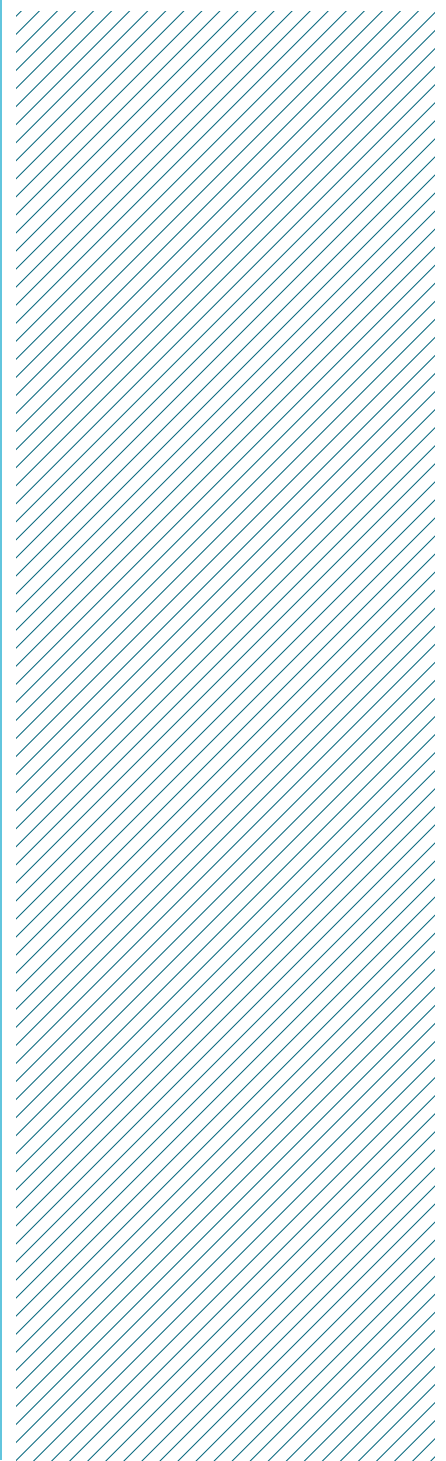


Leksell Gamma Knife®

Health economics

May 1994–May 2021



Contents

Metastases	3
AVM	12
Meningioma	13
Trigeminal neuralgia	13
Vestibular schwannoma	17
Other	19

Metastases

Group and individual change in cognitive functioning in patients with 1 to 10 brain metastases following gamma knife radiosurgery.

Clin Oncol (R Coll Radiol). 2021;33(5):314–21. DOI: 10.1016/j.clon.2021.01.003.

Schimmel WCM, Verhaak E, Bakker M, Hanssens PEJ, Sitskoorn MM, Gehring K.

Aims

Stereotactic radiosurgery is increasingly used to treat multiple (four or more) brain metastases. Preserving cognitive functions is a highly relevant treatment goal because cognitive deteriorations may negatively affect a patient's quality of life. The aim of this study was to assess cognitive change, at the group and individual level, in patients with 1 to 10 brain metastases up to 9 months after Gamma Knife radiosurgery (GKRS).

Materials and Methods

Ninety-two patients with 1 to 10 newly diagnosed brain metastases, expected survival >3 months and Karnofsky Performance Status (KPS) \geq 70 and 104 non-cancer controls were included. A neuropsychological test battery was administered before GKRS (n = 92) and at 3 (n = 66), 6 (n = 52) and 9 (n = 41) months after GKRS. The course of test performances, while taking into account practice effects, was analysed using linear mixed models. Pre-GKRS predictors of cognitive trajectories were analysed. To determine proportions of individuals with cognitive changes, reliable change indices, with correction for practice effects, were calculated.

Results

At the group level, immediate memory, working memory and information processing speed significantly improved over 9 months after GKRS. There were no cognitive declines. Neither number nor volume of brain metastases influenced cognitive change over time. At the individual level, proportions of patients with stable, improved or declined performances were comparable with controls, except for information processing speed (more individuals with improvements in patients) and motor dexterity (more improvements and declines in patients).

Conclusions

Cognitive functioning in patients with 1 to 10 brain metastases was preserved, or improved, up to 9 months after GKRS. Neither number nor volume of brain metastases influenced cognitive performance.

Cognitive functioning and health-related quality of life of long-term survivors with brain metastases up to 21 months after gamma knife radiosurgery.

Neurosurg. 2021;88(5):E396–405. DOI: 10.1093/neuros/nyaa586.

Verhaak E, Schimmel WCM, Gehring K, Hanssens PEJ, Sitskoorn MM.

Background

Survival rates have improved in the past years for patients with brain metastases (BMs).

Objective

To evaluate cognitive functioning and health-related quality of life (HRQoL) after Gamma Knife radiosurgery (GKRS) in a relatively large sample of long-term survivors.

Methods

Data from 38 long-term survivors (assessments available \geq 12 mo post-GKRS) with, at time of enrollment, 1 to 10 newly diagnosed BMs, expected survival > 3 mo, and Karnofsky Performance Status \geq 70 were analyzed. Cognitive functioning and HRQoL were assessed pre-GKRS (n = 38) and at 3 (n = 38), 6 (n = 37), 9 (n = 37), 12 (n = 34), 15 (n = 28), and 21 (n = 21) mo post-GKRS. The course of cognitive test performance and of HRQoL over time was analyzed using linear mixed models. Individual changes in cognitive performance and HRQoL from pre-GKRS to 21 mo were determined using reliable change indexes (RCIs) and clinical meaningful cutoffs, respectively.

Results

Cognitive performances and HRQoL of long-term survivors remained stable or improved up to 21 mo after GKRS. Improvements were found for immediate and delayed verbal memory, working memory, information processing speed, and emotional well-being. On the individual level, most patients had stable or improved test performances or HRQoL. For physical well-being only, most patients (47.6%) showed a decline (vs 28.6% improvement or 23.8% no change) from pre-GKRS until 21 mo post-GKRS.

Conclusion

Up to 21 mo after GKRS, cognitive functioning and overall HRQoL improved or remained stable in long-term survivors. In long-term survivors with 1 to 10 BMs, GKRS did not cause (additional) cognitive deteriorations or declines in HRQoL at longer-term follow-up.



Quality of life is maintained using Gamma Knife radiosurgery: a prospective study of a brain metastases patient cohort.

J Neurosurg 2017;126(3):708–725.

Skeie BS, Eide GE, Flatebø M, Heggdal JI, Larsen E, Bragstad S Pedersen PH, Enger PØ.

Objective

Gamma Knife radiosurgery (GKRS) is increasingly used in the management of brain metastases (BMs), but few studies have evaluated how GKRS impacts quality of life (QOL). The aim of this study was to monitor QOL as the primary end point following GKRS in a patient cohort with BM.

Methods

The study included 97 consecutive patients with 1–6 BMs treated with GKRS between May 2010 and September 2011. QOL was assessed at baseline and at 1, 3, 6, 9, and 12 months postoperatively using the Functional Assessment of Cancer Therapy-Brain (FACT-BR) questionnaire with the brain cancer subscale (BRCS) questionnaire. Factors predicting QOL were identified by mixed linear regression analyses. Local control and toxicity were evaluated according to Response Evaluation Criteria in Solid Tumors (RECIST) and the European Organisation for Research and Treatment/Radiation Therapy Oncology Group (EORTC/RTOG) criteria of late effects, respectively.

Results

Compliance was high from baseline (97%) to 12-month follow-up (78%). Mean BRCS scores remained high during follow-up: they improved in 66% of patients and remained unchanged in 6% at 9 months. Local control ($p = 0.018$), improved symptoms ($p = 0.005$), and stable extracerebral disease ($p = 0.001$) correlated with high QOL-BRCS score. High baseline recursive partitioning analysis class predicted improved QOL ($p = 0.031$), whereas high Karnofsky Performance Scale score ($p = 0.017$), asymptomatic BMs ($p = 0.001$), and no cognitive deficits ($p = 0.033$) or seizures ($p = 0.040$) predicted high, stable QOL-BRCS during the 12-month follow-up.

