku, N.; Akabane, A.; Yoshimoto, T.

**Reference:** AJNR. American journal of neuroradiology, 21, 8, 1540-6, 2000

**Title:** Serial follow-up MR imaging after gamma knife radiosurgery for vestibular schwannoma

**Abstract:** BACKGROUND AND PURPOSE: Gamma knife radiosurgery has become an important treatment option for vestibular schwannoma. The effect of treatment can be assessed only by neuroimaging. We analyzed the evolution of follow-up MR imaging findings after gamma knife radiosurgery to provide information for the clinical management of these tumors. METHODS: Changes in tumor volume and enhancement were assessed visually on 341 follow-up MR studies obtained in 78 of 86 consecutive patients with unilateral vestibular schwannoma who underwent gamma knife radiosurgery. RESULTS: Follow-up MR studies were obtained between 10 and 63 months (mean, 34 months) after treatment. Tumor control rate was 81%. Changes in tumor volume were classified as temporary enlargement (41%), no change or sustained regression (34%),

alternating enlargement and regression (13%), or continuous enlargement (12%). Temporary enlargement occurred within 2 years after radiosurgery. Changes in tumor enhancement were classified as transient loss of enhancement (84%), continuous increase in enhancement (5%), or no change in enhancement (11%). There was no significant correlation between changes in tumor volume and tumor enhancement. Areas of T2 hyperintensity in adjacent brain tissue appeared in 31% of patients. **CONCLUSION:** Dynamic changes in vestibular schwannoma are seen on serial follow-up MR studies obtained after gamma knife radiosurgery. An increase in tumor size up to 2 years after radiosurgery is likely to be followed by regression. Changes in contrast enhancement are not predictive of clinical outcome. Neuroimaging follow-up is recommended.

72.

**Year:** 2000

**Patient number:** 153

**Author:** Prasad, D.; Steiner, M.; Steiner, L.

**Reference:** Journal of neurosurgery, 92, 5, 745-59, 2000

**Title:** Gamma surgery for vestibular schwannoma

**Abstract:** **OBJECT:** The goal of this study was to assess the results of gamma surgery (GS) for vestibular schwannoma (VS) in 200 cases treated over the last 10 years and to review the role of this neurosurgical procedure in the management of VS. **METHODS:** Follow-up reviews ranging from 1 to 10 years were available in 153 of these patients. Follow-up images in these cases were analyzed using computer software that we developed to obtain volume measurements for the tumors, and the clinical condition of the patients was assessed using questionnaires. Gamma surgery was the primary treatment modality in 96 cases and followed microsurgery in 57 cases. Tumors ranged in volume from 0.02 to 18.3 cm<sup>3</sup>. In the group in which GS was the primary treatment, a decrease in volume was observed in 78 cases (81%), no change in 12 (12%), and an increase in volume in six cases (6%). The decrease was more than 75% in seven cases. In the group treated following microsurgery, a decrease in volume was observed in 37 cases (65%), no change in 14 (25%), and an increase in volume in six (11%). The decrease was more than 75% in eight cases. Five patients experienced trigeminal dysfunction; in three cases this was transient and in the other two it was persistent, although there has been improvement. Three patients had facial paresis (in one case this was transient, lasting 6 weeks; in one case there was 80% recovery at 18 months posttreatment; and in one case surgery was performed after the onset of facial paresis for presumed increase in tumor size). Over a 6-year period, hearing deteriorated in 60% of the patients. Three patients showed an improvement in hearing. No hearing deterioration was observed during the first 2 years of follow-up review. **CONCLUSIONS:** Gamma surgery should be used to treat postoperative residual tumors as well as tumors in patients with medical conditions that preclude surgery. Microsurgery should be performed whenever a surgeon is confident of extirpating the tumor with a risk-benefit ratio superior to that presented in this study.

73.

**Year:** 2000

**Patient number:** 27

**Author:** Roche, P. H.; Régis, J.; Pellet, W.; Thomassin, J. M.; Grégoire, R.; Dufour, H.; Peragut, J. C.

**Reference:** Neuro-Chirurgie, 46, 4, 339-53, 2000

**Title:** Neurofibromatosis type 2 Preliminary results of gamma knife radiosurgery of vestibular schwannomas

**Abstract:**BACKGROUND AND PURPOSE: The aim of this study was to assess tolerance and efficacy of gamma knife radiosurgery on vestibular schwannomas for patients affected with neurofibromatosis type 2. METHODS: Between July 1992 and December 1997, a gamma knife procedure was performed on 35 vestibular schwannomas affecting 27 patients (12 females and 15 males, mean age=27 years-old, range: 14-65). Fifteen of the patients were included in the Wishart subtype (severe form) and 12 patients in the Gardner subtype (mild form). This group of 27 patients represented 8,2% of the total group of vestibular schwannomas radiosurgically treated by our team. The mean tumor volume was 4,000 mm<sup>3</sup> (range: 400-14,400 mm<sup>3</sup>) and staging according to Koos classification was 9 stage 2 tumors (extension in the cerebellopontine angle), 19 stage 3 tumors (in contact with the brain stem or cerebellum) and 7 stage 4 tumors (compression of axial structures). The delivered mean marginal dose (50% isodose) was 13 Gy (range: 10-18 Gy). After the treatment, the mean clinical and radiological follow-up was 32 months (range: 6-70). RESULTS: Twenty six (74%) of the treated tumors were controlled by the treatment (15 stabilizations and 11 regressions of the tumor volume) at last follow-up. One microsurgical removal was required in a growing stage 4 tumor and in 2 cases of growing stage 3 tumors. Three post-radiosurgical facial nerve deficits (9%) were observed, 2 of them were transient. According to the Gardner and Robertson classification, classes I (good) and II (serviceable) hearing were preserved at last follow-up in 57% of the patients having the same hearing level prior to the gamma knife. CONCLUSIONS: Our experience confirms that tolerance of gamma knife radiosurgery compares favorably with microsurgery of bilateral vestibular schwannomas. This treatment should be restricted to small and medium growing tumors. Treatment strategy of neurofibromatosis type 2 patients should be planned by multidisciplinary experienced teams disposing of the whole armamentarium. A longer follow-up study is required to confirm the current results regarding the tumor control rate.

74.

**Year:** 2000

**Patient number:** 186

**Author:** Unger, F.; Papaefthymiou, G.; Eustacchio, S.; Trummer, M.; Pendl, G.

**Reference:** Acta Chirurgica Austriaca, 32, 5, 233-235, 2000

**Title:** Hydrocephalus - A major complication after stereotactic radiosurgical gamma knife treatment?

**Abstract:**Background: Hydrocephalus formation following Gamma Knife radiosurgery

has been repeatedly reported in the literature. Experiences in patients treated at our own institution are presented here. Methods: 1500 patients underwent stereotactic radiosurgery with the Gamma Knife at the Department of Neurosurgery at the Karl Franzens University in Graz from April 1992 until January 1999 (age ranging from 2 to 88 years, median 51). Single dose radiosurgery was performed with use of a Gamma Unit (Modell B, 201 Cobalt-60 bears). Among those patients were 333 with meningioma, 277 with metastases, 189 had glial tumors, 186 acoustic neurinoma and 150 arteriovenous malformations. Clinical and neuroradiological follow-up examinations were performed every six months, in patients with malignant tumors at intervals of 3 months. Results: 33 patients had a preexistent hydrocephalus 20 of whom had been treated surgically with tumor resection prior to Gamma Knife treatment, in all patients ventriculoperitoneal shunts had to be inserted radiosurgery. After radiosurgery 3 patients with acoustic neurinomas and initially normal ventricular system developed hydrocephalus. Microsurgical tumor debulking was performed in two cases. The third patient was treated by means of a ventriculoperitoneal shunt. Conclusions: Tumor-associated hydrocephalus with predictable course was observed in 2 % of all patients. By contrast, treatment-related peritumoral reaction sufficient to block the CSF circulation and requiring shunt insertion was observed only in 0.2 % of all patients and concerned less than 2 % patients with acoustic neurinomas. The aim of radiosurgery in tumor patients is growth control. In cases with preexisting aquaeductal obstruction occlusive hydrocephalus may develop especially in the phase of radiogenic perifocal edema. This fact should be discussed with patients who are not operated due to medical problems or who refuse surgery. Patients having undergone a shunting procedure already before radiosurgery are likely to remain shunt-dependent. Hydrocephalus formation is not a typical complication but is a symptom that may aggravate after radiosurgery.

75.

**Year:** 2000

**Patient number:** 126

**Author:** Yu, C. P.; Cheung, J. Y.; Leung, S.; Ho, R.

**Reference:** Journal of neurosurgery, 93, Suppl 3, 82-9, 2000

**Title:** Sequential volume mapping for confirmation of negative growth in vestibular schwannomas treated by gamma knife radiosurgery

**Abstract:** OBJECT: The purpose of this study was to confirm, by using a sequential volume mapping (SVM) technique, that gamma knife radiosurgery (GKS) induces negative growth in vestibular schwannomas (VS). METHODS: Over a period of 5 years, 126 small- to medium-sized (< 15 cm<sup>3</sup>) VSs were treated using microradiosurgical techniques within a standard protocol. All patient data were collected prospectively. Sequential magnetic resonance imaging was performed every 6 months to assess the volume of the tumor, based on specially developed GammaPlan software. The mean follow-up duration was 22 months. At least three SVM measurements were obtained in 91 patients and at least four were obtained in 62 patients. The mean number of SVM measurements for each patient was 2.54. After GKS, the following patterns of volume change were seen: 1) 57 VSs showed transient increase in volume with a peak at 6

months, followed by shrinkage. Four VSs exhibited prolonged swelling beyond 24 months. Transient swelling and eventual shrinkage were independent of the initial VS volume; 2) 29 VSs showed direct volume shrinkage without swelling; and 3) five VSs showed persistent volume increase. All volume changes were greater than 10%. The overall mean volume reduction was 46.8% at 30 months. **CONCLUSIONS:** Sequential volume mapping appears to be superior to conventional two-dimensional measurements in monitoring volume changes in VS after GKS. It confirms that transient swelling is common. Ninety-two percent of tumors responded by showing significant volume shrinkage (mean 46.8%). It would seem that GKS can induce volume reduction in VS.

76.

**Year:** 1999

**Patient number:** 10

**Author:** Chang, J. W.; Kim, S. H.; Huh, R.; Park, Y. G.; Chung, S. S.

**Reference:** Stereotactic and Functional Neurosurgery, 72, SUPPL. 1, 29-37, 1999

**Title:** The effects of stereotactic radiosurgery on secondary facial pain

**Abstract:** Twenty-seven patients with tumor-related secondary facial pain were treated by stereotactic radiosurgical procedures between November 1991 and October 1998. They had 14 meningiomas, 11 schwannomas (one trigeminal, 10 vestibular), one nasopharyngeal cancer and one chordoma. The mean maximum dose administered was 26.4 Gy (range 16 to 35 Gy) and the margin of the tumor was encompassed within the 45 to 90% isodose. The patients were analyzed based on their pain relief with a mean follow-up duration of 32.1 months. In 24 patients (85.7%), there was initial pain improvement after radiosurgery, but half had recurrent pain. A pain response was obtained in 12 cases (pain response rate = 42.9%), five were pain free and seven had pain reduction. On the follow-up MRI, a decrease in tumor volume of more than 20% of the preoperative volume occurred in 14 of 25 cases. The mean time interval to initial pain improvement (10.3 months) and pain response (5.7 months) were shorter than for a decrease in tumor volume (18.6 months). Tumor-related secondary facial pain was less responsive to stereotactic radiosurgery than idiopathic trigeminal neuralgia. It would seem that the mechanism of pain relief in radiosurgery is not only trigeminal root decompression secondary to tumor volume reduction, but also other mechanisms involving inactivation of abnormal electrical transmission may be involved.

77.

**Year:** 1999

**Patient number:** 77

**Author:** Kwon, Y.; Khang, S. K.; Kim, C. J.; Lee, D. J.; Lee, J. K.; Kwun, B. D.

**Reference:** Stereotactic and functional neurosurgery, 72, Suppl 1, 2-10, 1999

**Title:** Radiologic and histopathologic changes after Gamma Knife radiosurgery for acoustic schwannoma

**Abstract:** Gamma knife radiosurgery (GKRS) is a widely used treatment option for

acoustic schwannomas, 3 cm in diameter or less. Between May 1990 and February 1998, 102 acoustic tumors in 101 patients were treated with GKRS. There are 77 patients with a follow-up period of more than six months (mean 55, range 7 to 90 months). Seventy (91%) of these tumors have remained unchanged or reduced in volume. After GKRS there was an increase in volume in seven cases. In four the volume increase affected solid tumour. Among these, three patients were in stable condition and are being observed. One of these patients developed brain stem compression symptoms and was operated. In another three cases, cysts with multiple septa developed medial to the tumor and compressed the brain stem and fourth ventricle, thus necessitating post-GKRS surgery. In these three patients, MRI had shown loss of central contrast enhancement followed by its return. Histological findings at surgery before and after GKRS were compared for these four tumours. In spite of the MRI changes, there were no definite histological findings after GKRS which could be attributed to radiation induced changes. The development of cysts occurred after the treatment of larger tumors.

78.

**Year:** 1999

**Patient number:** 121

**Author:** Liscak, R.; Vladyka, V.; Urgosik, D.; Simonova, G.; Bares, K.; Novotny, J., Jr.

**Reference:** Journal of Radiosurgery, 2, 1, 13-22, 1999

**Title:** Acoustic neurinoma and its treatment using the Leksell gamma-knife as a primary or secondary treatment

**Abstract:** Over 4 years (1992-1996) we have treated 122 patients with unilateral acoustic neurinoma using the Leksell gamma-knife; 121 patients had a follow-up of 2-48 months (median 24 months). Tumor volume was 0.1-17.8 cm<sup>3</sup> (median 2.9 cm<sup>3</sup>); dose to the tumor margin was 10-17.5 Gy (median 12 Gy) delivered on 40-80% isodose (median 50%). A decrease in the tumor volume was observed in 41.3% of patients, the tumor volume was unchanged in 54.6%, and an increase in the tumor despite radiosurgery was observed in 4.1%. Hearing loss was detected in 17.4% of patients, and 3% of patients gained useful hearing after radiosurgery. The overall risk of the method is 4.3% of hearing loss. Weakness of the facial nerve was observed in 1.9% of patients; normalization of the weakness, which was present before radiosurgery, was observed in 6.3% of patients. The overall risk of facial weakness is 1% for gamma-knife radiosurgery. Impairment of trigeminal neuropathy was observed in 5% of patients and improvement in 31%. Impairment of vertigo was observed in 5.8% of patients and improvement in 46%. Leksell gamma-knife radiosurgery was the primary treatment in 97 patients (80.7%); microsurgical resection preceded radiosurgery in 24 patients (19.8%). Hearing loss and neuropathy of facial and trigeminal nerves before gamma-knife radiosurgery were significantly more frequent in the group of patients with previous microsurgical resection than in the group with gamma-knife radiosurgery as the primary treatment. After radiosurgery there was no significant difference in impairment or improvement of hearing, facial and trigeminal nerve neuropathy, and vertigo and imbalance for the groups of patients with previous microsurgery or primary gamma-knife treatment. After gamma-knife radiosurgery neuropathy of facial and trigeminal nerves in the group of

patients with previous microsurgery was significantly worse.