Conclusions

QOL remained stable for up to 12 months following GKRS for the total cohort. High QOL was reported if local control occurred, cerebral symptoms improved/stabilized, or the need for steroids declined, which all reflected successful GKRS. Conversely, low QOL accompanied progression of intra- and extracerebral disease. Based on the study findings, GKRS appears to be a safe and effective treatment option for patients with BMs.

Gamma knife surgery for metastatic brain tumors from gynecologic cancer.

World Neurosurg. 2016;89:455–463.

Matsunaga S, Shuto T, Sato M.

Objective

The incidences of metastatic brain tumors from gynecologic cancer have increased. The results of Gamma Knife surgery (GKS) for the treatment of patients with brain metastases from gynecologic cancer (ovarian, endometrial, and uterine cervical cancers) were retrospectively analyzed to identify the efficacy and prognostic factors for local tumor control and survival.

Methods

The medical records were retrospectively reviewed of 70 patients with 306 tumors who underwent GKS for brain metastases from gynecologic cancer between January 1995 and December 2013 in our institution.

Results

The primary cancers were ovarian in 33 patients with 147 tumors and uterine in 37 patients with 159 tumors. Median tumor volume was 0.3 cm (3). Median marginal prescription dose was 20 Gy. The local tumor control rates were 96.4% at 6 months and 89.9% at 1 year. There was no statistically significant difference between ovarian and uterine cancers. Higher prescription dose and smaller tumor volume were significantly correlated with local tumor control. Median overall survival time was 8 months. Primary ovarian cancer, controlled extracranial metastases, and solitary brain metastasis were significantly correlated with satisfactory overall survival. Median activities of daily living (ADL) preservation survival time was 8 months. Primary ovarian cancer, controlled extracranial metastases, and higher Karnofsky Performance Status score were significantly correlated with better ADL preservation.

Conclusions

GKS is effective for control of tumor progression in patients with brain metastases from gynecologic cancer and may provide neurologic benefits and preservation of the quality of life.



Health state utilities for patients with brain metastases.

Cureus 2016;8(7):e667.

Lester-Coll NH, Dosoretz AP, Hayman JA, Yu JB.

Purpose

Estimating the cost-effectiveness of whole-brain radiation therapy (WBRT) and stereotactic radiosurgery (SRS), including Gamma Knife radiosurgery (GKRS), requires the quantitative measurement of patients' health states after treatment. We sought to quantify individuals' preferences for the relevant health states after WBRT or GKRS for brain metastases on a 0 to 1 scale, where 1 is perfect health and 0 is death.

Method

We prospectively measured utilities in patients with brain metastases evaluated at Yale for consideration of WBRT and/or GKRS, as well as oncology nurses who had cared for patients with brain metastases before and after WBRT or GKRS, using the Standard Gamble (SG) technique. Demographic information was also collected. Nonparametric tests were used to compare potential differences in utility values and for subgroups based on demographic characteristics.

Results

There were 24 patients and 31 nurses who completed the study between December 2013 and May 2015. Median utilities ranged from 0.85 for the status-post (S/P) GKRS state to 0.25 (for neurologic dying). The median utility of being S/P WBRT was 0.70 compared to 0.85 S/P GKRS ($p < 0.001$). The cognitive decline from WBRT was associated with a notably low utility score of 0.30. There were no statistically significant differences between patients' and nurses' median utility scores.

Conclusions

These SG utilities provide unique insights into brain metastases-related health states from the patient and provider perspective. As perceived by individuals with direct knowledge of the health states in question, WBRT has a significantly lower utility compared to GKRS. Cognitive decline following WBRT is associated with significant perceived reduction in quality of life. Differences in the relative importance of overall survival and quality of life with treatment existed between patients with different stages of disease. These utilities can be used to calculate quality-adjusted life expectancy in cost-effectiveness evaluations of SRS and WBRT.

A cost comparative study of gamma knife radiosurgery versus open surgery for intracranial pathology.

J Clin Neurosci. 2015;22(1):184–8.

Caruso JP, Moosa S, Fezeu F, Ramesh A, Sheehan JP.

Aims

Stereotactic radiosurgery is increasingly used to treat multiple (four or more) brain metastases. Preserving cognitive functions is a highly relevant treatment goal because cognitive deteriorations may negatively affect a patient's quality of life. The aim of this study was to assess cognitive change, at the group and individual level, in patients with 1 to 10 brain metastases up to 9 months after Gamma Knife radiosurgery (GKRS).

Materials and methods

Ninety-two patients with 1 to 10 newly diagnosed brain metastases, expected survival >3 months and Karnofsky Performance Status (KPS) ≥ 70 and 104 non-cancer controls were included. A neuropsychological test battery was administered before GKRS ($n = 92$) and at 3 ($n = 66$), 6 ($n = 52$) and 9 ($n = 41$) months after GKRS. The course of test performances, while taking into account practice effects, was analysed using linear mixed models. Pre-GKRS predictors of cognitive trajectories were analysed. To determine proportions of individuals with cognitive changes, reliable change indices, with correction for practice effects, were calculated.

Results

At the group level, immediate memory, working memory and information processing speed significantly improved over 9 months after GKRS. There were no cognitive declines. Neither number nor volume of brain metastases influenced cognitive change over time. At the individual level, proportions of patients with stable, improved or declined performances were comparable with controls, except for information processing speed (more individuals with improvements in patients) and motor dexterity (more improvements and declines in patients).

Conclusions

Cognitive functioning in patients with 1 to 10 brain metastases was preserved, or improved, up to 9 months after GKRS. Neither number nor volume of brain metastases influenced cognitive performance.



Cost-effectiveness of stereotactic radiosurgery with and without whole-brain radiotherapy for the treatment of newly diagnosed brain metastases.

J Neurosurg. 2014;121 Suppl:84–90.

Hall MD, McGee JL, McGee MC, Hall KA, Neils DM, Klopfenstein JD, Elwood PW.

Objective

Stereotactic radiosurgery (SRS) alone is increasingly used in patients with newly diagnosed brain metastases. Stereotactic radiosurgery used together with whole-brain radiotherapy (WBRT) reduces intracranial failure rates, but this combination also causes greater neurocognitive toxicity and does not improve survival. Critics of SRS alone contend that deferring WBRT results in an increased need for salvage therapy and in higher costs. The authors compared the cost-effectiveness of treatment with SRS alone, SRS and WBRT (SRS+WBRT), and surgery followed by SRS (S+SRS) at the authors' institution.

Methods

The authors retrospectively reviewed the medical records of 289 patients in whom brain metastases were newly diagnosed and who were treated between May 2001 and December 2007. Overall survival curves were plotted using the Kaplan-Meier method. Multivariate proportional hazards analysis (MVA) was used to identify factors associated with overall survival. Survival data were complete for 96.2% of patients, and comprehensive data on the resource use for imaging, hospitalizations, and salvage therapies were available from the medical records. Treatment costs included the cost of initial and all salvage therapies for brain metastases, hospitalizations, management of complications, and imaging. They were computed on the basis of the 2007 Medicare fee schedule from a payer perspective. Average treatment cost and average cost per month of median survival were compared. Sensitivity analysis was performed to examine the impact of variations in key cost variables.

Results

No significant differences in overall survival were observed among patients treated with SRS alone, SRS+WBRT, or S+SRS with respective median survival of 9.8, 7.4, and 10.6 months. The MVA detected a significant association of overall survival with female sex, Karnofsky Performance Scale (KPS) score, primary tumor control, absence of extracranial metastases, and number of brain metastases. Salvage therapy was required in 43% of SRS-alone and 26% of SRS+WBRT patients ($p < 0.009$). Despite an increased need for salvage therapy, the average cost per month of median survival was \$2412 per month for SRS alone, \$3220 per month for SRS+WBRT, and \$4360 per month for S+SRS ($p < 0.03$). Compared with SRS+WBRT, SRS alone had an average incremental cost savings of \$110 per patient. Sensitivity analysis confirmed that the average treatment cost of SRS alone remained less than or was comparable to SRS+WBRT over a wide range of costs and treatment efficacies.