79.

**Year:** 1999

**Patient number:** 21

**Author:** Ma, Z.; Qiu, B.; Tang, J.; Hou, Y.; Ma, J.; Liu, Y.

**Reference:** Hunan yi ke da xue xue bao, 24, 1, 59-61, 1999

**Title:** Preservation of hearing and facial nerve function after Gamma knife therapy for acoustic neurinomas

**Abstract:**Thirty-five patients with acoustic neurinomas were treated by Gamma knife from Sept. 1995 to Oct. 1997. Neuroimaging studies performed in 21 patients with more than 12 months showed that tumor size decreased in 9(43%) cases, unchanged in 11(51%) cases, and increased in 1(15%) case. The tumor growth control and regression rates were 95% and 43%, respectively. Some hearing was preserved in four patients (36%) who had hearing prior to Gamma knife treatment. There was new transient facial weakness in five patients(23%), and there was new trigeminal neuropathy after treatment in one patient (4.8%). These findings indicate that Gamma knife therapy is a safe and effective management for acoustic neurinomas, especially in preventing facial function and hearing.

80.

**Year:** 1999

**Patient number:** 42

**Author:** Miller, R. C.; Foote, R. L.; Coffey, R. J.; Sargent, D. J.; Gorman, D. A.; Schomberg, P. J.; Kline, R. W.

**Reference:** International journal of radiation oncology biology physics, 43, 2, 305-11, 1999

**Title:** Decrease in cranial nerve complications after radiosurgery for acoustic neuromas: a prospective study of dose and volume

**Abstract:**PURPOSE: To determine whether tumor control can be maintained, and cranial nerve complications decreased by reducing the radiosurgical dose to acoustic neuromas. METHODS AND MATERIALS: Forty-two consecutive patients with acoustic neuromas were treated prospectively using an initial standard-dose protocol in which the tumor-margin dose (50% isodose) was 20, 18, and 16 Gy for tumor diameters  $\leq$  2 cm, 2.1-3 cm, and 3.1-4 cm, respectively. After analysis of tumor control and complications, the next 40 patients were treated using a reduced- dose protocol in which the tumor-margin dose was 16, 14, and 12 Gy for tumor volumes  $\leq$  4.2 cm<sup>3</sup>, 4.2-14.1 cm<sup>3</sup>, and  $\geq$  14.1 cm<sup>3</sup>, respectively. RESULTS: Median follow-up was 2.3 years (range 0.1-6) for 80 of 82 patients. The actuarial incidence (Kaplan-Meier) of facial neuropathy at 2 years was 38% (95% confidence interval (CI), 23-53%) for the standard-dose protocol and 8% (95% CI, 0-17%) for the reduced-dose protocol ( $p = 0.006$ ). Univariate analysis revealed an association between risk of facial neuropathy and use of CT planning, higher

radiosurgical dose, and neurofibromatosis, type 2. Multivariate analysis revealed that the only factor associated with increased risk of post-treatment facial neuropathy was a tumor margin dose  $\geq 18$  Gy. The incidence of trigeminal neuropathy at 2 years was 29% (95% CI, 15-43%) for the standard-dose protocol and 15% (95% CI, 3-27%) for the reduced-dose protocol ( $p = 0.17$ ). Univariate analysis revealed an association between maximal tumor diameter and increased risk of trigeminal neuropathy; multivariate analysis revealed no additional statistically significant associations between tumor and dosimetric and patient characteristics and risk of trigeminal neuropathy. Two tumors in the standard-dose protocol required salvage surgery for progression. To date, no tumor in the reduced-dose protocol has shown progression. **CONCLUSION:** Our analysis suggests that a tumor margin dose of  $\geq 18$  Gy is the most significant risk factor for facial nerve complications after acoustic neuroma radiosurgery. Patients receiving a minimal tumor dose of  $\leq 16$  Gy are at significantly lower risk for permanent facial neuropathy after radiosurgery. Longer follow-up is required before definitive conclusions can be made about the ultimate rate of tumor control using reduced radiosurgical doses.

81.

**Year:** 1999

**Patient number:** 15

**Author:** Niranjana, A.; Lunsford, L. D.; Flickinger, J. C.; Maitz, A.; Kondziolka, D.

**Reference:** Neurosurgery, 45, 4, 753-62, 1999

**Title:** Dose reduction improves hearing preservation rates after intracanalicular acoustic tumor radiosurgery

**Abstract:** **OBJECTIVE:** To assess the potential for long-term serviceable hearing preservation in intracanalicular acoustic tumor patients who underwent stereotactic radiosurgery. **METHODS:** Between August 1987 and December 1997, 29 patients with intracanalicular acoustic tumors underwent stereotactic radiosurgery at our center using the Leksell gamma knife (Elekta Instruments, Inc., Atlanta, GA). Fifteen assessable patients had serviceable preradiosurgery hearing (pure tone average,  $\leq 50$  dB; speech discrimination score,  $\geq 50\%$ ). We retrospectively analyzed our hearing results and compared hearing preservation in patients who received a minimal tumor dose of 14 Gy or less versus those who received more than 14 Gy to the tumor margin. **RESULTS:** No perioperative patient morbidity or mortality was observed. Serviceable hearing was preserved in 11 (73%) of 15 assessable patients (actuarial rate, 65%). Long-term follow-up demonstrated serviceable hearing preservation in 10 (100%) of 10 patients who received marginal tumor doses of 14 Gy or less but in only one of five patients who received more than 14 Gy. Preradiosurgery Gardner-Robertson class was preserved in 49%, and testable hearing was present in 68% of patients who had any testable hearing at presentation. Five patients demonstrated improvement in hearing (three had serviceable and two had nonserviceable hearing before radiosurgery). No patient developed a facial or trigeminal neuropathy. Seven of 13 patients with preoperative tinnitus continued to experience tinnitus in follow-up. Episodic vertigo continued in 3 of the 11 patients who presented with vertigo. **CONCLUSION:** Gamma knife radiosurgery (using conformal dose planning, small-beam geometry, and  $\leq 14$

Gy to the margin) prevents tumor growth and achieves excellent hearing preservation rates.

82.

**Year:** 1999

**Patient number:** 21

**Author:** Niranjan, A.; Lunsford, L. D.; Flickinger, J. C.; Maitz, A.; Kondziolka, D.

**Reference:** Neurosurgery clinics of North America, 10, 2, 305-15, 1999

**Title:** Can hearing improve after acoustic tumor radiosurgery?

**Abstract:**Advances in noninvasive diagnostic techniques have enabled physicians to diagnose acoustic tumors early, while hearing is still present. Applications of advanced operative techniques have allowed surgeons to decrease progressively the operative mortality to virtually zero, to save facial nerve function in a large number of patients, and even to preserve serviceable hearing in selected patients. Documented improvement in hearing after acoustic tumor surgery is rare. During the last decade, stereotactic radiosurgery has evolved as a noninvasive surgical option for acoustic tumors. Hearing improvement after radiosurgery has not been reported. The authors observed hearing improvement in 21 out of 487 patients who had radiosurgery during a 10-year interval. This article reviews their experience of hearing improvement after radiosurgery and suggests possible reasons that hearing can not only be retained but also improved in selected patients.

83.

**Year:** 1999

**Patient number:** 40

**Author:** Subach, B. R.; Kondziolka, D.; Lunsford, L. D.; Bissonette, D. J.; Flickinger, J. C.; Maitz, A. H.

**Reference:** Journal of neurosurgery, 90, 5, 815-22, 1999

**Title:** Stereotactic radiosurgery in the management of acoustic neuromas associated with neurofibromatosis Type 2

**Abstract:**OBJECT: Stereotactically guided radiosurgery is one of the primary treatment modalities for patients with acoustic neuromas (vestibular schwannomas). The goal of radiosurgery is to arrest tumor growth while preserving neurological function. Patients with acoustic neuromas associated with neurofibromatosis Type 2 (NF2) represent a special challenge because of the risk of complete deafness. To define better the tumor control rate and long-term functional outcome, the authors reviewed their 10-year experience in treating these lesions. METHODS: Forty patients underwent stereotactic radiosurgery at the University of Pittsburgh, 35 of them for solitary tumors. The other five underwent staged procedures for bilateral lesions (10 tumors, 45 total). Thirteen patients (with 29% of tumors) had undergone a median of two prior resections. The mean tumor volume at radiosurgery was 4.8 ml, and the mean tumor margin dose was 15 Gy (range 12-20 Gy). The overall tumor control rate was 98%. During the median follow-up period of

36 months, 16 tumors (36%) regressed, 28 (62%) remained unchanged, and one (2%) grew. In the 10 patients for whom more than 5 years of clinical and neuroimaging follow-up results were available (median 92 months), five tumors were smaller and five remained unchanged. Surgical resection was performed in three patients (7%) after radiosurgery; only one showed radiographic evidence of progression. Useful hearing (Gardner-Robertson Class I or II) was preserved in six (43%) of 14 patients, and this rate improved to 67% after modifications made in 1992. Normal facial nerve function (House-Brackmann Grade 1) was preserved in 25 (81%) of 31 patients. Normal trigeminal nerve function was preserved in 34 (94%) of 36 patients. **CONCLUSIONS:** Stereotactically guided radiosurgery is a safe and effective treatment for patients with acoustic tumors in the setting of NF2. The rate of hearing preservation may be better with radiosurgery than with other available techniques.

84.

**Year:** 1999

**Patient number:** 56

**Author:** Unger, F.; Walch, C.; Haselsberger, K.; Papaefthymiou, G.; Trummer, M.; Eustacchio, S.; Pendl, G.

**Reference:** Acta neurochirurgica, 141, 12, 1281-5, 1999

**Title:** Radiosurgery of vestibular schwannomas: a minimally invasive alternative to microsurgery

**Abstract:** From April 1992 till December 1998 stereotactic radiosurgery (Gamma Knife) was applied to 192 patients with vestibular schwannomas. 56 of them had radiosurgery as primary treatment modality and were followed-up for at least 4 years (48-80 months, median 62). Without fatal complications, control of tumour growth was achieved in all but three cases, useful hearing being preserved in more than one half of the patients (62%). The neurological state improved in 30 patients (54%). Irradiation-associated adverse effects (18%) comprised neurological signs (incomplete facial palsy, four cases (two recovered completely), and mild trigeminal neuropathy, three cases, respectively) and morphological changes (three patients) marked by an enlargement of pre-existing cystic components calling for additional surgical treatment: Microsurgical decompression was performed in two cases, the third patient underwent a shunting procedure because of hydrocephalus formation. Based on the present data, radiosurgery represents an effective treatment for vestibular schwannomas associated with an exceptionally low mortality rate and a good quality of life. With respect to the preservation of cranial nerve function, results are comparable to microsurgical resection. A short duration of hospitalization and a quick return to normal activities constitute further advantages and contribute to cost effectiveness in public health care.

85.

**Year:** 1999

**Patient number:** 181

**Author:** Unger, F.; Walch, C.; Papaefthymiou, G.; Trummer, M.; Eustacchio, S.; Pendl, G.

**Reference:** HNO, 47, 12, 1046-51, 1999

**Title:** Radiosurgery of acoustic neurinoma as a minimally invasive alternative to microsurgery

**Abstract:** From April 1992 to July 1998 stereotactic radiosurgery (Gamma Knife) was used to treat 1382 patients; 181 had acoustic neurinomas and were followed up, 44 of them for at least 4 years (48-75 months, median 60). With no mortality control of growth tumor was achieved in all cases but one. It was possible to preserve useful hearing in more than half of the patients (60%). In two patients complications due to the radiation with enlargement of the cystic component were observed. One patient needed additional microsurgical decompression. Three patients suffered transient incomplete facial palsy (one permanent, HBI III), and two patients complained of mild trigeminal neuropathy. One suffered from hydrocephalus and a shunting procedure was necessary. The neurological state improved in 23 patients (52%); five complained of new or worsened deficits. Radiosurgery is an effective alternative treatment for acoustic neurinomas with exceptionally low mortality and morbidity. With respect to preserving cranial nerve function the results are just as good as those of microsurgical resection. Short duration of hospitalization and quick return to normal activities make radiosurgery quite cost effective.

86.

**Year:** 1999

**Patient number:** 51

**Author:** Walch, C.; Anderhuber, W.; Unger, F.; Papaefthymiou, G.; Fock, C.

**Reference:** Minimally Invasive Therapy and Allied Technologies, 8, 3, 197-204, 1999

**Title:** gamma-knife therapy in acoustic neuroma

**Abstract:** During 1992-95 79 patients suffering from acoustic neuromas were treated by radiosurgery at the Department of Neurosurgery of the University Medical School at Graz. Fifty-one patients underwent gamma-knife treatment as primary therapy, 28 patients after neurosurgical operation because of remaining or recurrent tumour. The tumour diameter ranged from 5.3 to 37.7 mm and patient follow-up was 3-6 years. In all patients contrast-enhanced CT (until 1993) or MRI was performed, with the stereotactic head-frame applied to determine the target. The total central tumour dose varied from 14 to 50 Gy, the total peripheral dose ranged from 9 to 18 Gy, respective to the 30-70% isodose. Tumour shrinkage was seen in 10.1% of the neuromas and 57.0% showed variable changes in morphology, due to a partial necrosis. There was no increase in tumour size during the study. The overall hearing preservation rate was approximately 85%. Seven patients became deaf after radiosurgery, six patients (7.6%) developed facial neuropathies after stereotactic treatment and two patients (2.5%) trigeminal symptoms. Three patients developed a post-therapeutic perifocal oedema, two of them asymptomatic, the other one with neurological signs, including vertigo, nausea and dizziness. All patients returned to their preoperative function level within a couple of days. Stereotactic radiosurgery using the Leksell gamma-knife is a safe, non-invasive therapy for acoustic neuromas and is a good alternative to microsurgery in cases of inoperable

patients and those who refused surgery. For recurrent or partially removed tumours, radiosurgery seems to be the therapy of choice.

87.

**Year:** 1998

**Patient number:** 162

**Author:** Kondziolka, D.; Lunsford, L. D.; McLaughlin, M. R.; Flickinger, J. C.

**Reference:** The New England journal of medicine, 339, 20, 1426-33, 1998

**Title:** Long-term outcomes after radiosurgery for acoustic neuromas

**Abstract:**BACKGROUND: Stereotactic radiosurgery is the principal alternative to microsurgical resection for acoustic neuromas (vestibular schwannomas) . The goals of radiosurgery are the long-term prevention of tumor growth, maintenance of neurologic function, and prevention of new neurologic deficits. Although acceptable short-term outcomes have been reported, long-term outcomes have not been well documented. METHODS: We evaluated 162 consecutive patients who underwent radiosurgery for acoustic neuromas between 1987 and 1992 by means of serial imaging tests, clinical evaluations, and a survey between 5 and 10 years after the procedure. The average dose of radiation to the tumor margin was 16 Gy, and the mean transverse diameter of the tumor was 22 mm (range, 8 to 39). Resection had been performed previously in 42 patients (26 percent); in 13 patients the tumor represented a recurrence of disease after a previous total resection. Facial function was normal in 76 percent of the patients before radiosurgery, and 20 percent had useful hearing. RESULTS: The rate of tumor control (with no resection required) was 98 percent. One hundred tumors (62 percent) became smaller, 53 (33 percent) remained unchanged in size, and 9 (6 percent) became slightly larger. Resection was performed in four patients (2 percent) within four years after radiosurgery. Normal facial function was preserved in 79 percent of the patients after five years (House- Brackmann grade 1), and normal trigeminal function was preserved in 73 percent. Fifty-one percent of the patients had no change in hearing ability. No new neurologic deficits appeared more than 28 months after radiosurgery. An outcomes questionnaire was returned by 115 patients (77 percent of the 149 patients still living). Fifty-four of these patients (47 percent) were employed at the time of radiosurgery, and 37 (69 percent) remained so. Radiosurgery was believed to have been successful by all 30 patients who had undergone surgery previously and by 81 (95 percent) of the 85 who had not. Thirty-six of the 115 patients (31 percent) described at least one complication, which resolved in 56 percent of those cases. CONCLUSIONS: Radiosurgery can provide long-term control of acoustic neuromas while preserving neurologic function. Grant ID: K08 NS 017293, Acronym: NS, Agency: NINDS.

88.

**Year:** 1998

**Patient number:** 462

**Author:** Kondziolka, D.; Subach, B. R.; Lunsford, L. D.; Bissonette, D. J.; Flickinger, J. C.

**Reference:** Neurosurgical focus, 5, 3, e2, 1998

**Title:** Outcomes after gamma knife radiosurgery in solitary acoustic tumors and neurofibromatosis Type 2

**Abstract:** Surgeons perform stereotactic radiosurgery as the main alternative to acoustic tumor (vestibular schwannoma) resection. The goals of radiosurgery include preservation of neurological function and prevention of tumor growth. Longer-term outcomes are not well documented for patients with solitary tumors or those with neurofibromatosis Type 2 (NF2). To define outcomes, the authors evaluated 462 consecutive patients with solitary acoustic tumors and 40 patients with NF2 (total of 45 tumors treated) who underwent radiosurgery between 1987 and 1998. Serial imaging studies, clinical evaluations, and a patient survey were performed. The average tumor margin dose was 15 Gy, and the mean transverse tumor diameter was 22 mm. In patients with solitary tumors, prior resection had been performed in 111 patients (24%); 27 patients experienced tumor recurrence after a total resection. The clinical tumor control rate (no resection required) was 98%. In non-NF2 patients followed for at least 5 years, 100 tumors (61.7%) were smaller, 53 (32.7%) remained unchanged in size, and nine (5.6%) were slightly larger. Resection was performed in four patients (2.4%). Neurological deficits after radiosurgery all occurred within the first 28 months. The rates of facial and trigeminal neuropathy varied with radiosurgery technique. In patients with NF2, 16 tumors were smaller, 28 remained unchanged, and one enlarged (overall 98% control rate at median 3-year follow up). Resection was performed in three patients (7%). Useful hearing was preserved in six (43%) of 14 NF2 patients who had useful hearing before radiosurgery. Radiosurgery provided long-term tumor control associated with high rates of neurological function preservation. No further tumor surgery was necessary in 98% of patients with solitary tumors followed for a minimum of 5 years.

89.

**Year:** 1998

**Patient number:** 63

**Author:** Kwon, Y.; Kim, J. H.; Lee, D. J.; Kim, C. J.; Lee, J. K.; Kwun, B. D.

**Reference:** Stereotactic and Functional Neurosurgery, 70, SUPPL. 1, 57-64, 1998

**Title:** Gamma knife treatment of acoustic neurinoma

**Abstract:** The results of treatment of acoustic neurinomas using Gamma Knife radiosurgery (GKR) during a 6-year period in our center were reviewed. Since May 7, 1990, we treated 88 cases of acoustic neurinoma with GKR. During a 52-month mean follow-up period, MRI was obtained in 63 patients. Reduction in tumor size occurred in 34 (54%) cases, and another 27 (42.8%) tumors showed no change. The tumor control rate was thus 95%. Tumor size increased in 3 (4.8%) cases, but one case is still in early follow-up. Two cases were operated after GKR. Histological examination of the tumors removed at surgery 8 months after GKR were obtained. The examinations showed enlargement of nucleoli and cytoplasm and proliferation of endothelial cells due to delayed radiation changes. Post-GKR facial neuropathy was noted in 7 (8.8%) patients, of which 4 recovered during the follow-up period. The tumor volume, margin dose, number of isocenters and marginal isodose did not have any statistically significant

relationship with the development of facial neuropathy. Transient trigeminal neuropathy were noted in 3 patients. Hearing was preserved in 2 of 3 hearing patients. In conclusion, our GKR results for acoustic neurinomas were very similar to the previously reported series, which makes GKR for acoustic tumors an excellent treatment modality for small- to medium- sized tumors with or without microsurgical tumor removal.

90.

**Year:** 1998

**Patient number:** 121

**Author:** Liscak, R.; Vladyka, V.; Urgosik, D.; Simonova, G.; Novotny, J., Jr.; Bares, K.

**Reference:** Otorinolaryngologie a Foniatrie, 47, 3, 103-115, 1998

**Title:** Acoustic neurinoma and its treatment using leksell gamma knife

**Abstract:** During 4 years (1992 - 1996) we have treated using Leksell gamma knife 122 patients with unilateral acoustic neurinoma. 121 patients had follow up 2 - 48 months (mean 24.3 months). Tumour volume was 0.1 - 17.8 cm<sup>3</sup> (mean 3.8 cm<sup>3</sup>), dose to the tumour margin was 10 - 17.5 Gy (mean 12.7 Gy) delivered on average 51% isodose. Decrease of the tumour volume was observed in 41.3% of patients, tumour volume was unchanged in 54.6% of patients and increase of the tumour despite the radiosurgery was observed in 4.1% of patients. Hearing loss was detected in 17.4% of patients and 3% of patients gain the hearing after radiosurgery. Overall risk of the method is 4.3% of hearing loss. Weakness of the facial nerve was observed in 1.9% of patients, normalisation of the weakness presented before radiosurgery was observed in 6.3% of patients. Overall risk of facial weakness is for gamma knife radiosurgery 1%. Impairment of trigeminal neuropathy was observed in 5%, improvement in 31%. Impairment of dizzy-vertigo was observed in 5.8%, improvement in 46%. Leksell gamma knife radiosurgery was primary treatment in 97 patients (80.7%); microsurgical resection preceded radiosurgery in 24 patients (19.8%). Hearing loss, neuropathy of facial and trigeminal nerve were significantly worse in the group of the patients with the previous microsurgical resection than in the group of patients with gamma knife radiosurgery as a primary treatment.

91.

**Year:** 1998

**Patient number:** 669

**Author:** Noren, G.

**Reference:** Stereotactic and Functional Neurosurgery, 70, SUPPL. 1, 65-73, 1998

**Title:** Long-term complications following gamma knife radiosurgery of vestibular schwannomas

**Abstract:** Since its inception in 1969, Gamma Knife radiosurgery (GKR) for vestibular schwannomas has been documented as an efficient and safe procedure based on more than 8,000 treatments worldwide. The author's personal experience comprises 669 treatments for patients with vestibular schwannoma between 1969-1997. This experience demonstrates long-term growth control, usually with shrinkage, in 95% of unilateral

tumors. In the mid-1970s, early facial weakness occurred in 38% and facial numbness in 33%. This has gradually decreased to less than 2% in the 1990s. Preservation of hearing (unchanged or almost unchanged) is currently achieved in 65 to 70%. Tinnitus is rarely changed by the treatment. The risks of intracranial bleeding, infection and CSF leak are avoided because of the noninvasive nature of the treatment. Hydrocephalus directly induced by the tumor occurred in 9.2% of patients. On the other hand, a treatment-related peritumoral reaction sufficient to block the CSF circulation and require shunt insertion was seen in only 1.4%. Based on experiences worldwide, the incidence of secondary neoplasia seems to be 0.1%. The effectiveness of GKR together with its low complication rate makes it a suitable treatment for anyone, regardless of age and general health. With few exceptions, schwannomas with an intracranial size of up to approximately 3 cm are suitable for GKR.

92.

**Year:** 1998

**Patient number:** 76

**Author:** Pollock, Bruce E.; Lansford, L. Dade; Flickinger, John C.; Clyde, Brent L.; Kondziolka, Douglas

**Reference:** Journal of Neurosurgery, 89, 6, 944-948, 1998

**Title:** Vestibular schwannoma management. Part I. Failed microsurgery and the role of delayed stereotactic radiosurgery

**Abstract:** Object. The purpose of this study was to analyze patient outcomes and to define the role of radiosurgery in patients who have undergone prior microsurgical resection of their vestibular schwannoma. Methods. The authors evaluated the pre- and postoperative clinical and neuroimaging characteristics of 76 consecutive patients with 78 vestibular schwannomas who underwent radiosurgery after previous surgical resection. Twenty-nine patients (37% of tumors) had undergone more than one prior resection. Forty-three patients (55% of tumors) had significant impairment of facial nerve function (House-Brackmann Grades III-VI) after their microsurgical procedure; 50% had trigeminal sensory loss, and 96% had poor speech discrimination (< 50%). The median evaluation period following radiosurgery was 43 months (range 12-101 months). Tumor growth control after radiosurgery was achieved in 73 tumors (94%). Six patients underwent additional surgical resection despite radiosurgery (median of 32 months after radiosurgery), and one patient underwent repeated radiosurgery for tumor progression outside the irradiated volume. Eleven (23%) of 47 patients with Grades I to III facial function before radiosurgery developed increased facial weakness after radiosurgery. Eleven patients (14%) developed new trigeminal symptoms. Conclusions. Radiosurgery proved to be a safe and effective alternative to additional microsurgery in patients in whom the initial microsurgical removal failed. Stereotactic radiosurgery should be considered for all patients who have regrowth or progression of previously surgically treated vestibular schwannomas.

93.

**Year:** 1998

**Patient number:** 13

**Author:** Pollock, Bruce E.; Lunsford, L. Dade; Kondziolka, Douglas; Sekula, Raymond; Subach, Brian R.; Foote, Robert L.; Flickinger, John C.

**Reference:** Journal of Neurosurgery, 89, 6, 949-955, 1998

**Title:** Vestibular schwannoma management. Part II. Failed radiosurgery and the role of delayed microsurgery

**Abstract:** Object. The indications, operative findings, and outcomes of vestibular schwannoma microsurgery are controversial when it is performed after stereotactic radiosurgery. To address these issues, the authors reviewed the experience at two academic medical centers. Methods. During a 10-year interval, 452 patients with unilateral vestibular schwannomas underwent gamma knife radiosurgery. Thirteen patients (2.9%) underwent delayed microsurgery at a median of 27 months (range 7-72 months) after they had undergone radiosurgery. Six of the 13 patients had undergone one or more microsurgical procedures before they underwent radiosurgery. The indications for surgery were tumor enlargement with stable symptoms in five patients, tumor enlargement with new or increased symptoms in five patients, and increased symptoms without evidence of tumor growth in three patients. Gross-total resection was achieved in seven patients and near-gross-total resection in four patients. The surgery was described as more difficult than that typically performed for schwannoma in eight patients, no different in four patients, and easier in one patient. At the last follow-up evaluation, three patients had normal or near-normal facial function, three patients had moderate facial dysfunction, and seven had facial palsies. Three patients were incapable of caring for themselves, and one patient died of progression of a malignant triton tumor. Conclusions. Failed radiosurgery in cases of vestibular schwannoma was rare. No clear relationship was demonstrated between the use of radiosurgery and the subsequent ease or difficulty of delayed microsurgery. Because some patients have temporary enlargement of their tumor after radiosurgery, the need for surgical resection after radiosurgery should be reviewed with the neurosurgeon who performed the radiosurgery and should be delayed until sustained tumor growth is confirmed. A subtotal tumor resection should be considered for patients who require surgical resection of their tumor after vestibular schwannoma radiosurgery.

94.

**Year:** 1998

**Patient number:** Interesting

**Author:** Pollock, Bruce E.; Lunsford, L. Dade; Noren, Georg

**Reference:** Neurosurgery (Baltimore), 43, 3, 475-481, 1998

**Title:** Vestibular schwannoma management in the next century: A radiosurgical perspective

**Abstract:** PURPOSE: To discuss how the evolution of vestibular schwannoma radiosurgery, changes in health care delivery, and patient accessibility to medical information will affect the management of vestibular schwannomas in the future.