Conclusions

Despite an increased need for salvage therapy, patients with newly diagnosed brain metastases treated with SRS alone have similar overall survival and receive more cost-effective care than those treated with SRS+WBRT. Compared with SRS+WBRT, initial management with SRS alone does not result in a higher average cost.



Comparing the cost-effectiveness of two brain metastasis treatment modalities from a payer's perspective: stereotactic radiosurgery versus surgical resection.

Clin Neurol Neurosurg. 2013;115(3):276–84. DOI: 10.1016/j.clineuro.2012.05.005. Epub 2012 Jun 16.

Vuong DA, Rades D, van Eck ATC, Horstmann GA, Busse R.

Objectives

This study aims to identify the cost-effectiveness of two brain metastatic treatment modalities, stereotactic radiosurgery (SRS) versus surgical resection (SR), from the perspective of Germany's Statutory Health Insurance (SHI) System.

Methods

Retrospectively reviewing 373 patients with brain metastases (BMs) who underwent SR (n = 113) and SRS (n = 260). Propensity score matching was used to adjust for selection bias (n = 98 each); means of survival time and survival curves were defined by the Kaplan–Meier estimator; and medical costs of follow-up treatment were calculated by the Direct (Lin) method. The bootstrap resampling technique was used to assess the impact of uncertainty.

Results

Survival time means of SR and SRS were 13.0, 18.4 months, respectively (P = 0.000). Medians of free brain tumor time were 10.4 months for SR and 13.8 months for SRS (P = 0.003). Number of repeated SRS treatments significantly influenced the survival time of SRS (R² = 0.249; P = 0.006). SRS had a lower average cost per patient (D9964 – SD: 1047; Skewness: 7273) than SR (D11647 – SD: 1594; Skewness: 0.465), leading to an incremental cost effectiveness ratio of D–3740 per life year saved (LYS), meaning that using SRS costs D1683 less than SR per targeted patient, but increases LYS by 0.45 years.

Conclusion

SRS is more cost-effective than SR in the treatment of brain metastasis (BM) from the SHI perspective. When the clinical conditions allow it, early intervention with SRS in new BM cases and frequent SRS repetition in new BM recurrent cases should be advised.

Cost-effectiveness analysis of a randomized study comparing radiosurgery and whole brain radiation therapy in patients with 1 to 3 brain metastases.

Am J Clin Oncol. 2012;35(1):45–50. DOI: 10.1097/COC.0b013e3182004a8f. Epub 2011 Feb 5.

Lal LS, Byfield SD, Chang EL, Franzini L, Miller LA, Arbuckle R, Reasonda L, Feng C, Adamus A, Swint JM.

Background

In this study, we compare 2 treatment options and determine cost-effectiveness and cost-utility.

Methods

We carried out a decision analysis populated with data from patients with brain metastasis in a concurrent trial randomized to either stereotactic radiosurgery (SRS) and observation or SRS and whole brain radiation therapy. Outcomes included actual life years saved (LYS), quality-adjusted life years (QALYs), and incremental cost-effectiveness ratio (ICER). Costs used were from the healthcare perspective and utilities were captured through a time-trade-off method, using 10-year, 5-year, and 1-year time horizons. One-way sensitivity analyses were carried out to determine robustness of the decision analysis model.

Results

Compared with SRS and whole brain radiation therapy, SRS and observation not only had a higher average cost (\$74,000 vs \$119,000, respectively) but also a higher average effectiveness (0.60 LYS vs 1.64 LYS, respectively) with an ICER of \$44,231/LYS or \$41,783/QALY (with utilities captured using a 10-year horizon). Slightly higher ICER estimates were achieved with utilities captured using the other time horizons (\$43,280/QALY and \$44,064/QALY, respectively). Sensitivity analysis showed that the following variables had the highest impact on the ICER: probability of no recurrence in recursive-partitioning analysis class 2 after SRS and observation; probability of being alive after SRS and observation in recursive-partitioning analysis class 2 and being treated for recurrence.

Conclusions

Compared with other interventions in the \$50,000 to \$100,000/QALY cost-effectiveness range, the application of SRS and observation, with subsequent neurosurgical management of recurrences, is shown to be a reasonable treatment modality for brain metastases.



Economic impact of stereotactic radiosurgery for malignant intracranial brain tumors.

Expert Rev Pharmacoecon Outcomes Res. 2011;11(2):195–204. DOI: 10.1586/erp.11.10. Epub 2011 Apr 12.

Lal LS, Franzini L, Panchal J, Chang E, Meyers CA, Swint JM.

Abstract

Brain metastases occur frequently in cancer patients and can lead to neurological complications that result in decreased quantity and quality of life. Treatment alternatives include whole-brain radiation therapy, neurosurgery and the newest modality, stereotactic radiosurgery (SRS). This article reviews economic evaluations of SRS in the metastatic setting compared with other treatment options. Studies were included if they were published in peer-reviewed journals, primarily focused on patients with malignant brain metastasis and included a cost analysis between interventions. Uncertainty surrounding

the cost-effectiveness of SRS is due to a lack of efficacy information between treatment alternatives, methodological limitations and design differences between the available studies. When cost-effectiveness ratios are available, SRS appears to be a reasonable option in resource-limited settings, with incremental cost-effectiveness ratios just below the US\$50,000 range. However, better-designed economic analysis in the setting of randomized clinical trials or observational studies needs to be conducted to fully understand the economic value of SRS.

[Study on medical economic evaluation methods for metastatic brain tumors therapy.]

Neurological Surgery [JP]. 2010;38(7):629–37. Epub 2010 Jul 16.

Takura T, Hayashi M, Muragaki Y, Iseki H, Uetsuka Y.

Introduction

Treatment design for metastatic brain tumors is required to firstly care about the life and function for which the patient hopes because it is terminal care. Therefore, to discuss the value of the therapy, a viewpoint of the QOL and the socioeconomic factors other than the survival rate is important. However, examination that applies these factors to the therapy needs to be carried out more thoroughly. With this in mind, we discuss cost effectiveness of therapy for metastatic brain tumor, through a pilot study on gamma knife therapy.

Materials and method

We studied 18 patients (mean age 61.6 years old) undergoing therapy for metastatic brain tumors. The health rate QOL was assessed by the profile-type measure SF-36 (Short-Form 36-Item Ver1.2) and the preference-based measure EQ-5D (EuroQoL-5D), before and six months after gamma knife therapy. Cost-utility-analysis (yen/Qaly) was carried out from quality adjusted life years (Qalys) and medical fee claims. In addition, we made a correlation analysis of the irradiation procedure and the gains attained.

Results

The observation by SF-36 for six months was useful for metastatic brain tumor. As a result, the QOL indicators showed increased mental health (MH: $p=0.040$) and role emotional (RE: $p=0.029$) with significant difference. In the measurement of EQ-5D, it was added only for one month based on the significant difference ($p=0.022$) from the pre-therapy QOL. The utilities that were analyzed became 0.052 ± 0.175 SD (score), and Qalys were 0.135. Because the cost was 721.4 ± 5.2 SD (thousand yen), the performance of cost-utility-analysis was estimated as 5,330,000 (yen/Qaly). In addition, positive correlation ($r=0.845/p=0.034$) was found between the EQ-5D utility score and the tumor irradiation energy (mJ), etc.

Conclusion

We established a new value over and above mere survival rate concerning metastatic brain tumor therapy. The socioeconomics and efficacy of therapy are more difficult to discuss in this disease than in other diseases. We did this by clarifying the measurement and analysis of QOL as compared with the cost factor. We found that quantitatively, the mental health rate involved in the QOL, had improved. We established that it is appropriate to cover this disease by public insurance, because cost-utility-analysis showed that it was under the threshold line. Our study also suggested that, when guessing the QOL of the prognosis, there should be grades of sensitivity according to the irradiation element involved in the therapy.



Outcomes and cost-effectiveness of gamma knife radiosurgery and whole brain radiotherapy for multiple metastatic brain tumors.

J Clin Neurosci. 2009;16(5):630–4. DOI: 10.1016/j.jocn.2008.07=6.021. Epub 2009 Mar 9.