**CONCEPT:** In comparison with microsurgical resection of vestibular schwannomas, radiosurgery has a lower morbidity rate, a similar risk of requiring further surgery, and higher patient satisfaction. As this information becomes more widely available to patients and third-party payors, radiosurgery may replace surgical resection as the preferred management strategy for patients with small to medium sized vestibular schwannomas in the United States. **RATIONALE:** It is estimated that 2500 patients are diagnosed with vestibular schwannomas each year in the United States. Assuming that 80% undergo surgery, 2000 operations are performed annually for newly diagnosed vestibular-schwannomas. Data available since 1987 regarding the number of cases for which gamma knife radiosurgery was performed were used to predict the number of patients who will undergo vestibular schwannoma radiosurgery in the future. If the current trend continues, an equal number of patients will undergo surgical resection and radiosurgery to treat their vestibular schwannomas (apprx 1000/yr) sometime between 2005 and 2010. Moreover, it is predicted that by 2020, two-thirds of the patients who are newly diagnosed with vestibular schwannomas will undergo radiosurgery, with surgical resection being reserved for patients with large tumors associated with symptomatic brain stem compression. **DISCUSSION:** Early data regarding vestibular schwannoma radiosurgery predicted an exponential growth curve. Although it is premature to assume that the current trend will continue, it is likely that an ever increasing percentage of patients will undergo radiosurgery as accessibility to this alternative increases, and more data are published regarding long-term tumor growth control rates. If the mathematical model proves to be accurate, then stereotactic radiosurgery will replace surgical resection as the preferred management strategy for the majority of patients with vestibular schwannomas.

95.

**Year:** 1998

**Patient number:** 100

**Author:** Régis, J.; Pellet, W.

**Reference:** Cancer radiothérapie, 2, 2, 191-201, 1998

**Title:** Radiosurgery or microsurgery of vestibular schwannomas?

**Abstract:****PURPOSE:** Microsurgical excision is the reference treatment of vestibular schwannomas. Yet, morbidity and functional risk of this surgery is significant, as Pellet et al have demonstrated in their study. In order to define the role of gamma knife surgery we have designed a prospective study concerning effectiveness and tolerance of this treatment. **PATIENTS AND METHODS:** Between July 14, 1992 and August, 1997, 400 patients were included. All the treatments were carried out according to a homogeneous methodology, with multiisocentric planning. We use low marginal doses dependent mainly on the treatment volume: 14 Gy for small stade II tumors, 12 Gy or less for larger tumors and 16 Gy for intracanalicular tumors. The evaluation protocol included preoperative examination with clinical examination, House grading, Shirmer's test, tonal and vocal audiometry, brain stem electrical response audiometry (BERA), vestibular caloric and pendular tests, magnetic resonance imaging (MRI) or computerized tomography (CT) scan; control at 6 months, 1 year and 2 years with clinical examination,

tonal audiometry and MRI and/or CT scan; at 3 years the preoperative examination was repeated and a questionnaire based on Pellet's concerning functional results was completed. RESULTS: Among the 400 treatments, 80% were first intended treatment of unilateral vestibular schwannoma. At the time of the analysis, 100 consecutive patients with unilateral schwannoma (treated in first intention) had a 3 year follow-up (results concerned these 100 patients). Average age was 61 years (17-82 years). According to Portmann's classification, five patients presented a stade 1 tumor, 60 a stade 2 tumor, 33 a stade 3, and two a stade 4 tumor. According to House's grading at preoperative examination, there was 86 (86%) grade 1 tumors, 12 grade 2, two grade 3, and at 3 year follow-up: 77 (94%) grade 1 and five grade 2 (17 patients had no House grading). At preoperative examination, three patients presented an hemispasm; at 3 years this had disappeared for all patients. Two others patients presented a transient hemispasm at 8 and 11 months, respectively. At preoperative examination, four patients presented with facial numbness and 14 with hypoesthesia. At 3 year follow-up, trigeminal function was normal for all patients but one, for whom this had only improved. Seven others patients presented a transient numbness or hypoesthesia. At preoperative examination, five patients presented hydrocephalus without cerebro spinal fluid (CSF) shunting. At 3 year follow-up, seven patients presented CSF shunting: three presented a preoperative hydrocephalus, three a hydrocephalus after treatment and one a hydrocephalus secondary to tumor growth. Average age for these six patients was 71 years. Audiological classification was based on Gardner-Robertson's. Seventy percent of patients with normal hearing maintained useful hearing, and 50% of patients with useful hearing maintained serviceable hearing. Three (3%) patients (two with stade 2 tumors and one with a stade 3) had microsurgical excision at 16, 35 and 36 months, respectively. During microsurgical excision no unusual difficulty was encountered. Seventeen questionnaires investigating functional outcome and quality of life were completed: 100% (63% in Pellet's study) of the patients answered they had no facial motion disturbance, 49% (17% in Pellet's study) had no ocular problems, 20% (in Pellet's study 55%) had subjective trigeminal problems, 8% (in Pellet's study 13%) had deglutition problems, none (16% in Pellet's study) had other eating problems, 91% (61% in Pellet's study) had no change in their life. Mean hospitalization stay was 3 days (for 23 days in Pellet's study). All the patients who worked, except one, had the same professional activity (66% in Pellet's study). Mean work cessation was 7 days (130 days in Pellet's study). (ABSTRACT TRUNCATED).

96.

**Year:** 1998

**Patient number:** 104

**Author:** Thomassin, J. M.; Epron, J. P.; Regis, J.; Delsanti, C.; Sarabian, A.; Peragut, J. C.; Pellet, W.

**Reference:** Stereotactic and Functional Neurosurgery, 70, SUPPL. 1, 74-79, 1998

**Title:** Preservation of hearing in acoustic neuromas treated by gamma knife surgery

**Abstract:** 138 acoustic schwannomas were treated by Gamma Knife surgery from July 1992 to May 1994. Cases with neurofibromatosis were excluded because of differences

in the patterns of growth and development of tumors in these cases. Hearing was evaluated by tonal and vocal audiometry and classified using the Gardner and Robertson score. 104 patients were observed at 3 years after treatment. Hearing studies, the relation of tumor volume to hearing, central and marginal dose, number of shots and preoperative brain-stem-evoked responses (BER) were all recorded. 70% of patients with normal hearing maintained a useful hearing, and 50% of patients with useful hearing maintained serviceable hearing. No correlation was found between hearing preservation and tumor volume, central and marginal dose and number of shots. Gamma Knife surgery seems to be superior to microsurgery with regard to preservation of useful hearing.

97.

**Year:** 1998

**Patient number:** 52

**Author:** Vermeulen, S.; Young, R.; Posewitz, A.; Grimm, P.; Blasko, J.; Kohler, E.; Raisons, J.

**Reference:** Stereotactic and Functional Neurosurgery, 70, SUPPL. 1, 80-87, 1998

**Title:** Stereotactic radiosurgery toxicity in the treatment of intracanalicular acoustic neuromas: The Seattle Northwest gamma knife experience

**Abstract:** Patients with acoustic neuromas have several treatment options. The appropriate individual treatment decision and expected control rates and risks for the individual techniques have been outlined in several texts (1-4, 6-8). This article describes radiosurgery toxicity in those patients with acoustic neuromas who have intracanalicular disease. 52 patients with 54 acoustic neuromas were treated between September 1993 and April 1997. 14 tumors were intracanalicular lesions, with a mean diameter < 1 cm and volume < 1 cm<sup>3</sup>. Dose to the periphery of the intracanalicular lesion extension ranged from 12-18 Gy (mean 16 Gy). The margin isodose was 40-60% (mean 47%). 32 isocenters were used to treat the 14 intracanalicular tumors (mean 2.3 isocenters per patient). At a mean follow-up of 18 months (range 1-39 months), 12/12 or 100% of the intracanalicular lesions demonstrated regression or no change in size on subsequent imaging. The following acute side effects were observed post-treatment in intracanalicular tumors: diminished hearing 14%, facial neuropathy 43%, trigeminal neuropathy 21%, balance disorder 14%, dizziness 7%, and headache 7%. Facial and trigeminal neuropathy, balance disorder, dizziness, vertigo and headaches were more common in patients with intracanalicular tumors than those with an extracanalicular extension. Although it has been suggested that small acoustic neuromas (i.e. < 1 cm<sup>3</sup>) tolerate doses of 18 Gy with acceptable toxicity, when the lesion is located in the auditory canal a lesser dose may be warranted to minimize potential side effects. For now, our center has established a protocol that limits radiosurgical stereotactic intracanalicular peripheral doses to 12 Gy until further toxicity studies have been collected and reviewed.

98.

**Year:** 1997

**Patient number:** 43

**Author:** Fukuoka, S.; Seo, Y.; Nakagawara, J.; Takashina, M.; Takahashi, S.; Takeda, R.; Suematsu, K.; Nakamura, J.; Yamaguchi, A.; Himi, T.; Kataura, A.  
**Reference:** Japanese Journal of Neurosurgery, 6, 2, 90-96, 1997

**Title:** Gamma knife radiosurgery for acoustic neurinomas - Part 1: The analysis of tumor control

**Abstract:**Forty-three patients with the unilateral type of acoustic neurinoma who were treated with gamma knife radiosurgery were analyzed from the viewpoint of tumor control. The follow-up period ranged from 22 to 55 months (mean 36 months). The tumors, which ranged in volume from 0.1 to 18.7 ml (mean 4.0 ml), were treated with marginal radiation doses of 9-15 Gy (mean 13.4 Gy) with multiple isocenters (mean 8.7). The Actuarial tumor reduction rates were 42% at one year, 75% at 2 years, and 92% at 3 years after gamma knife radiosurgery. Transient tumor expansion (mean 2.1 mm) was seen in 33% of patients, which correlated with previous surgical cases ( $p = 0.002$  by multiple regression analysis). The present control rate was 91%. Single photon emission computed tomography (SPECT) was performed on 15 selected patients before and 1 year and 2 years after gamma knife radiosurgery. 201Tl SPECT was used to determine tumor viability, and the early and delayed 99mTc DTPA human serum albumin (HSA-D) SPECT images were used to assess tumor vascularity and permeability, respectively. The TI index and HSA-D index of the delayed images were not significantly different from the respective preoperative values. However, there was a statistically significant decrease in the HSA-D index of the early images 1 year after treatment ( $p=0.02$ ). A statistically significant reduction in tumor volume was seen 2 years after treatment in these 15 patients, meaning that a reduction in tumor vascularity was followed by a reduction in tumor size. One patient underwent surgical excision of the tumor 18 months after gamma knife radiosurgery because the tumor had expanded and resulted in cerebellar ataxia. Histopathologic investigation revealed the presence of some tumor cells with irregularly shaped nuclei and marked intimal thickening or obliteration of the tumor vessels. These findings suggest that the reduction of tumor vascularity may be one of the effects of gamma knife radiosurgery, which gradually decreases the size of acoustic neurinomas.

99.

**Year:** 1997

**Patient number:** 43

**Author:** Fukuoka, S.; Takashina, M.; Seo, Y.; Takahashi, S.; Nakagawara, J.; Takeda, R.; Suematsu, K.; Nakamura, J.; Yamaguchi, T.; Himi, T.; Kataura, A.

**Reference:** Japanese Journal of Neurosurgery, 6, 3, 180-185, 1997

**Title:** Gamma knife radiosurgery for acoustic neurinomas - Part 2: The analysis of functional outcome

**Abstract:**Forty-three patients with the unilateral type of acoustic neurinoma treated by gamma knife radiosurgery were evaluated from the viewpoint of functional preservation of cranial nerves and complications. The follow-up period ranged from 22 to 55 months (mean 36 months). The tumors, which ranged in volume from 0.1 to 18.7 ml (mean 4.0 ml),

were treated with marginal radiation doses of 9-15 Gy (mean 13.4 Gy) with multiple isocenters (mean 8.7). Functional hearing was preserved in 80% of patients, and actuarial hearing preservation rates were 83% at 1 year, 77% at 2 years, and 77% at 3 years after gamma knife radiosurgery. No factor was found to correlate with hearing deterioration using Cox's proportional hazards regression model. Transient facial and trigeminal neuropathies occurred in 2.3% and 4.7% of patients, respectively. Ten patients (23%) experienced transient dizziness 3 to 6 months after radiosurgery, but only preradiosurgery canal palsy was found to correlate with this using multiple regression analysis ( $p=0.02$ ). Three patients developed communicating hydrocephalus, which may have been due to the high cerebrospinal fluid protein concentration (mean 149 mg/dl). Our results show that gamma knife radiosurgery should be considered as alternative therapy for patients with small to medium sized acoustic neurinomas, especially in those with functional hearing, due to the high cranial nerve function preservation rates achieved with this procedure.

100.

**Year:** 1997

**Patient number:** 46

**Author:** Ito, K.; Kurita, H.; Sugasawa, K.; Mizuno, M.; Sasaki, T.

**Reference:** International journal of radiation oncology biology physics, 39, 5, 983-8, 1997

**Title:** Analyses of neuro-otological complications after radiosurgery for acoustic neurinomas

**Abstract:** **PURPOSE:** To find out the optimum treatment parameters and the proper indications for treatment of acoustic neurinomas, univariate and multivariate actuarial analyses of neuro-otological complications after stereotactic radiosurgery for acoustic neurinomas were performed. **METHODS AND MATERIALS:** The subjects were 46 patients with acoustic neurinomas who underwent unilateral radiosurgery between June 1990 and June 1994 and were followed up at the University of Tokyo. Age ranged from 13 to 77 years (median, 54 years). Tumor diameter ranged from 0 to 25 mm (mean, 12 mm) at the cerebellopontine angle and from 2 to 15 mm (mean, 8.3 mm) in the internal auditory meatus. Maximum tumor doses ranged from 20 to 40 Gy (mean, 31.4 Gy), and peripheral doses from 12 to 25 Gy (mean, 16.8 Gy). One to eight isocenters were used (mean, 3.2). Median follow-up was 39 months. Eight events concerning neuro-otological complications were chosen, and the potential risk factors for them were analyzed by the actuarial analyses (univariate and multivariate). The events examined include hearing loss, vestibular function loss, facial palsy, and trigeminal nerve dysfunction. In order to point out potential risk factors for neuro-otological complications, univariate analyses were performed using both the Wilcoxon test and the log rank test, and multivariate analyses were performed with the Cox proportional hazards model. Variables nominated as potential risk factors were 1) demographic variables such as patient age and sex, 2) tumor dimensions, 3) treatment variables such as tumor doses and number of isocenters, and 4) pretreatment hearing levels. A variable with significant p-values ( $p < 0.05$ ) in two or more of the three actuarial analyses (two univariate and one multivariate) was considered a possible risk factor. **RESULTS:** The possible variables that increase the risk for each

event analyzed were: neurofibromatosis type II (NF2) and the number of isocenters for total hearing loss; experience of prior operation, the tumor diameter in the internal auditory meatus, and NF2 for hearing threshold elevation; peripheral tumor dose for vestibular function loss; patient age or midporus transverse tumor diameter (the two variables were correlated), and the number of isocenters for facial palsy; and the number of isocenters for trigeminal neuropathy. **CONCLUSION:** NF2 and the tumor diameter were the common risk factors for hearing loss in previous studies and ours. For the 5th/7th nerve dysfunction, the tumor diameter was the common risk factor. The risk of using more isocenters remains controversial. The difference in risk factors for hearing impairment and vestibular function loss suggests different mechanisms for the two. Further studies with larger populations and longer follow-up periods are required in order to draw conclusions on the risk factors in radiosurgery.

101.

**Year:** 1997

**Patient number:** 21

**Author:** Nagano, H.; Tanohata, K.; Kato, E.; Nakayama, S.; Fujino, H.; Matsubara, S.

**Reference:** Stereotactic and Functional Neurosurgery, 66, SUPPL. 1, 146-156, 1997

**Title:** Does distribution and shrinkage of acoustic neurinomas 2 years after gamma knife treatment

**Abstract:** To examine the relationship between dose distribution and tumor shrinkage of acoustic neurinomas, correlation coefficients between distribution probabilities of some dose areas and residual tumor ratios of 21 cases were studied at 2 years. Approximating a dose- volume histogram to beta-distribution, two essential dose areas for tumor control were extracted: a dose area from 14.2 to 24.7 Gy contributed to tumor shrinkage, whereas a dose area from 27.3 to 29.4 Gy was contraindicated. Given that there are at least two different dose areas with reverse characters, a formula with two opposing logistic components is proposed to predict tumor control. With this formula, Gamma Knife treatment of acoustic neurinomas may be optimized.

102.

**Year:** 1997

**Patient number:** 92

**Author:** van, Roijen L.; Nijs, H. G.; Avezaat, C. J.; Karlsson, G.; Linquist, C.; Pauw, K. H.; Rutten, F. F.

**Reference:** Acta neurochirurgica, 139, 10, 942-8, 1997

**Title:** Costs and effects of microsurgery versus radiosurgery in treating acoustic neuroma

**Abstract:** This study analyses costs and effects of treating acoustic neuroma patients by using microsurgery compared to radiosurgery. Radiosurgery is the stereotactic application of radiotherapy and an innovative medical technology. Cost and effect estimates of conventional treatment were based on a retrospective study in the Netherlands. Similar data for a comparable group of patients in Sweden were collected

for radiosurgery, as this treatment option is currently not available in the Netherlands. Fifty-three acoustic neuroma patients who had been operated on the University Hospital Rotterdam between November 1990 and February 1995 were included. This group was compared with 92 acoustic neuroma patients treated with radiosurgery (Gamma Knife. Stockholm, Sweden) in the same period. Data on health care use were collected from patient files. To obtain data on production losses and quality of life, a questionnaire was sent by mail in February 1995. This booklet consisted of the Health and Labour-questionnaire (HLQ), the Short Form-36 (SF36) and the EuroQol. The response rate was 92%. Direct costs for microsurgery amounted to Dfl. 20.072,- and for radiosurgery to Dfl. 14.272,-. Indirect costs were respectively Dfl. 16.400,- and Dfl. 1.020,-. General health rating was better for radiosurgery than for microsurgery. On the whole, differences in clinical outcomes between the two patient groups were small. Assuming a reasonable occupancy rate of the expensive radiosurgery equipment, we demonstrated that for the short term treating patients with acoustic neuroma with an extra-meatal tumour diameter of less than 3 centimeters, radiosurgery is more cost-effective than microsurgery.

103.

**Year:** 1997

**Patient number:** 75

**Author:** Wowra, B.; Horstmann, G. A.; Cibis, R.; Czempiel, H.

**Reference:** Der Radiologe, 37, 12, 1003-15, 1997

**Title:** Profile of ambulatory radiosurgery with the gamma knife system 2: Report of clinical experiences

**Abstract:** Gamma Knife radiosurgery (GKRS) was applied in 500 consecutive treatments for 445 patients within 2 years. Indications were arterio-venous malformations (93 patients), schwannomas of cranial nerves (75 patients), meningiomas (79 patients; 73 of the tumors involving the skull base), pituitary adenomas (40 patients), craniopharyngiomas (13 cases), gliomas (13 cases), rare indications (12 cases), and brain metastases (126 patients). In arterio-venous malformations two complications were observed whereas two other patients underwent surgery due to intracranial hemorrhage in the latent period after GKRS. In all cases follow-up with MRI showed evidence of an active obliteration process. Out of 24 patients with a follow-up over 1 year, angiography revealed complete obliteration in 9 patients so far. A partial obliteration was evidenced by MRI in 15 cases. In benign tumors (meningiomas and vestibular schwannomas) tumor control rates of 88% and 89% were achieved, respectively. Treatment related side effects were mild and rare; no facial palsy occurred after primary Gamma Knife treatment. GKRS was particularly effective in inoperable skull base meningiomas. Cerebral metastases were controlled in 89.5% by a single Gamma Knife treatment. The mean survival period was 11.8 months. In patients receiving a single Gamma Knife treatment the mean survival time was 9.1 months. For patients undergoing multiple (up to 5) sessions of GKRS (because of new tumors) the mean survival period was 17.2 months. MRI showed evidence of adverse radiation reactions in 10/124 patients (8.1%) which were symptomatic in 3 patients (0.8%). The results obtained in patients with cerebral

metastases emphasize that GKRS alone is as effective as the combined treatment of these lesions by surgery and fractionated radiotherapy. Our results demonstrated an attractively high therapeutic gain factor of Gamma Knife treatment in key indications of radiosurgery.

104.

**Year:** 1996

**Patient number:** 238

**Author:** Flickinger, J. C.; Kondziolka, D.; Lunsford, L. D.

**Reference:** Radiotherapy and oncology, 41, 3, 215-9, 1996

**Title:** Dose and diameter relationships for facial, trigeminal, and acoustic neuropathies following acoustic neuroma radiosurgery

**Abstract:** **PURPOSE AND OBJECTIVE:** To define the relationships between dose and tumor diameter for the risks of developing trigeminal, facial, and acoustic neuropathies after acoustic neuroma radiosurgery, a large single-institution experience was analyzed. **MATERIALS AND METHODS:** Two hundred and thirty-eight patients with unilateral acoustic neuromas who underwent Gamma knife radiosurgery between 1987-1994 with 6-91 months of follow-up (median 30 months) were studied. Minimum tumor doses were 12-20 Gy (median 15 Gy). Transverse tumor diameter varied from 0.3-5.5 cm (median 2.1 cm). The relationships of dose and diameter to the development of cranial neuropathies were delineated by multivariate logistic regression. **RESULTS:** The development of post-radiosurgery neuropathies affecting cranial nerves V, VII, and VIII were correlated with minimum tumor dose and transverse tumor diameter ( $P < 0.01$  for all except Dmin for VIII where  $P = 0.10$ ). A comparison of the dose-diameter response curves showed the acoustic nerve to be the most sensitive to doses of 12-16 Gy and the facial nerve to be the least sensitive. **CONCLUSION:** The risks of developing trigeminal, facial, and acoustic neuropathies following acoustic neuroma radiosurgery can be predicted from the transverse tumor diameter and the minimum tumor dose using models constructed from data presently available.

105.

**Year:** 1996

**Patient number:** 273

**Author:** Flickinger, J. C.; Kondziolka, D.; Pollock, B. E.; Lunsford, L. D.

**Reference:** International journal of radiation oncology biology physics, 36, 2, 275-80, 1996

**Title:** Evolution in technique for vestibular schwannoma radiosurgery and effect on outcome

**Abstract:** **PURPOSE:** To define changes in treatment technique for vestibular schwannoma radiosurgery and to relate them to changes in outcome, a large single institution experience was reviewed. **METHODS AND MATERIALS:** Two hundred seventy-three patients with unilateral vestibular schwannomas underwent Gamma knife

radiosurgery: 118 with computed tomography (CT) treatment planning during 1987-1991, and 155 with magnetic resonance imaging (MR) treatment planning in 1991-1994. Mean treatment parameters differed between the CT and MR groups: minimum tumor dose (D(min)) was 17 vs. 14 Gy, number of isocenters was 3.4 vs. 5.8, and volume was 3.5 vs 2.7 cc., respectively. RESULTS: The actuarial 7-year clinical tumor control rate (no requirement for surgical intervention) for the entire series was 96.4 +/- 2.3%, with a radiographic tumor control rate of 91.0 +/- 3.4%; these rates were similar for the CT and MR groups. Significantly lower rates of postradiosurgery facial, trigeminal, and auditory neuropathy were observed in the MR group compared to the CT group. Multivariate analyses found significant independent correlations of increasing rates of facial and trigeminal neuropathy with increasing transverse tumor diameter and D(min), as well as with CT treatment planning (compared to MR). Decreased hearing was similarly correlated with diameter and CT planning but not with D(min). CONCLUSIONS: Changes in radiosurgery technique and the use of lower doses improved the outcome after vestibular schwannoma radiosurgery by decreasing cranial neuropathy rates. MR-based treatment planning appears to have significantly contributed to this improvement. Despite decreases in radiation dose, no change in the high rate of tumor control has yet been observed.

106.

**Year:** 1996

**Patient number:** 27

**Author:** Forster, D. M.; Kemeny, A. A.; Pathak, A.; Walton, L.

**Reference:** British journal of neurosurgery, 10, 2, 169-74, 1996

**Title:** Radiosurgery: a minimally interventional alternative to microsurgery in the management of acoustic neuroma

**Abstract:** We report the results of treatment with radiosurgery of 29 tumours in 27 patients with acoustic neuromas between 1986 and 1989. The median follow-up was 6.6 years. The treatment appears to be an effective alternative to surgery for patients with tumours of 3 cm diameter or less. The mortality and morbidity of the treatment and the presentation of cranial nerve function is comparable to the very best surgical results. Every patient with an acoustic neuroma should be informed about this alternative to direct surgery.

107.

**Year:** 1996

**Patient number:** 29

**Author:** Hirato, M.; Inoue, H.; Zama, A.; Ohye, C.; Shibasaki, T.; Andou, Y.

**Reference:** Stereotactic and functional neurosurgery, 66, Suppl 1, 134-41, 1996

**Title:** Gamma Knife radiosurgery for acoustic schwannoma: effects of low radiation dose and functional prognosis

**Abstract:** The effects of relatively low dose Gamma Knife irradiation on acoustic

schwannoma were evaluated in 29 patients followed over 2 years after treatment. The mean dose delivered to the tumor periphery was 12.1 Gy. Lowering of the magnetic resonance signal intensity in the tumor center appeared in 69% and signs of tumor shrinkage appeared in 59% of cases. The cyst in the tumor enlarged in 3 cases, and 2 cases developed hydrocephalus. The percentage of pure-tone hearing preservation was 82% at 3 months, 73% at 6 months, 68% at 12 months. 64% at 18 months and 59% at 24 months in 22 out of 29 cases. Relatively low dose Gamma Knife radiosurgery was effective in suppressing tumor growth, with preservation of hearing.

108.

**Year:** 1996

**Patient number:** 46

**Author:** Ito, K.; Kurita, H.; Sugasawa, K.; Okuno, T.; Mizuno, M.; Sasaki, T.

**Reference:** Archives of otolaryngology--head & neck surgery, 122, 11, 1229-33, 1996

**Title:** Neuro-otological findings after radiosurgery for acoustic neurinomas

**Abstract:**OBJECTIVE: To evaluate the neuro-otological complications in patients after radiosurgery for acoustic neurinomas. DESIGN: Inception cohort, retrospective study. SETTING: University hospital. PATIENTS: A consecutive sample of 46 patients with acoustic neurinomas who underwent unilateral gamma knife radiosurgery at the University of Tokyo, Japan, between June 1990 and June 1994 were followed up by otolaryngologists for more than 3 months. INTERVENTION: Gamma knife stereotactic radiosurgery. MAIN OUTCOME MEASURES: Neuro-otological examinations including pure tone audiometry, auditory brain stem response, and caloric test. RESULTS: Tumor growth occurred in 2 patients (4.3%). Seven (18%) of the 38 patients with preserved hearing of any extent became deaf within 1 year. In cases of gradual hearing loss, the average deterioration rate was approximately 8 dB per year. Abnormalities of auditory brain stem response preceded deafness in 2 patients. Caloric response, preserved before treatment in 13 patients, disappeared 4 to 13 months after treatment (median, 8 months) in 9 (69%) of them, whereas their hearing was preserved. Delayed facial palsy and persistent trigeminal neuropathy occurred in 10 (22%) and 7 (15%) of the 46 patients, respectively. Severe facial palsy tended to persist. CONCLUSIONS: The rates of neuro-otological complications of radiosurgery are almost comparable with those previously reported from other institutions. The deafness within 1 year after treatment might be attributed to a lesion in the cochlear nerve. Hearing loss did not parallel vestibular function loss. The persistent severe facial palsy contrasts with previously reported findings. Considering the serious facial nerve complications that occurred in some of our patients, further study to disclose the risk factors for neurological dysfunction would be needed for radiosurgery to become a true, safe alternative to microsurgery.

109.

**Year:** 1996

**Patient number:** 21

**Author:** Nagano, H.; Tanohata, K.; Kato, E.; Nakayama, S.; Fujino, H.; Matsubara, S.

**Reference:** Stereotactic and functional neurosurgery, 66, Suppl 1, 146-56, 1996

**Title:** Dose distribution and shrinkage of acoustic neurinomas 2 years after Gamma Knife treatment

**Abstract:** To examine the relationship between dose distribution and tumor shrinkage of acoustic neurinomas, correlation coefficients between distribution probabilities of some dose areas and residual tumor ratios of 21 cases were studied at 2 years. Approximating a dose- volume histogram to beta-distribution, two essential dose areas for tumor control were extracted: a dose area from 14.2 to 24.7 Gy contributed to tumor shrinkage, whereas a dose area from 27.3 to 29.4 Gy was contraindicated. Given that there are at least two different dose areas with reverse characters, a formula with two opposing logistic components is proposed to predict tumor control. With this formula, Gamma Knife treatment of acoustic neurinomas may be optimized.