Lee WY, Cho DY, Lee HC, Chuang HC, Chen CC, Liu JL, Yang SN, Liang JA, Ho LH.

Abstract

We aimed to analyze the outcomes and cost-effectiveness of gamma knife radiosurgery (GKRS) and whole brain radiotherapy (WBRT) for multiple metastatic brain tumors. Over a period of 5 years, 156 patients with multiple metastatic brain tumors were enrolled and freely assigned by the referring doctors to either gamma knife radiosurgery (GKRS, Group A, n=56), or to whole brain radiotherapy (WBRT, Group B, n=100). The follow-up time was set at 1200 days (3.3 years) post-treatment. The number of tumors, patient age, extent of systemic disease and Karnofsky performance scale (KPS) score, were recorded and recursive partitioning analysis used. The outcomes analyzed were: mortality, survival time, neurological complications, post-treatment KPS score, quality-adjusted life years (QALY), and cost-effectiveness. A paired t-test was used for statistical analysis. Mortality rates for patients receiving GKRS and WBRT were 81.1% and 93.0%, respectively ($p=0.05$). The mortality rate was lower for GKRS (74.4%) than for WBRT (97.1%) in patients with initial KPS70

($p=0.02$). The mortality rate was also significantly lower for GKRS (78.9%) than WBRT (95.5%) in patients with 2-5 tumors ($p<0.05$). Post-treatment KPS score (mean \pm standard deviation [s.d.]) was higher for patients receiving GKRS (73.8 \pm 13.2) than for those receiving WBRT (45.5 \pm 26.0), $p<0.01$. The median survival time for GKRS and WBRT was 9.5 months and 8.3 months, respectively, $p=0.72$. The mean (\pm s.d.) QALY was 0.76 \pm 0.23 for GKRS and 0.59 \pm 0.18 for WBRT, respectively ($p<0.05$). The cost-effectiveness per unit of QALY was better for the GKRS treatment (US\$10,381/QALY) than in the WBRT treatment (US\$17,622/QALY), $p<0.05$. The cost-effectiveness per KPS score was also higher for the GKRS treatment (US\$139/KPS score) than for WBRT (US\$229/KPS score), $p<0.01$. Thus, the mortality rate for multiple metastatic brain tumors treated by GKRS is significantly better with a good initial KPS score and when the tumor number is 2-5. GKRS results in a better post-treatment KPS score, QALY, and higher cost-effectiveness than WBRT for treating multiple metastatic brain tumors.



A cost-effectiveness and cost-utility analysis of radiosurgery vs resection for single-brain metastases.

Int J Radiat Oncol Biol Phys. 1997;39(2):445–54. DOI: 10.1016/s0360-3016(97)00071-0.

Mehta M, Noyes W, Craig B, Lamond J, Auchter R, French M, Johnson M, Levin A, Badie B, Robbins I, Kinsella T.

Purpose

The median survival of well-selected patients with single-brain metastases treated with whole-brain irradiation and resection or radiosurgery is comparable, although a randomized trial of these two modalities has not been performed. In this era of cost containment, it is imperative that health-care professionals make fiscally prudent decisions. The present environment necessitates a critical appraisal of apparently equi-efficacious therapeutic modalities, and it is within this context that we present a comparison of the actual costs of resection and radiosurgery for brain metastases.

Methods and materials

Survival and quality of life outcome data for radiation alone or with surgery were obtained from two randomized trials, and radiosurgical results were obtained from a multiinstitutional analysis that specifically evaluated patients meeting surgical criteria. Only linear accelerator radiosurgery data were considered. Cost analysis was performed from a societal view point, and the following parameters were evaluated: actual cost, cost ratios, cost effectiveness, incremental cost effectiveness, cost utility, incremental cost utility, and national cost burden. The computerized billing records for all patients undergoing resection or radiosurgery for single-brain metastases from January 1989 to July 1994 were reviewed. A total of 46 resections and 135 radiosurgery procedures were performed. During the same time period, 454 patients underwent whole-brain radiation alone. An analysis of the entire bill was performed for each procedure, and each itemized cost was assigned a proportionate figure. The relative cost ratios of resection and radiosurgery were compared using the Wilcoxon rank sum test. Cost effectiveness of each modality, defined as the cost per year of median survival, was evaluated. Incremental cost effectiveness, defined as the additional cost per year of incremental gain in median survival, compared to the next least expensive modality, was also determined. To calculate the societal or national impact of these practices, the proportion of patients potentially eligible for aggressive management was estimated and the financial impact was determined using various utilization ratios for radiosurgery and surgery.

Results

Both resection and radiosurgery yielded superior survival and functional independence, compared to whole brain radiotherapy alone, with minor differences in outcome between the two modalities; resection resulted in a 1.8-fold increase in cost, compared to radiosurgery. The latter modality yielded superior cost outcomes on all measures, even when a sensitivity analysis of up to 50% was performed. A reversal estimate indicated that in order for surgery to yield equal cost effectiveness, its cost would have to decrease by 48% or median survival would have to improve by 108%. The average cost per week of survival was \$310 for radiotherapy, \$524 for resection plus radiation, and \$270 for radiosurgery plus radiation.

Conclusions

For selected patients, aggressive strategies such as resection or radiosurgery are warranted, as they result in improved median survival and functional independence. Radiosurgery appears to be the more cost-effective procedure.



The cost effectiveness of stereotactic radiosurgery versus surgical resection in the treatment of solitary metastatic brain tumors.

Neurosurgery.1995;37(3):445-53; discussion 453-5. DOI: 10.1227/00006123-199509000-00012.

Rutigliano MJ, Lunsford LD, Kondziolka D, Strauss MJ, Khanna V, Green M.

Abstract

Solitary metastatic brain tumors are the most common intracranial neoplasms encountered by neurosurgeons. Surgical resection of brain metastasis with whole brain radiotherapy (WBR) significantly increases survival in comparison with WBR alone. Stereotactic radiosurgery (SR) seems to provide results that are similar to those of surgical resection. To analyze the economic efficiency of these different treatments, we compared the results of surgical resection and SR as reported in the medical literature between 1974 and 1994. We included studies in which: 1) at least 75% of patients received WBR; 2) study dates were in the computed tomography era (after 1975); 3) operative morbidity, mortality, and median survival were reported; 4) study dates were not included in a more recent update or review; 5) tumor histologies were reported; and 6) the cobalt-60 gamma unit was used for SR. Three surgical resection studies and one SR study met all entry requirements. The WBR baseline was developed from two

prospective, randomized trials and used for incremental cost effectiveness analysis. We developed a model of typical resource usage for uncomplicated procedures, reported complications, and subsequent craniotomies (for recurrent tumor or radiation necrosis) for both treatment options. Costs were estimated from the societal viewpoint using the 1992 Medicare Provider Analysis and Review database with average cost:charge ratios for surgery and WBR. A survey of capital and operating costs from five sites was used for radiosurgery. Our analysis revealed that radiosurgery had a lower uncomplicated procedure cost (\$20,209 versus \$27,587), a lower average complication cost per case (\$2,534 versus \$2,874), and a lower total cost per procedure (\$22,743 versus \$30,461), was more cost effective (\$24,811 versus \$32,149 per life year), and had a better incremental cost effectiveness (\$40,648 versus \$52,384 per life year) than surgical resection. A sensitivity analysis revealed that large changes in key assumptions would be required to change the analysis outcome.

Cost and survival analysis of metastatic cerebral tumors treated by resection and radiation.

Neurosurgery. 1994 May;34(5):888-93; discussion 893-4.

Penar PL, Wilson JT.