110.

**Year:** 1996

**Patient number:** 16

**Author:** Seo, Y.; Fukuoka, S.; Nakagawara, J.; Takanashi, M.; Takahashi, S.; Suematsu, K.; Nakamura, J.

**Reference:** Stereotactic and functional neurosurgery, 66, Suppl 1, 93-102, 1996

**Title:** Effect of Gamma Knife radiosurgery on acoustic neurinomas Assessment by <sup>99m</sup>Tc-DTPA-human serum albumin- and <sup>201</sup>TlCl-single photon emission computed tomography

**Abstract:** Single photon emission computed tomography (SPECT) was performed on 16 patients with acoustic neurinoma before and 1 and 2 years after Gamma Knife surgery. <sup>201</sup>TlCl-SPECT was used to determine tumor viability. Early and delayed images of <sup>99m</sup>Tc-DTPA-human serum albumin (<sup>99m</sup>Tc-HSA- D)-SPECT were used to assess tumor vascularity and permeability, respectively. There was a statistically significant decrease in the <sup>99m</sup>Tc-HSA-D index of the early image at 1 year ( $p = 0.013$ ) and at 2 years ( $p = 0.018$ ) after Gamma Knife surgery. On the other hand, the <sup>201</sup>Tl index and the <sup>99m</sup>Tc-HSA-D index of the delayed image were not significantly different from their pretreatment values. These observations demonstrate that a reduction in tumor vascularity without a decrease in tumor viability may be one of the effects of Gamma Knife surgery on acoustic neurinomas.

111.

**Year:** 1996

**Patient number:** 22

**Author:** Yamasoba, T.; Kurita, H.; Ito, K.; Mizuno, M.; Nakamura, M.; Sugasawa, M.; Sasaki, T.

**Reference:** Skull Base Surgery, 6, 3, 163-167, 1996

**Title:** Auditory findings after stereotactic radiosurgery in acoustic neurinoma

**Abstract:** Auditory function after gamma knife stereotactic radiosurgery (GK) was evaluated in 22 patients with newly diagnosed unilateral acoustic neuroma who had had some measurable hearing preoperatively. No tumor growth was observed in any patients. The preservation rates for useful hearing (n = 13) and any measurable hearing (n = 22) were 62% and 86%, respectively, at 2 years after GK. Postoperative hearing dysfunction was attributed to progressive cochlear impairment in 13 patients and to progressive injury in the retrocochlear auditory pathway in 5 patients. Hearing tended to be well preserved when caloric response was unchanged postoperatively. Preservation of hearing was not associated with the initial tumor volume, decrease of tumor size, maximum tumor dose, or peripheral tumor dose.

112.

**Year:** 1995

**Patient number:** 36

**Author:** Foote, R. L.; Coffey, R. J.; Swanson, J. W.; Harner, S. G.; Beatty, C. W.; Kline, R. W.; Stevens, L. N.; Hu, T. C.

**Reference:** International journal of radiation oncology biology physics, 32, 4, 1153-60, 1995

**Title:** Stereotactic radiosurgery using the gamma knife for acoustic neuromas

**Abstract:** **PURPOSE:** To assess the efficacy and toxicity of stereotactic radiosurgery using the gamma knife for acoustic neuromas. **METHODS AND MATERIALS:** Between January 1990 and January 1993, 36 patients with acoustic neuromas were treated with stereotactic radiosurgery using the gamma knife. The median maximum tumor diameter was 21 mm (range: 6-32 mm). Tumor volumes encompassed within the prescribed isodose line varied from 266 to 8,667 mm<sup>3</sup> (median: 3,135 mm<sup>3</sup>). Tumors  $\leq$  20 mm in maximum diameter received a dose of 20 Gy to the margin, tumors between 21 and 30 mm received 18 Gy, and tumors  $>$  30 mm received 16 Gy. The dose was prescribed to the 50% isodose line in 31 patients and to the 45%, 55%, 60%, 70%, and 80% isodose line in one patient each. The median number of isocenters per tumor was 5 (range: 1-12). **RESULTS:** At a median follow-up of 16 months (range: 2.5-36 months), all patients were alive. Thirty-five patients had follow-up imaging studies. Nine tumors (26%) were smaller, and 26 tumors (74%) were unchanged. No tumor had progressed. The 1- and 2-year actuarial incidences of facial neuropathy were 52.2% and 66.5%, respectively. The 1- and 2-year actuarial incidences of trigeminal neuropathy were 33.7% and 58.9%, respectively. The 1- and 2-year actuarial incidence of facial or trigeminal neuropathy (or both) was 60.8% and 81.7%, respectively. Multivariate analysis revealed that the following were associated with the time of onset or worsening of facial weakness or trigeminal neuropathy: (a) patients  $<$  age 65 years, (b) dose to the tumor margin, (c) maximum tumor diameter  $\geq$  21 mm, (d) use of the 18 mm collimator, and (e) use of  $>$  five isocenters. The 1- and 2-year actuarial rates of preservation of useful hearing (Gardner-Robertson class I or II) were 100% and 41.7%  $\pm$  17.3, respectively. **CONCLUSION:** Stereotactic radiosurgery using the gamma knife provides short-term control of acoustic neuromas when a dose of 16 to 20 Gy to the tumor margin is used. Preservation of useful hearing can be accomplished in a significant proportion of patients.

113.

**Year:** 1995

**Patient number:** 28

**Author:** Hirato, M.; Inoue, H.; Nakamura, M.; Ohye, C.; Hirato, J.; Shibazaki, T.; Andou, Y.

**Reference:** Neurologia medico-chirurgica, 35, 10, 737-41, 1995

**Title:** Gamma knife radiosurgery for acoustic schwannoma: early effects and preservation of hearing

**Abstract:** The effects of relatively low dose gamma knife irradiation on acoustic schwannoma were evaluated. The signal intensity change and tumor shrinkage on magnetic resonance (MR) images, change in hearing, and complications in 28 patients (mean age 47.0 +/- 13.6 yrs) were studied. Three patients had bilateral tumors. Six were already deaf when treated. The maximum tumor diameter was 35 mm. The mean dose delivered to the tumor was 12.1 +/- 1.6 Gy at the periphery, and 25.2 +/- 4.3 Gy at the center. The mean follow-up time was 16 months and the longest 24 months. Lowering of the MR signal intensity in the tumor center appeared after 3 months at earliest but generally after 6 months. Signs of tumor shrinkage appeared within 12 months on average. Cyst in the tumor enlarged rapidly after treatment in two patients. The percentage of hearing preservation was 85% (17/20) at 3 months, 80% (16/20) at 6 months, 72% (13/18) at 9 months, 75% (12/16) at 12 months, 67% (8/12) at 15 months, 60% (6/10) at 18 months, and 50% (2/4) at 24 months. Subtle changes in hearing were detected by speech tone audiometry. Temporary facial numbness and weakness was seen in one patient each. No patient had lower cranial nerve paresis. Relatively low dose gamma knife radiosurgery is effective in suppressing growth of acoustic schwannoma with preservation of hearing.

114.

**Year:** 1995

**Patient number:** 48

**Author:** Kobayashi; Kida; Tanaka; Oyama; Iwakoshi

**Reference:** Dept. of Neurosurgery, Komaki City Hosp., Komaki 485, Japan. English. NOTNLM. 19950401., 1995

**Title:** The stereotactic radiosurgery using gamma knife on 150 cases of brain tumors (Meeting abstract)

**Abstract:** We have treated more than 300 cases of intracranial lesions by Leksell Gamma Unit since May 1991 at Komaki City Hospital. There are 154 cases of vascular anomaly and 150 cases of brain tumors. There were 48 cases of neurinoma (32.0%), 29 of meningioma (19.2%), 24 of gliomas (16.0%), 21 of metastatic tumors (14.0%), 6 of pituitary adenomas (4.0%), 4 of craniopharyngioma (2.7%), 3 of malignant lymphoma (2.0%) and 15 of other tumors. Dose planning and dosimetry were made on MRI images with fixation of Leksell G frame to the skull, which consist of 3-mm slices of both axial and

coronal plane with gadolinium enhanced T1 images by

115.

**Year:** 1995

**Patient number:** 10

**Author:** Matsui, S.; Sagawa, T.; Iizuka, T.; Yajima, K.; Matsuzaki, M.; Kamei, T.; Inoue, H.; Hirato, M.; Shibasaki, T.

**Reference:** Equilibrium Research, 54, 3, 264-270, 1995

**Title:** Gamma knife for acoustic neurinomas

**Abstract:** Ten patients (5 male, 5 female) with acoustic neurinoma underwent stereotactic radiosurgery with a gamma unit. Their ages ranged from 29 to 68 years (mean, 52 years). The follow-up periods were 20 to 38 months (mean, 26 months). The doses delivered to the tumor were 9.9 to 13.5 Gy at the periphery and 17 to 30 Gy at the center.

Neuroimaging studies showed that 6 tumors became smaller, 3 were unchanged, and 1 was larger. Severe complications such as hydrocephalus were not seen. Hearing was preserved with a change in the pure tone audiometric threshold of 10 dB or less in 6 of the 8 patients tested. One patient became deaf 5 months after surgery. His CT scan had shown large cysts in the tumor before surgery. Indications for this type of therapy for such patients must be decided cautiously.

116.

**Year:** 1995

**Patient number:** 10

**Author:** Ogunrinde, O. K.; Lunsford, D. L.; Kondziolka, D. S.; Bissonette, D. J.; Flickinger, J. C.

**Reference:** Stereotactic and functional neurosurgery, 64, Suppl 1, 87-97, 1995

**Title:** Cranial nerve preservation after stereotactic radiosurgery of intracanalicular acoustic tumors

**Abstract:** We reviewed our initial stereotactic radiosurgery experience in 10 patients with intracanalicular acoustic tumors managed by radiosurgery during a 5-year period. These patients constitute 4.7% of acoustic tumor patients who underwent Gamma Knife radiosurgery during this period. Tumor volume stabilization was achieved in 8. Two patients had initial growth followed by delayed growth arrest. Preservation of preoperative hearing was achieved in all patients in the immediate postoperative period and in 8 of 10 at 1 year. No patient had developed facial or trigeminal nerve dysfunction at the last follow-up, which varied from 3 to 64 months (mean 25 months). Tumor growth was delayed in 2 patients, but neither has required delayed microsurgical resection. All patients returned to their preoperative functional status within 3-5 days after radiosurgery. Stereotactic radiosurgery using the Gamma Knife is a safe and effective management strategy for intracanalicular acoustic tumor patients. Our initial results indicate that high cranial nerve preservation rates and a rapid return to previous activity and employment are benefits of radiosurgery.

117.

**Year:** 1995

**Patient number:** 31

**Author:** Ogunrinde, O. K.; Lunsford, L. D.; Flickinger, J. C.; Kondziolka, D. S.

**Reference:** Archives of neurology, 52, 1, 73-9, 1995

**Title:** Cranial nerve preservation after stereotactic radiosurgery for small acoustic tumors

**Abstract:**OBJECTIVE: To assess those factors associated with and predictive of cranial nerve preservation after stereotactic radiosurgery in patients with small acoustic tumors identified by magnetic resonance imaging. DESIGN: We performed a retrospective analysis of our experience with 31 patients with preserved hearing and acoustic tumors measuring 10 mm or smaller (pons-to-petrous dimension). All patients underwent clinical and audiologic evaluations varying from 6 to 48 months (mean, 20 months) after stereotactic radiosurgery performed with use of the 201 source cobalt 60 gamma unit. RESULTS: Stabilization or reduction in tumor volume was achieved in 29 of 31 patients. One patient required delayed microsurgical resection. Useful hearing (pure tone average  $\leq$  50 dB and speech discrimination score  $\geq$  50%) preservation was achieved in 10 of 10 patients immediately postoperatively, eight of 10 patients at 6 months, six of 10 patients at 1 year, and five of 10 at 2 years. Preservation of some measurable hearing was possible in all patients immediately after radiosurgery, in 84% and in more than half of patients at 2 years. Preoperative facial nerve function was preserved in 19 of 20 patients at 2 years after radiosurgery. All patients returned to their preoperative employment status within 2 to 5 days after radiosurgery. CONCLUSION: Stereotactic radiosurgery performed with current technology (multiple radiation isocenters and magnetic resonance imaging guidance) is a safe and effective management strategy for patients with small acoustic tumors. The risk of facial and trigeminal neuropathy after gamma knife radiosurgery is low, and useful hearing can be preserved in up to 50% of patients with useful preoperative hearing. Stereotactic radiosurgery is a valuable alternative strategy to surgical removal for many patients with newly diagnosed small acoustic tumors.

118.

**Year:** 1995

**Patient number:** 87

**Author:** Pollock, B. E.; Lunsford, L. D.; Kondziolka, D.; Flickinger, J. C.; Bissonette, D. J.; Kelsey, S. F.; Jannetta, P. J.

**Reference:** Neurosurgery, 36, 1, 215-24, 1995

**Title:** Outcome analysis of acoustic neuroma management: a comparison of microsurgery and stereotactic radiosurgery

**Abstract:**Currently, microsurgical resection of acoustic neuromas by an experienced, multidisciplinary team is thought to be the treatment of choice. During the past 20 years stereotactic radiosurgery has been used as an alternative to surgical removal. To

compare the results of both microsurgery and stereotactic radiosurgery, we conducted a study of 87 patients with unilateral, previously unoperated acoustic neuromas with an average diameter less than 3 cm treated by the neurosurgical service during 1990 and 1991. Preoperative patient characteristics and average tumor size were similar between the treatment groups. State of the art microsurgical or radiosurgical techniques were used by experienced surgeons in both treatment groups. The treatment groups were compared based on cranial nerve preservation, tumor control, postoperative complications, patient symptomatology, length of hospital stay, total management charges, effect on employment status, and overall patient satisfaction. Stereotactic radiosurgery was more effective in preserving normal postoperative facial function ( $P < 0.05$ ), and hearing preservation ( $P < 0.03$ ) with less treatment associated morbidity ( $P < 0.01$ ). Effect on preoperative symptoms were similar between the treatment groups. Postoperative functional outcomes and patients' satisfaction of their tumor management were greater after stereotactic radiosurgery when compared to the microsurgical group, although they did not reach statistical significance ( $P = 0.07$  and  $P = 0.10$ , respectively). Patients returned to independent functioning sooner after stereotactic radiosurgery ( $P < 0.001$ ). Hospital length of stay and total management charges were less in the radiosurgical group ( $P < 0.001$ ). When compared to microsurgical removal, stereotactic radiosurgery proved to be an effective and less costly management strategy of unilateral acoustic neuromas less than 3 cm in diameter. For many acoustic neuroma patients, stereotactic radiosurgery should be offered as an alternative management strategy.

119.

**Year:** 1994

**Patient number:** 44

**Author:** Kobayashi, T.; Tanaka, T.; Kida, Y.

**Reference:** Acta neurochirurgica. Supplement, 62, 93-7, 1994

**Title:** The early effects of gamma knife on 40 cases of acoustic neurinoma

**Abstract:** Early results of gamma radiosurgery on 44 cases of acoustic neurinoma were studied by follow-up MRIs and changes of neurological signs every 3 months. Mean follow-up period was 12 (3 to 20) months. Enhanced MRI revealed that the central low intensity signal area (LISA) appeared at 3 to 6 months after the treatment, which was re-enhanced at 6 to 9 months, then the tumours begun to decrease in size at 9 to 12 months, which observation was noted in 11 out of 44 cases (25%). The other tumours were unchanged in size. Regarding the side effects, facial palsy appeared in 7 cases (16%) after the treatment, of whom 3 cases have improved. Trigeminal nerve palsy was found in 3 cases (7%). Deterioration of hearing was found in 11 out of 21 cases (52%) who had hearing disturbances before treatment. The pathological study of a treated tumour at 11 months revealed that central LISA was found as complete necrosis and degeneration of tumour cells and vessels with thickening walls found at the margin of the tumour. MRI is not only useful for the dose planning of radiosurgery but valuable for the follow-up study of treated tumours.

120.

**Year:** 1994

**Patient number:** 20

**Author:** Ogunrinde, O. K.; Lunsford, L. D.; Flickinger, J. C.; Kondziolka, D.

**Reference:** Journal of neurosurgery, 80, 6, 1011-7, 1994

**Title:** Stereotactic radiosurgery for acoustic nerve tumors in patients with useful preoperative hearing: results at 2-year follow-up examination

**Abstract:** Twenty patients with acoustic nerve tumors (mean diameter  $\leq$  30 mm) and useful preoperative hearing were examined 2 years after stereotactic radiosurgery to determine the effectiveness of the surgery in the control of tumor growth and the preservation of cranial nerve function. Results showed tumor volume stabilization (12 cases) or reduction (seven cases) was achieved in a total of 19 patients (95%). Useful hearing (defined as Gardner and Robertson Class I or II) preservation was obtained in 100% of cases immediately postoperatively, 50% at 6 months, and 45% at both 1 and 2 years. Two years after stereotactic radiosurgery, facial nerve function was preserved in 90% of patients and 75% continued to have normal trigeminal nerve function. All patients returned to and maintained their preoperative functional status within 3 to 5 days after radiosurgery. These findings indicate that stereotactic radiosurgery with multiple isocenters and narrow radiation beams is a safe and effective management strategy for progressive acoustic nerve tumors. Auditory, facial, and trigeminal nerve function can be preserved in most patients. Prevention of further growth and preservation of cranial nerve function appear to be satisfactory goals in the current management of patients with acoustic neuromas.

121.

**Year:** 1994

**Patient number:** 98

**Author:** Ogunrinde, O. K.; Lunsford, L. D.; Flickinger, J. C.; Maitz, A.; Kondziolka, D.

**Reference:** Skull Base Surgery, 4, 2, 87-92, 1994

**Title:** Facial nerve preservation and tumor control after gamma knife radiosurgery of unilateral acoustic tumors

**Abstract:** To assess the long-term risk of facial nerve dysfunction after unilateral acoustic tumor stereotactic radiosurgery, we retrospectively analyzed our initial experience in 98 unilateral acoustic tumor patients who were evaluated at least 2 years after treatment. This observation interval permits an analysis of both the risk of onset and the potential for recovery of facial nerve function. The overall risk of developing any degree of delayed transient or permanent postoperative facial neuropathy was 21.4% (21 of 98 patients). Only one patient undergoing radiosurgery alone had poor residual: facial nerve dysfunction worse than House-Brackmann grade III. Normal facial nerve function (House-Brackmann grade 1) was preserved in 95% of patients with small tumors (10 mm or less petrous-pons dimension) and in 90% of patients who had useful hearing and normal facial function preoperatively. Normal facial function was preserved in all patients with intracanalicular acoustic tumors. The risk of delayed facial neuropathy was reduced

by performing radiosurgery when tumors were small (1000 mm<sup>3</sup> or less), by enclosing the tumor within the 50% isodose volume, by using multiple small radiation isocenters, and by detailed identification of the tumor volume using stereotactic magnetic resonance imaging.

122.

**Year:** 1994

**Patient number:** 13

**Author:** Oyama, H.; Kobayashi, T.; Kida, Y.; Tanaka, T.; Mori, Y.; Iwakoshi, T.; Niwa, M.; Kai, O.; Hirose, M.

**Reference:** Neurologia medico-chirurgica, 34, 9, 607-11, 1994

**Title:** Early changes in volume and non-enhanced volume of acoustic neurinoma after stereotactic gamma-radiosurgery

**Abstract:** The effectiveness of stereotactic gamma-radiosurgery for treating acoustic neurinoma was evaluated by measuring the volumes of the tumor, non-enhanced tumor, and cerebellar edema in 13 patients with acoustic neurinoma who were followed up for 9 to 15 months (median 12.7 mos) after treatment. The tumor volume and non-enhanced volume tended to reach a maximum after 6 months, and cerebellar edema volume after 9 months, then decreased gradually thereafter. Hearing loss tended to increase gradually, but involvement of the facial nerve was transient.

123.

**Year:** 1994

**Patient number:** 16

**Author:** Pendl, G.; Schröttner, O.; Friehs, G. M.; Legat, J.; Leber, K.; Mokry, M.; Papaefthymiou, G.; Langmann, G.

**Reference:** Acta neurochirurgica, 127, 3-4, 170-9, 1994

**Title:** Radiosurgery with the first Austrian cobalt-60 Gamma-unit A one year experience

**Abstract:** During the period of one year, from the 21. 4. 1992 to 21. 4. 1993, a total of 201 radiosurgical sessions on 181 patients were performed with the first Austrian Gamma-unit in Graz. 42% of radiosurgical sessions were undertaken for malignomas, 20% for meningiomas, 11.5% for vascular malformations, 9% for neurinomas, 8.5% for low grade astrocytomas and glomus jugulare tumours, 5% for sellar and suprasellar lesions, and 4% for functional disorders. Dose plan data for all the lesions treated are shown. Clinical and imaging data of the first year which are available for 120 patients (66%) are presented and discussed.

124.

**Year:** 1994

**Patient number:** 44

**Author:** Tanaka, T.; Kobayashi, T.; Kida, Y.; Oyama, H.; Iwakoshi, T.; Niwa, M.

**Reference:** Japanese Journal of Neurosurgery, 3, 3, 196-200, 1994

**Title:** Early results of gamma knife radiosurgery of acoustic neurinomas: An evaluation by forty-four cases

**Abstract:** The authors have evaluated early results of gamma knife treatment of forty-four cases of acoustic neurinoma by follow-up MRIs and changes in the neurological signs every three months. The follow-up period ranged between 3 to 22 months (mean: 12 months). Enhanced MRI (T1 WI) at 3 to 6 months postoperatively revealed a region of low intensity at the center of tumor, which was re-enhanced at 9 to 12 months. Thereafter, in 11 cases (25%) the tumor size gradually decreased. As for side effects, facial nerve palsy after the radiosurgery appeared in 7 cases after the radiosurgery, three of which had been improving. Trigeminal nerve palsy was found in 3 cases. With regard to hearing, a deterioration of hearing was found in 11 out of 21 cases that showed hearing disturbances. A pathological study was made of one treated tumor, which was removed by surgery 11 months after the treatment. The findings included complete necrosis at the center of the tumor and degeneration of the tumor cells and vessels at the periphery of the tumor.

125.

**Year:** 1993

**Patient number:** 134

**Author:** Flickinger, J. C.; Lunsford, L. D.; Linskey, M. E.; Duma, C. M.; Kondziolka, D.

**Reference:** Radiotherapy and oncology, 27, 2, 91-8, 1993

**Title:** Gamma knife radiosurgery for acoustic tumors: multivariate analysis of four year results

**Abstract:** In order to evaluate the results of radiosurgery for acoustic tumors and to identify optimum treatment parameters, an analysis of tumor control, as well as incidences of hearing loss, facial and trigeminal neuropathies was undertaken. Between August 1987 and August 1991, 134 patients with 136 acoustic tumors received stereotactic gamma knife radiosurgery at the University of Pittsburgh. Median follow-up was 24 months (range: 6-56 months). Tumor volumes ranged from 0.10 to 17.00 cm<sup>3</sup> (median = 2.75 cm<sup>3</sup>). From one to ten isocenters were utilized per tumor treated (median = 3). Minimum tumor doses varied from 12 to 20 Gy (median = 17 Gy). The 4-year actuarial tumor control rate was 89.2 +/- 6.0%. Some degree of hearing (by pure tone audiometry) was preserved in 71.0 +/- 4.4% of patients. The actuarial rates for preservation of either pretreatment hearing level or useful hearing were 34.4 +/- 6.6% and 35.1 +/- 9.7% respectively. Respectively, the actuarial incidences of postradiosurgery facial and trigeminal neuropathies were 29.0 +/- 4.4% and 32.9 +/- 4.5%, respectively. No significant factors affecting tumor control were identified. Multivariate analysis identified a significantly increased risk of hearing loss in patients with neurofibromatosis ( $p = 0.0003$ ) as well as decreased risks of facial and trigeminal neuropathies with both decreasing tumor diameter ( $p = 0.001$ ) and increasing number of isocenters treated ( $p = 0.003$ ). Radiosurgery is a safe and effective treatment for acoustic neuromas with acceptable morbidity that may be lowered by the use of multiple isocenter treatment techniques and

by earlier treatment of small tumors.

126.

**Year:** 1993

**Patient number:** 92

**Author:** Linskey, M. E.; Flickinger, J. C.; Lunsford, L. D.

**Reference:** International journal of radiation oncology biology physics, 25, 2, 227-33, 1993

**Title:** Cranial nerve length predicts the risk of delayed facial and trigeminal neuropathies after acoustic tumor stereotactic radiosurgery

**Abstract:** **PURPOSE:** To test the hypothesis that length of cranial nerve irradiated is a major factor predicting the risk of cranial nerve injury following radiosurgery and to identify any other significant related treatment factors. **METHODS AND MATERIALS:** Ninety-two patients (93 acoustic tumors) were treated with a 201 source Cobalt-60 gamma unit from 1987 to 1990 and prospectively followed. The range of minimum tumor dose was 12-20 Gy and maximum dose 24-50 Gy. Univariate and multivariate analyses were used to evaluate any correlations between tumor measurements and treatment factors, with the development of trigeminal and facial neuropathies following radiosurgery. **RESULTS:** The risks of trigeminal and facial neuropathy following radiosurgery were associated with the pon-petrous distance and mid porous transverse tumor diameters respectively (anatomically related to the irradiated length of cranial nerves V and VII respectively) in both univariate ( $p = .002$  for V and  $p = .026$  for VII) and multivariate ( $p = .004$  for V and  $p = .055$  for VII) analyses. Tumor volume, other tumor measurements, maximum dose, minimum tumor dose, and tumor dose inhomogeneity were not significantly related to either trigeminal or facial neuropathy in univariate and multivariate analyses. **CONCLUSION:** Within a minimum tumor dose range of 12-20 Gy, the incidence of delayed trigeminal or facial neuropathy depended more on the estimated length of nerve irradiated than the tumor dose or tumor volume. In the future, the risk of delayed facial or trigeminal cranial neuropathy may be reduced significantly by performing radiosurgery when the tumor still has both a small mid-porous transverse diameter and a small pons-petrous distance.

127.

**Year:** 1993

**Patient number:** 254

**Author:** Norén, G.; Greitz, D.; Hirsch, A.; Lax, I.

**Reference:** Acta neurochirurgica. Supplementum, 58, 104-7, 1993

**Title:** Gamma knife surgery in acoustic tumours

**Abstract:** Presentation of the experiences with 254 acoustic neurinomas, treated at the Karolinska Gamma Knife Center from 1969 to 1991, with a minimum follow-up of 12 months. Early loss of contrast enhancement on CT or MRI was seen in 70%. Unilateral tumours showed size decrease in 55%, no change in 33%, and increase in 12%. NF 2

tumours had decrease in 33%, no change in 43%, and increase in 24%. Some degree of facial weakness was seen after 17% of treatments, but always with later improvement of function. The incidence of trigeminal neuropathy was 19%. Preservation of hearing was 77%. Gamma knife treatment is as efficient as microsurgery, but without risk of infection, bleeding or CSF leak. It requires no hospitalisation. The patient can go back to work after a few days. It therefore should be offered as an alternative to every acoustic neurinoma patient.

128.

**Year:** 1992

**Patient number:** 17

**Author:** Linskey, M. E.; Lunsford, L. D.; Flickinger, J. C.

**Reference:** Neurosurgery, 31, 5, 829-38, 1992

**Title:** Tumor control after stereotactic radiosurgery in neurofibromatosis patients with bilateral acoustic tumors

**Abstract:** During a 4-year interval, 17 patients with bilateral acoustic tumors (vestibular schwannomas) underwent unilateral stereotactic radiosurgery using a multisource gamma unit; 2 patients underwent radiosurgery of both tumors in separate sessions. Eleven patients with unoperated contralateral tumors served as concurrent controls to compare the effects of radiosurgery with the natural history of acoustic tumors. After radiosurgery, the tumor control and regression rates were 89.5 and 21.1%, respectively (median neuroimaging follow-up, 1.4 years; range, 0.3-3.9). The tumor regression rate increased to 40% for patients evaluated at least 12 months after radiosurgery. In comparison to the unoperated contralateral tumors, stereotactic radiosurgery achieved tumor control, as assessed by the ultimate change in tumor size at follow-up (P, 0.012), the change in tumor size over time (P, 0.006), and tumor growth rates (P, 0.003). This study provided convincing evidence that tumor stabilization after radiosurgery (as assessed by neuroimaging) truly represented tumor control. The incidence of delayed facial neuropathy after radiosurgery compared favorably with the incidence reported after microsurgical removal. Some hearing was preserved in one-third of the patients who had preoperative hearing, including three patients who were contralaterally deaf. Stereotactic radiosurgery should be considered as a primary surgical modality for many patients with neurofibromatosis Type II.