Abstract

The surgical treatment of metastatic brain tumors remains controversial, primarily because of the limited prognosis of patients with metastatic cancer. The cost effectiveness of even standard therapies is of increasing concern to third-party payers. We reviewed the records of patients who had a single metastatic brain tumor resected at the Medical Center Hospital of Vermont (a referral center in a rural state) since cost data recording began. The 32 patients ranged in age from 35 to 77 years, with a 2.2:1 female-to-male ratio. Thirty-four percent of tumors originated in the lung, 15.6% were renal, 12.5% were breast, 12.5% were gynecological, 9.4% were gastrointestinal, and 9.4% were ultimately of unknown origin. Thirty-one tumors were completely resected; 30 patients were irradiated, most after

surgery (mean dose, 3,908 +/- 1,250 cGy). Karnofsky scores improved from 80 +/- 11 to 88 +/- 16 postoperatively (P = 0.0038, one-tailed paired t-test). Patients were hospitalized an average of 8.22 +/- 6.26 days postoperatively, with total operative and postoperative charges of \$19,190 +/- 5,684, noninclusive of radiotherapy. The expected median survival of all patients was 26 months (Kaplan-Meier estimate). The presence of disseminated disease was not significantly correlated with survival (P = 0.237). The number of postoperative days was more for patients with disseminated disease (P = 0.0274), but not for patients with infratentorial tumors (P = 0.6991). Age higher than the median was not correlated with an increased number of postoperative days (P = 0.1366) nor was a preoperative Karnofsky score of 70 or less (P = 0.1382).



A cost comparative study of gamma knife radiosurgery versus open surgery for intracranial pathology.

J Clin Neurosci. 2015;22(1):184–8. DOI: 10.1016/j.jocn.2014.08.012.

Caruso JP, Moosa S, Fezeu, Ramesh A, Sheehan JP.

Abstract

Resection is the traditional treatment for common intracranial pathologies including brain metastases, arteriovenous malformations (AVM), and acoustic neuromas. However, more recently Gamma Knife radiosurgery (GKRS; Elekta AB, Stockholm, Sweden) has emerged as an effective, alternative treatment modality. There are limited data investigating the cost effectiveness of these two treatment modalities. In this study, we compare the costs of GKRS and open surgical excision. This was a retrospective study including all patients at a single institution across a 3-year period with at least 12 months of post-resection follow-up for brain metastases, acoustic neuromas, or AVM. The costs of care were then totaled and compared to known average costs for GKRS at the same institution. The average 12-month costs of treating patients

with brain metastases, acoustic neuromas, and AVM using open surgery were USD\$55,938, \$67,538, and \$78,332, respectively. The average 12-month costs of treating brain metastases, acoustic neuromas, and AVM with GKRS were USD\$23,069, \$37,840, and \$46,293, respectively. This shows that GKRS was on average 58.8%, 44.0%, and 40.9% of the cost of open surgery for brain metastases, acoustic neuromas, and AVM, respectively. GKRS is a cost effective, first-line, alternative to open surgery for treatment of brain metastatic lesions, acoustic neuromas, and AVM in selected patients. This result conforms to previous studies, which also demonstrate that radiosurgery is the more cost-effective treatment for brain metastases and acoustic neuromas when patients are well suited for either approach. Further prospective studies are needed to show that this result is valid at other institutions.

Comparative effectiveness of treatments for cerebral arteriovenous malformations: Trends in nationwide outcomes from 2000 to 2009.

Neurosurg Focus. 2012;33(1):E11. DOI: 10.3171/2012.5.FOCUS12107.

Davies JM, Yanamadala V, Lawton MT.

Object

The development of multimodality approaches for the treatment of cerebral arteriovenous malformations (AVMs), including microsurgery, endovascular therapy, and radiosurgery, has shifted modern treatment paradigms in the last 10 years. This study examines these changes in detail from a nationwide perspective.

Methods

The authors examined data from 2001 to 2009 in the Nationwide Inpatient Sample (NIS) database, and they assessed the safety, quality, and cost-effectiveness, including the total number of discharges, discharge proportion, length of stay, and hospital charges. The authors also examined patient demographics (including age, sex, income level, and insurance), hemorrhage status at presentation, and trends in open surgical and endovascular treatment.

Results

A total of 33,997 inpatient admissions for patients with a primary diagnosis of intracranial AVM were identified, with a mean of 4191 patients admitted annually. The mean hospital charges increased 2-fold over the study period without significant differences in outcomes. There were substantial differences between surgical, endovascular, radiosurgical,

and multimodality treatments. The proportion of AVMs treated microsurgically remained stable over this period, while the proportion treated endovascularly dramatically increased in size, and the data demonstrate important patient-level distinctions among groups. Outcomes and complication profiles were significantly different between treatment modalities and were impacted by age and hemorrhage status.

Conclusions

Charges associated with treatment of cerebral AVMs to the payer and society have increased dramatically over the first decade of the 21st century without clear improvements in quality parameters. However, analysis of the 3 primary treatment modalities has demonstrated differences and warrants further investigation to understand which patient population would benefit maximally from each. Unfortunately, with only imprecise measurements of quality in health care delivery, it remains imperative to develop national databases in which parameters, such as survival, functional outcomes, quality of life, and complication rates, can be assessed to examine the value of care delivered in a more meaningful way. Demonstrating an ever-increasing value of delivered health care will be imperative in our evolving health care system.



Meningioma

A microcosting study of microsurgery, linac radiosurgery, and gamma knife radiosurgery in meningioma patients.
J Neurooncol. 2011;101(2):237–45. DOI: 10.1007/s11060-010-0243-4. Epub 2010 Jun 6.

Tan SS, van Putten E, Nijdam WM, Hanssens P, Beute GN, Nowak PJ, Dirven CM, Hakkaart-van Roijen L

Abstract

The aim of the present study is to determine and compare initial treatment costs of microsurgery, linear accelerator (LINAC) radiosurgery, and gamma knife radiosurgery in meningioma patients. Additionally, the follow-up costs in the first year after initial treatment were assessed. Cost analyses were performed at two neurosurgical departments in The Netherlands from the healthcare providers' perspective. A total of 59 patients were included, of whom 18 underwent microsurgery, 15 underwent LINAC radiosurgery, and 26 underwent gamma knife radiosurgery. A standardized microcosting methodology was employed to ensure that the identified cost differences would reflect only actual cost differences. Initial treatment costs, using equipment costs per fraction, were €12,288 for microsurgery, €1,547 for LINAC radiosurgery, and €2,412 for

gamma knife radiosurgery. Higher initial treatment costs for microsurgery were predominantly due to inpatient stay (€5,321) and indirect costs (€4,350). LINAC and gamma knife radiosurgery were equally expensive when equipment was valued per treatment (€2,198 and €2,412, respectively). Follow-up costs were slightly, but not significantly, higher for microsurgery compared with LINAC and gamma knife radiosurgery. Even though initial treatment costs were over five times higher for microsurgery compared with both radiosurgical treatments, our study gives indications that the relative cost difference may decrease when follow-up costs occurring during the first year after initial treatment are incorporated. This reinforces the need to consider follow-up costs after initial treatment when examining the relative costs of alternative treatments.

Trigeminal neuralgia

Outcomes of two-isocenter gamma knife radiosurgery for patients with typical trigeminal neuralgia: pain response and quality of life.

World Neurosurg. 2018;109:e531–8. DOI: 10.1016/j.wneu.2017.10.014. Epub 2017 Oct 13.

Zhao H, Shen Y, Yao D, Xiong N, Abdelmaksoud A, Wang H.

Objective

To evaluate the effectiveness and safety of 2-isocenter Gamma Knife surgery (GKS) by reviewing patients with trigeminal neuralgia (TN) from the last 10 years.

Methods

A total of 247 patients were followed up and the Barrow Neurological Institute scale was used to evaluate pain degree. Patients' age, gender, pain duration and location, preoperative/postoperative Barrow Neurological Institute scale score, time to initial pain relief, recurrence time, and complications were documented and analyzed.

Results

Patients who underwent a 2-isocenter GKS achieved earlier initial pain relief. The median time of initial pain relief was 2.0 months. Kaplan-Meier analysis showed that the patients with a shorter history of TN and the patients without preoperative surgery achieved earlier initial pain relief. During the 122.8 months of follow-up, the median time of recurrence-free pain relief was 49.7 months. Age was found to be a risk factor of recurrence. Patients who underwent 2-isocenter GKS had a higher rate of postoperative facial numbness, but only 9 cases reported bothersome facial numbness. Multibranch involvement was a risk factor for postoperative facial numbness.

Conclusions

Compared with other modalities, 2-isocenter GKS was a safe and highly effective option for patients with TN. However, more data need to be collected to verify its long-term effect.



Stereotactic radiosurgery for trigeminal neuralgia: a systematic review.

J Neurosurg. 2018;130(3):733–57. DOI: 10.3171/2017.9.JNS17545.

Tuleasca C, Régis J, Sahgal A, De Salles A, Hayashi M, Ma L, Martínez-Álvarez R, Paddick I, Ryu S, Slotman BJ, Levivier M.

Objectives

The aims of this systematic review are to provide an Objective summary of the published literature specific to the treatment of classical trigeminal neuralgia with stereotactic radiosurgery (RS) and to develop consensus guideline recommendations for the use of RS, as endorsed by the International Society of Stereotactic Radiosurgery (ISRS).

Methods

The authors performed a systematic review of the English-language literature from 1951 up to December 2015 using the Embase, PubMed, and MEDLINE databases. The following MeSH terms were used in a title and Abstract screening: “radiosurgery” AND “trigeminal.” Of the 585 initial results obtained, the authors performed a full text screening of 185 studies and ultimately found 65 eligible studies. Guideline recommendations were based on level of evidence and level of consensus, the latter predefined as at least 85% agreement among the ISRS guideline committee members.

Results

The results for 65 studies (6461 patients) are reported: 45 Gamma Knife RS (GKS) studies (5687 patients [88%]), 11 linear accelerator (LINAC) RS studies (511 patients [8%]), and 9 CyberKnife RS (CKR) studies (263 patients [4%]). With the exception of one prospective study, all studies were retrospective. The mean maximal doses were 71.1–90.1 Gy (prescribed at the 100% isodose line) for GKS, 83.3 Gy for LINAC, and 64.3–80.5 Gy for CKR (the latter two prescribed at the 80% or 90% isodose lines, respectively). The ranges of maximal doses were as follows: 60–97 Gy for GKS, 50–90 Gy for LINAC, and 66–90 Gy for CKR. Actuarial initial freedom from pain (FFP) without medication ranged

from 28.6% to 100% (mean 53.1%, median 52.1%) for GKS, from 17.3% to 76% (mean 49.3%, median 43.2%) for LINAC, and from 40% to 72% (mean 56.3%, median 58%) for CKR. Specific to hypesthesia, the crude rates (all Barrow Neurological Institute Pain Intensity Scale scores included) ranged from 0% to 68.8% (mean 21.7%, median 19%) for GKS, from 11.4% to 49.7% (mean 27.6%, median 28.5%) for LINAC, and from 11.8% to 51.2% (mean 29.1%, median 18.7%) for CKR. Other complications included dysesthesias, paresthesias, dry eye, deafferentation pain, and keratitis. Hypesthesia and paresthesia occurred as complications only when the anterior retrogasserian portion of the trigeminal nerve was targeted, whereas the other listed complications occurred when the root entry zone was targeted. Recurrence rates ranged from 0% to 52.2% (mean 24.6%, median 23%) for GKS, from 19% to 63% (mean 32.2%, median 29%) for LINAC, and from 15.8% to 33% (mean 25.8%, median 27.2%) for CKR. Two GKS series reported 30% and 45.3% of patients who were pain free without medication at 10 years.

Conclusions

The literature is limited in its level of evidence, with only one comparative randomized trial (1 vs 2 isocenters) reported to date. At present, one can conclude that RS is a safe and effective therapy for drug-resistant trigeminal neuralgia. A number of consensus statements have been made and endorsed by the ISRS.



Effectiveness of gamma knife radiosurgery in improving psychophysical performance and patient's quality of life in idiopathic trigeminal neuralgia

World Neurosurg. 2018;110:e776–85. DOI: 10.1016/j.wmei/2017.11.096.

Gagliardi F, Spina A, Bailo M, Boari N, Cavalli S, Franzin A, Fava A, Del Vecchio A, Bolognesi A, Mortini P.

Objective

To assess effectiveness of Gamma Knife Radiosurgery (GKRS) in improving quality of life (QoL) in patients with idiopathic trigeminal neuralgia (TN).

Methods

Between January 2001 and October 2013, 166 patients with medically resistant TN were treated at our institution with GKRS. Patients were divided into 2 groups: patients with typical TN (TTN) and patients with atypical TN (ATN). All patients underwent clinical evaluation using Marseille and Barrow Neurological Institute pain and numbness scales; in addition, they completed the Short-Form 36 Health Survey, Activities of Daily Living, and Excellent Good Fair Poor questionnaires and underwent psychological and neurologic examination.

Results

Mean follow-up time was 64.7 months. All Short-Form 36 domains were significantly improved in both groups after treatment, with an evident trend to reach the median values of healthy Italian population. Mean postoperative Activities of Daily Living score in the TTN group and ATN group were 5.8 and 5.4, respectively, and Karnofsky Performance Status increased to 94.2 and 86.4, respectively. Pain recurrence negatively affected patients' QoL and psychofunctional performance without reaching statistical significance. At the last follow-up, 73% of patients were clustered in the pain-relief group.

Conclusions

GKRS significantly improves QoL and functional and psychosocial performance of patients with idiopathic trigeminal neuralgia. A trend was observed toward a more favorable outcome in patients with TTN, compared with patients with ATN, without reaching a statistically significant distinction.



Quality-of-life outcomes after gamma knife surgery for trigeminal neuralgia.

J Neurosurg. 2010;113 Suppl:191–98. DOI: 10.3171/2010.8.GKS10879.

Pan HC, Sheehan J, Huang CF, Sheu ML, Yang DY, Chiu WT.

Object

Gamma Knife surgery (GKS) is an important part of the neurosurgical armamentarium for treatment of patients with trigeminal neuralgia (TN) and is regarded as the first-line treatment in patients with TN who have serious medical comorbidities. In this study, the authors investigated the efficacy of GKS on TN in patients with serious medical comorbidities.

Methods

Between May 2004 and September 2007, 52 severely ill patients who also had TN with Barrow Neurological Institute (BNI) facial pain scores of IV or V were entered into this study. The patients' medical records and imaging findings were reviewed by an anesthesiologist and neurosurgeons to determine whether GKS was a reasonable approach to palliate the patient's pain. All patients underwent GKS, in which a maximum dose of 80 Gy was targeted to the trigeminal nerve with or without plugging to keep the dose received by the brainstem at less than 16 Gy. After treatment, every patient had clinical follow-up every 1–3 months and filled out questionnaires designed to assess BNI facial pain and numbness scores, visual analog scale scores, and 36-Item Short Form Health Survey (SF-36) scores every 3 months until the end of the study. Statistical analysis was performed to find favorable prognostic factors related to pain relief and changes in quality of life.

Results

The median age of the patients was 71 years, and the male/female ratio was 30:22. The median follow up period was

54 months (at least 2 years). All patients had a positive initial response to GKS, with BNI facial pain scores at least 1 point less than respective pre-GKS scores. Three patients (5.7%) obtained BNI facial pain Score I. Twenty-three patients (44.2%) experienced pain recurrence at a median follow-up of 33 months. One patient suffered from angina and required time in an intensive care unit; another patient had bleeding from a pin wound that required suturing. Alterations in BNI scores were highly correlated to visual analog scale scores ($R^2 = 0.978$). In both univariate and multivariate analyses, a decreased BNI facial pain score at different time points was significantly ($p < 0.05$) related to younger patient age, no previous treatment, evidence of vessel compression on MR imaging, time of first GKS ≤ 24 months, physical function (SF-36), role limitation due to a physical problem (SF-36), role limitation due to an emotional problem (SF-36), mental health (SF-36), social functioning (SF-36), bodily pain (SF-36), and general health (SF-36), but was not related to vitality (SF-36). Five patients (9.6%) experienced facial numbness at a mean of 13.2 ± 3.1 months after GKS (4 patients with BNI facial numbness Score II and 1 with BNI facial numbness Score III). Post-GKS MR imaging changes, including focal contrast enhancement or T2-weighted signal alterations, were identified in 3 patients (5.7%).

Conclusions

Gamma Knife surgery produced significant pain relief in severely ill patients who had TN without causing appreciable morbidity. The effect of reduced pain significantly paralleled an improvement in SF-36 quality-of-life indices.