129.

**Year:** 1992

**Patient number:** NA abstract

**Author:** Linskey, M. E.; Lunsford, L. D.; Flickinger, J. C.; Kondziolka, D.

**Reference:** Neurosurgery clinics of North America, 3, 1, 191-205, 1992

**Title:** Stereotactic radiosurgery for acoustic tumors

**Abstract:** Stereotactic radiosurgery is an important alternative treatment for carefully selected patients with acoustic tumors. We perform radiosurgery under local anesthesia,

and 91% of our patients have been discharged from the hospital within 24 hours after treatment. All returned to their preoperative level of function or employment within 5 to 7 days after treatment. Our current tumor control rate is 97%, but reduction in tumor size, judged by strict, objective criteria, was achieved in only 23%. Our actuarial rate of useful hearing preservation after radiosurgery is 38% at 1 year. Three tumors increased in size after treatment. Only one of the three demonstrated increased mass effect on surrounding brain structures by neuroimaging criteria. No increase has led to worsened clinical symptoms or has required surgical excision at this point in follow-up. The 1-year rates for developing new facial or trigeminal neuropathies after radiosurgery were 30% and 33%, respectively. Cranial neuropathies had a delayed onset, with the median onset occurring after 5 to 6 months. The vast majority were partial at onset, and most improved over time. Communicating hydrocephalus requiring ventriculoperitoneal shunts developed after radiosurgery in four patients. Eight patients developed increased signal within adjacent brain parenchyma on T2-weighted MR imaging, consistent with edema or blood-brain barrier breakdown. It is unlikely that stereotactic radiosurgery using the gamma knife will obviate the need for microsurgical removal performed by skilled and experienced microsurgeons. However, radiosurgery is a safe and effective treatment for patients whose medical problems make surgery unacceptably dangerous, those with bilateral tumors or a tumor in their only hearing ear, those who have recurrent tumor despite surgical resection, or patients who refuse microsurgical excision.

130.

**Year:** 1991

**Patient number:** 85

**Author:** Flickinger, J. C.; Lunsford, L. D.; Coffey, R. J.; Linskey, M. E.; Bissonette, D. J.; Maitz, A. H.; Kondziolka, D.

**Reference:** Cancer, 67, 2, 345-53, 1991

**Title:** Radiosurgery of acoustic neurinomas

**Abstract:** Eighty-five patients with acoustic neurinomas underwent stereotactic radiosurgery with the gamma unit at the University of Pittsburgh (Pittsburgh, PA) during its first 30 months of operation. Neuroimaging studies performed in 40 patients with more than 1 year follow-up showed that tumors were smaller in 22 (55%), unchanged in 17 (43%), and larger in one (2%). The 2-year actuarial rates for preservation of useful hearing and any hearing were 46% and 62%, respectively. Previously undetected neuropathies of the trigeminal (n = 12) and facial nerves (n = 14) occurred 1 week to 1 year after radiosurgery (median, 7 and 6 months, respectively), and improved at median intervals of 13 and 8 months, respectively, after onset. Hearing loss was significantly associated with increasing average tumor diameter (P = 0.04). No deterioration of any cranial nerve function has yet developed in seven patients with average tumor diameters less than 10 mm. Radiosurgery is an important treatment alternative for selected acoustic neurinoma patients.

131.

**Year:** 1991

**Patient number:** 88

**Author:** Linskey, M. E.; Lunsford, L. D.; Flickinger, J. C.

**Reference:** AJNR. American journal of neuroradiology, 12, 6, 1165-75, 1991

**Title:** Neuroimaging of acoustic nerve sheath tumors after stereotaxic radiosurgery

**Abstract:**Using a strict method for measuring tumor size, we evaluated tumor response to radiosurgery in 88 patients with 89 acoustic tumors treated over 3 years with a 201-source cobalt-60 gamma unit. Overall, tumor size was unchanged in 73% of patients and increased in 4%. In 22% of patients, tumor diameter decreased an average of 4.9 mm 3-33 months after treatment. Tumor shrinkage occurred in 36% of 50 patients who were followed for at least 1 year after treatment. Loss of tumor contrast enhancement was seen in 79% of patients 1-18 months after treatment. Delayed communicating hydrocephalus developed in four patients. In eight patients, increased signal on T2-weighted MR images developed in the adjacent cerebellar peduncle (n = 5) or the peduncle and dorsolateral pons (n = 3) 5-15 months after treatment. T1-weighted MR imaging and CT were insensitive to these adjacent brain changes. Stereotaxic radiosurgery is an important alternative treatment for selected patients with acoustic tumors. There is no mortality or major perioperative morbidity, hospitalization time and costs are smaller than for microsurgery, patient employment or functional level is maintained, and hearing preservation and facial neuropathy rates are comparable to those in published microsurgical series. Although the rate of occurrence of trigeminal neuropathy is greater than those reported in published microsurgical series, the majority of cases are mild, transient, and nondebilitating. MR imaging before and after radiosurgery is the most sensitive imaging tool to evaluate tumor response, the presence of adjacent parenchymal signal changes, and ventricular size. With a mean follow-up time of 14.6 months, the rate of complications detected by neuroimaging is low and the tumor control rate is 96%.

132.

**Year:** 1990

**Patient number:** 26

**Author:** Linskey, M. E.; Lunsford, L. D.; Flickinger, J. C.

**Reference:** Neurosurgery, 26, 5, 736-44, 1990

**Title:** Radiosurgery for acoustic neurinomas: early experience

**Abstract:**We reviewed our early experience with the first 26 patients with acoustic neurinomas (21 unilateral, 5 bilateral) treated by stereotactic radiosurgery using the first North American 201-source cobalt-60 gamma knife. Follow-up ranged from 6 to 19 months (median, 13 months). Serial postoperative imaging showed either a decrease in tumor size (11 patients) or growth arrest (15 patients). Loss of central contrast enhancement was a characteristic change (18 patients). Seven patients had good or serviceable hearing preoperatively. In all 7 the preoperative hearing status was retained immediately after radiosurgery. At follow-up, 3 had preserved hearing, 1 had reduced hearing, and 3 had lost all hearing in the treated ear. Hearing in 1 patient that was nonserviceable preoperatively later improved to a serviceable hearing level. Delayed

facial paresis developed in 6 patients, and delayed trigeminal sensory loss developed in 7 patients, none of whom had significant deficits before radiosurgery. Both facial and trigeminal deficits tended to improve within 3 to 6 months of onset with excellent recovery anticipated. Lower cranial nerve dysfunction was not observed. All 26 patients remain at their preoperative employment or functional status. At present, stereotactic radiosurgery is an alternative treatment for acoustic neurinomas in patients who are elderly, have significant concomitant medical problems, have a tumor in their only hearing ear, have bilateral acoustic neurinomas, refuse microsurgical excision, or have recurrent tumor despite surgical resection. Although longer and more extensive follow-up is required, the control of tumor growth and the acceptable rate of complications in this early experience testifies to the future expanding role of this technique in the management of selected acoustic neurinomas.

133.

**Year:** 1990

**Patient number:** 57

**Author:** Yamamoto, M.; Norén, G.

**Reference:** No shinkei geka, 18, 12, 1101-6, 1990

**Title:** Stereotactic radiosurgery in acoustic neurinomas

**Abstract:** The records of 57 patients with 61 acoustic neurinomas treated with stereotactic radiosurgery at the Karolinska Hospital, Stockholm, from 1982 through 1984, were reviewed. Adequate radiological and clinical follow-up evaluations were available in these cases. An additional 8 patients were treated during this same period but were not included because of insufficient data. The tumors were evaluated with CT or MRI. Their post-operative follow-up period was 6-66 months (mean 28 months). Decrease of tumor size or no change was considered as a response to radiosurgery. This was found in 54 (88%) of the tumors. Small tumors with a diameter of less than 15 mm responded better (93%) than large ones (85%). Ninety-five percent of unilateral tumors and 74% of tumors associated with neurofibromatosis responded well. Seven tumors had definite radiographic signs of subsequent growth. Four were removed using standard microsurgical techniques and three have so far not required further treatment. Facial and trigeminal nerve function was evaluated in 58 facial surfaces where tumors had been irradiated. Transient facial weakness developed in 9% and facial hypesthesia in 9% of the irradiated cases. The onset of these nerve dysfunctions appeared with a latency period of 4 to 15 months after radiosurgery. Excluding the ears which had been totally deaf before the treatment, forty-one ears were evaluated fully by audiometry prior to and one year after irradiation. 30% of them had no change in hearing, 68% had a more or less pronounced deterioration and 2% had improvement. We regard efficiency in arresting tumor growth without endangering life, preservation of facial nerve function, and only a day of hospitalization as major benefits of radiosurgery.

134.

**Year:** 1988

**Patient number:** 111

**Author:** Hirsch, A.; Norén, G.

**Reference:** Acta oto-laryngologica, 106, 3-4, 244-51, 1988

**Title:** Audiological findings after stereotactic radiosurgery in acoustic neurinomas

**Abstract:** Stereotactic radiosurgery was used in the treatment of 126 patients with acoustic neurinomas up to 30 mm in diameter from 1969 to 1984. Adequate follow-up data (mean follow-up period 4.7 years) were available for 111 (116 ears) of these 126 patients; of these 111 patients, 64 (65 ears) had a pure-tone threshold of less than 90 dB before the treatment and were followed up audiological. Preserved hearing was found in 26% of the ears one year postoperatively. Shrinkage of the tumour was obtained in 44% and arrest of its growth in 42%. There was no mortality related to the radiosurgical treatment. Transitory facial weakness was noted in 15% of the patients (3% in 1983-84). Eighteen per cent of the patients had some, usually transitory, trigeminal dysfunction. The stapedius reflex threshold was improved in 13 ears (20%). In one patient the audiological tests became pathological in the contralateral ear during growth of a new tumour. Initially the stapedius reflex threshold was elevated, and 11 months later the BRA pattern also became abnormal.

135.

**Year:** 1988

**Patient number:** NA abstract

**Author:** Kamerer, D. B.; Lunsford, L. D.; Møller, M.

**Reference:** The Annals of otology rhinology and laryngology, 97, 6 Pt 1, 631-5, 1988

**Title:** Gamma knife: an alternative treatment for acoustic neurinomas

**Abstract:** Despite surgical advances and technologic means of better monitoring seventh and eighth nerve function intraoperatively, there remains a group of patients for whom alternative methods of treatment are desirable. These include the elderly, those with bilateral tumors or tumors in only hearing ears, individuals with medical contraindications to major surgery, and those who refuse surgical resection. The University of Pittsburgh became the fifth world center and the first in the United States to install the gamma knife for stereotactic radiosurgery. On the basis of the pioneering work done at the Karolinska Institute in Stockholm, acoustic tumor patients who fulfill the above criteria are being treated. A tumoricidal single treatment closed-skull radiation dose is given through 201 sharply focused cobalt 60 sources, minimizing the effects on surrounding brain or other tissues. Our early results are discussed and compared to those from more than 200 cases in Stockholm. Complications and expected long-term results are presented.

136.

**Year:** 1988

**Patient number:** 27

**Author:** Noren

**Reference:** Dept. of Neurosurgery, Karolinska Hosp., Stockholm, Sweden. English.

NOTNLM. 19880401., 1988

**Title:** STEREOTACTIC RADIATION TREATMENT IN BILATERAL ACOUSTIC NEUROMA

**Abstract:** The use of stereotactic radiation treatment (radiosurgery) is described in 27 patients (13 men and 14 women) with acoustic neuromas and neurofibromatosis treated from 1969-1985. All but one patient had bilateral tumors. Both neuromas were treated in 6 of the patients, so that a total of 33 tumors were irradiated. In most cases, stereotactic computerized tomography was used for tumor localization. The max dose of gamma radiation was usually 22-50 Gy, with a min of 18-25 Gy to the periphery of the neuroma. A decrease in tumor size was seen in 7 tumors, an increase in size was seen in 8, and no change was seen in 13 (28 tumors in 22 patients had adequate follow-up; mean 3.5 yr; range 1-14.4 yr). Two patients developed facial palsy beginning 5 mo after the irradiation, and gradually regained normal function within approx 6 mo. No patient exhibited improved hearing; preserved hearing was seen in 4 ears and deterioration, varying from slight to pronounced, was recorded in 16 ears. No shunting procedure was required in this group of patients. While there was no mortality related to the radiosurgical treatment, two patients died from rapid general progression of their neurofibromatosis. (10 Refs).

137.

**Year:** 1983

**Patient number:** 14

**Author:** Norén, G.; Arndt, J.; Hindmarsh, T.

**Reference:** Neurosurgery, 13, 1, 12-22, 1983

**Title:** Stereotactic radiosurgery in cases of acoustic neurinoma: further experiences

**Abstract:** Fourteen patients with acoustic neurinomas varying in size from 7 to 30 mm were treated by stereotactic radiosurgery and then were followed for 4 years. The tumors of eight patients decreased 1 to 10 mm in diameter, no change was found in two, and the tumor increased slightly in three patients. Loss of the ability to enhance with contrast administration on computed tomographic scan was a common effect of the treatment. One patient in poor general condition died from intercurrent disease 6 months after radiosurgery. At postmortem examination, a large central necrosis was found. Among five patients with hearing before treatment, full preservation was demonstrated in one; in the other four, the mean impairment of speech discrimination score was 43%. One patient with total unilateral deafness regained hearing and achieved a discrimination score of 60% at 1 year after treatment. There was transient facial weakness in five patients, which was detectable only by electromyography in one. Facial hypesthesia appeared in two patients and was transitory in one of them. Thirteen of the patients are in good or excellent general condition. Stereotactic radiosurgery offers the only therapeutic alternative to open operation in the management of acoustic neurinomas. It is worth considering for every patient, but especially for poor risk patients and those with bilateral tumors.