Vestibular schwannoma

Comparing costs of microsurgical resection and stereotactic radiosurgery for vestibular schwannoma

J Neurosurg. 2018 Nov 9;1–10. DOI: 10.3171/2018.5.JNS18508.

Schnurman Z, Golfinos JG, Epstein D, Friedmann DR, Roland JI, Kondziolka D.

Objective

Given rising scrutiny of healthcare expenditures, understanding intervention costs is increasingly important. This study aimed to compare and characterize costs for vestibular schwannoma (VS) management with microsurgery and radiosurgery to inform practice decisions and appraise cost reduction strategies.

Methods

In conjunction with medical records, internal hospital financial data were used to evaluate costs. Total cost was divided into index costs (costs from arrival through discharge for initial intervention) and follow-up costs (through 36 months) for 317 patients with unilateral VSs undergoing initial management between June 2011 and December 2015. A retrospective matched cohort based on tumor size with 176 patients (88 undergoing each intervention) was created to objectively compare costs between microsurgery and radiosurgery. The full sample of 203 patients treated with resection and 114 patients who underwent radiosurgery was used to evaluate a broad range of outcomes and identify cost contributors within each intervention group.

Results

Within the matched cohort, average index costs were significantly higher for microsurgery (100% by definition, because costs are presented as a percentage of the average index cost for the matched microsurgery group; 95% CI 93-107) compared to radiosurgery (38%, 95% CI 38-39). Microsurgery had higher average follow-up costs (1.6% per month, 95% CI 0.8%-2.4%) compared to radiosurgery (0.5% per month, 95% CI 0.4%-0.7%), largely due to costs incurred in the initial months after resection. A major contributor to total cost and cost variability for both resection and radiosurgery was the need for additional interventions in the follow-up period, which were necessary due to complications or persistent functional deficits. Although tumor size was not associated with increased total costs for radiosurgery, linear regression analysis demonstrated that, for patients who underwent microsurgery, each centimeter increase in tumor maximum diameter resulted in an estimated increase in total cost of 50.2% of the average index cost of microsurgery (95% CI 34.6%-65.7%) ($p < 0.001$, $R^2 = 0.17$). There were no cost differences associated with the proportion of inpatient days in the ICU or with specific surgical approach for patients who underwent resection.

Conclusions

This study is the largest assessment to date based on internal cost data comparing VS management with microsurgery and radiosurgery. Both index and follow-up costs are significantly higher when tumors were managed with resection compared to radiosurgery. Larger tumors were associated with increased resection costs, highlighting the incremental costs associated with observation as the initial management.



Gamma Knife radiosurgery for vestibular schwannomas and quality of life evaluation

Stereotact Funct Neurosurg. 2017;95(3):166–73. DOI: 10.1159/000472156. Epub 2017 May 23.

Berkowitz O, Han YY, Talbott EO, Iyer AK, Kano H, Kondziolka D, Brown MA, Lunsford LD.

Background

Further investigation is needed to look at the impact of vestibular schwannoma (VS) on the health-related quality of life (QOL) of participants who undergo Gamma Knife® radiosurgery (GKRS).

Objectives

Investigators compared the QOL for VS participants to reported US population norms in order to evaluate disease burden and long-term QOL several years after GKRS.

Methods

This cross-sectional study surveyed participants to assess hearing status, tinnitus, imbalance, vertigo, as well as the Short-Form 36-item Health Questionnaire (SF-36). The data were normalized, age adjusted, and functional status was correlated to determine clinically significant differences.

Results

A total of 353 participants who underwent GKRS between 1997 and 2007 were included in this study with a median postoperative period of 5 years. SF-36 scores were very similar to population norms, and age-adjusted scores for participants followed the US population curve. Frequent vertigo and balance problems had the largest statistically and clinically significant effect on physical and mental component summary scores followed by nonuseful hearing in the tumor ear.

Conclusions

Participants reported a good long-term QOL that was very similar to the QOL of US population norms. Of the common VS symptoms, vertigo had the greatest impact on QOL followed by imbalance and then hearing loss.

Long-term outcome of gamma knife radiosurgery for vestibular schwannoma.

J Neurol Surg B Skull Base. 2014;75(4):273–8. DOI: 10.1055/s-0034-1371525. Epub 2014 Apr 17.

Bir SC, Ambekar S, Bollam P, Nanda A.

Objective

We evaluated the long-term outcome of vestibular schwannoma (VS) treated with gamma knife radiosurgery (GKRS) as a primary treatment as well as an adjunct therapy.

Materials and methods

We performed a retrospective review (2000–2012) of 82 patients with VS who received GKRS. Of 82 patients, 20 patients with prior resection received GKRS treatment as an adjunct therapy. The remainder of the patients (62) received GKRS as a primary treatment.

Results

GKRS for VS showed significant variations in tumor growth control (decreased in 44 patients [54%], arrested growth in 30 patients [36%], and increased tumor size in 8 patients [10%]). Progression-free survival rates after GKRS at 3, 5, and 10 years were 98%, 95%, and 95%, respectively. Hearing, facial nerve function, and Karnofsky performance scale were significantly improved after GKRS compared with pretreated status (79 versus 90). Two patients (2.5%) required resection again due to tumor progression and worsening of signs and symptoms.

Conclusion

Long-term follow-up demonstrated that GKRS offers a high rate of tumor control, preservation of multiple nerve functions, and a good quality of life in both new and recurrent patients with VS.



Comparison of the surgical and follow-up costs associated with microsurgical resection and stereotactic radiosurgery for vestibular schwannoma.

J Neurosurg. 2008;108(6):1220–4. DOI: 10.3171/JNS/2008/108/6/1220. Epub 2008 Jun 4.

Banerjee R, Moriarty JP, Foote R, Pollock BE.

Object

The best approach to the management of vestibular schwannoma (VS) remains controversial. The aim of this study is to analyze the initial and follow-up costs of resection and stereotactic radiosurgery for patients with VS.

Methods

Initial and follow-up costs in 53 cases in which patients with unilateral, previously unoperated VSs > 3 cm underwent resection (21 cases) or radiosurgery (32 cases) at the Mayo Clinic from June 2000 until July 2002 were analyzed for 36 months. Follow-up treatment-specific utilization records were gathered prospectively for patients not returning to the Mayo Clinic after treatment. Six-month moving averages of incremental follow-up costs were calculated for the 2 patient groups.

Results

The mean cost of surgery in the microsurgery group was \$23,788 (95% confidence interval \$22,280–\$24,842) compared with \$16,143 (95% confidence interval \$15,277–\$17,545) for the radiosurgical group. Mean incremental follow-up costs per month for patients in the microsurgery group started just > \$1,000 per month, decreased steadily, and remained < \$70 per month by the 10th month of follow-up. Mean incremental follow-up costs per month for patients in the radiosurgery group were < \$10 per month for the first few months and thereafter increased to as much as \$200 per month.

Conclusions

Although the total cost of microsurgery is higher due to the costs of hospitalization, follow-up costs for radiosurgery are greater in general. From a societal perspective, radiosurgery is less expensive than microsurgical resection provided that the rate of tumor progression after radiosurgery remains low with long-term follow-up.

Other

Safety and efficacy of single-fraction gamma knife radiosurgery for benign confined cavernous sinus tumors: our experience and literature review.

Neurosurg Rev. 2020;43(1):27–40.

Tripathi M, Batish B, Kumar N, Ahuja CK, Oinam AS, Kaur R, Narayanan R, Gurnaani J, Kaur A.

Gamma knife radiosurgery (GKRS) has emerged as a suitable primary treatment option for confined cavernous sinus tumors (CSTs) and residual/recurrent benign tumors extending from the surrounding neighborhood. The aim of this review was to further investigate the safety and efficacy of single-fraction GKRS for primary confined CSTs (hemangioma, meningioma, and schwannoma). This was a retrospective analysis of 16 patients of CSTs, primarily treated with GKRS between 2009 and 2017. The patients underwent follow-up clinical and radiological evaluation at a regular interval. Data on clinical and imaging parameters were analyzed. The published literature on GKRS for CSTs was reviewed. There were total 16 patients (eight meningiomas, seven hemangiomas, and one schwannoma). Patients presented with a headache (56.3%), ptosis (50%), and/or restricted extraocular movements (50%). There was 46.6% tumor volume (TV) reduction after single-fraction GKRS.

Hemangiomas showed best TV reduction (64% reduction at >3-year follow-up) followed by schwannoma (41.5%) and meningioma (25.4%). 56.3% of patients developed transient hypoesthesia in trigeminal nerve distribution. 44.4% of patients became completely pain-free. Among cranial nerves, the superior division of the oculomotor nerve showed best outcome (ptosis 62.5%) followed by an improved range of EOM. There was no adverse event in the form of new-onset deficit, vascular complication, or malignant transformation except for one out of the field failures. Among available treatment options, GKRS is the most suitable option by virtue of its minimally invasive nature, optimal long-term tumor control, improvement in cranial neuropathies, cost-effectiveness, favorable risk-benefit ratio, and minimal long-term complications.

Outcomes of stereotactic radiosurgery for pilocytic astrocytoma: an international multiinstitutional study.

J Neurosurg. 2019 Nov 29;1–9. DOI: 10.3171/2019.9.JNS191335.

Murphy ES, Parsai S, Kano H, Sheehan JP, Martinez-Alvarez R, Martinez-Moreno N, Kondziolka D, Simonova G, Liscak R, Mathieu D, Lee CC, Yang HC, Lee JY, McShane BJ, Fang F, Trifiletti DM, Sharma M, Barnett GH.

Objective

The current standard initial therapy for pilocytic astrocytoma is maximal safe resection. Radiation therapy is considered for residual, recurrent, or unresectable pilocytic astrocytomas. However, the optimal radiation strategy has not yet been established. Here, the authors describe the outcomes of stereotactic radiosurgery (SRS) for pilocytic astrocytoma in a large multiinstitutional cohort.

Methods

An institutional review board-approved multiinstitutional database of patients treated with Gamma Knife radiosurgery (GKRS) between 1990 and 2016 was queried. Data were gathered from 9 participating International Radiosurgery Research Foundation (IRRF) centers. Patients with a histological diagnosis of pilocytic astrocytoma treated using a single session of GKRS and with at least 6 months of follow-up were included in the analysis.

Results

A total of 141 patients were analyzed in the study. The median patient age was 14 years (range 2–84 years) at the time of GKRS. The median follow-up was 67.3 months.

Thirty-nine percent of patients underwent SRS as the initial therapy, whereas 61% underwent SRS as salvage treatment. The median tumor volume was 3.45 cm³. The tumor location was the brainstem in 30% of cases, with a nonbrainstem location in the remainder. Five- and 10-year overall survival rates at the last follow-up were 95.7% and 92.5%, respectively. Five- and 10-year progression-free survival (PFS) rates were 74.0% and 69.7%, respectively. On univariate analysis, an age < 18 years, tumor volumes < 4.5 cm³, and no prior radiotherapy or chemotherapy were identified as positive prognostic factors for improved PFS. On multivariate analysis, only prior radiotherapy was significant for worse PFS.

Conclusions

This represents the largest study of single-session GKRS for pilocytic astrocytoma to date. Favorable long-term PFS and overall survival were observed with GKRS. Further prospective studies should be performed to evaluate appropriate radiosurgery dosing, timing, and sequencing of treatment along with their impact on toxicity and the quality of life of patients with pilocytic astrocytoma.

Gamma Knife radiosurgery for low-grade gliomas: Clinical results at long-term follow-up of tumor control and patients' quality of life.

World Neurosurg. 2017;101:540–53.

Gagliardi F, Bailo M, Spina A, Donofrio CA, Boari N, Franzin A, Fava A, Del Vecchio A, Bolognesi A, Mortini P.

Objective

First-line therapy for low-grade gliomas (LGGs) is surgery, in some cases followed by radiotherapy and chemotherapy. Gamma Knife radiosurgery (GKRS) has gained more relevance in the management of these tumors. The aim of this study was to assess efficacy and safety of GKRS for treatment of LGGs.

Methods

Between 2001 and 2014, 42 treatments were performed on 39 patients harboring LGGs; 48% of patients underwent previous surgery, and 20.5% underwent previous radiotherapy. Mean tumor volume was 2.7 cm³, and median margin dose was 15 Gy.

Results

Mean follow-up was 60.5 months (range, 6–164 months). Actuarial progression-free survival was 74.9%, 52.8%, and 39.1% at 1 year, 5 years, and 10 years; actuarial overall survival was 97.4%, 94.6%, and 91.8% at 9 months, 1 year,

and 5 years. Solid tumor control was achieved in 69.2% of patients, whereas cystic enlargement was recorded in 12.9% of cases. At last follow-up, volume reduction was recorded in 57.7% of cases, and median volume decreased by 33.3%. Clinical improvement was observed in 52.4% of patients. Karnofsky performance scale score was improved in 15 patients (45.5%), unchanged in 17 patients (51.5%), and worsened in 1 patient (3%). Mean posttreatment scores of 36-item short form health survey domains did not significantly differ from scores in a healthy Italian population.

Conclusions

This study confirms safety and effectiveness of GKRS for LGGs in controlling tumor growth, relevantly improving patients' overall and progression-free survival. GKRS improved patients' functional performance and quality of life, optimizing social functioning and minimizing disease-related psychological impact.



Treatment of the ventral intermediate nucleus for medically refractory tremor: A cost-analysis of stereotactic radiosurgery versus deep brain stimulation.

Radiother Oncol. 2017;125(1):136–9.

McClelland 3rd S, Jaboin JJ.

Introduction

Medically refractory tremor treatment has evolved over the past half-century from intraoperative thalamotomy to deep brain stimulation (DBS) of the thalamic ventral intermediate nucleus (VIM). Within the past 15 years, unilateral radiosurgical VIM thalamotomy has emerged as a comparably efficacious treatment modality.

Methods

An extensive literature search of VIM DBS series was performed; the total cost of VIM DBS was calculated from hospitals geographically representative of the entire United States using current procedural terminology and work relative value unit (RVU) codes. The 2016 Medicare Ambulatory Payment Classification for stereotactic radiosurgery (SRS) was added to the work RVU to determine the total cost of VIM SRS for both Gamma Knife and linear accelerator SRS. Cost estimates assumed that VIM DBS was performed without intraoperative microelectrode recording.

Results

The mean unilateral VIM DBS cost was \$17,932.41 per patient. For SRS VIM, the total costs for Gamma Knife (\$10,811.77) and linear accelerator (\$10,726.40) were 40% less expensive than for unilateral VIM DBS.

Conclusion

Radiosurgery of the VIM is 40% less expensive than unilateral VIM DBS in treatment of medically refractory tremor, regardless of radiosurgical modality. This finding argues for increased radiation oncology involvement in the management of medically refractory tremor patients.

First 1,000 cases of Gamma Knife surgery for various intracranial disorders in LSU Health–Shreveport: Radiological and clinical outcome.

J La State Med Soc. 2015;167(2):54–65. Epub 2015 Apr 15.

Bir SC, Ward T, Bollam P, Nanda A.

Objective

Gamma knife radiosurgery (GKRS) has emerged as an important therapeutic alternative for different intracranial lesions. We have reviewed our institution's first 1,000 cases of radiosurgeries.

Materials and methods

We performed a retrospective review (2000–2013) of 1,017 radiosurgeries in 911 patients with various intracranial lesions including vestibular schwannoma (82), meningioma (136), metastatic brain tumors (298), astrocytoma (49), pituitary adenoma (92), arteriovenous malformation (85) and trigeminal neuralgia (169).

Results

GKRS in different intracranial lesions showed significant variations in outcome and complications. Overall, the local tumor growth control for benign and malignant tumors was 89 percent and 70 percent respectively. The rate of obliteration of arteriovenous malformation nidus was 79 percent. The complete and partial relief of pain in the patients with trigeminal neuralgia was 55.6 percent and 22.4 percent respectively.

Conclusion

At recent follow-up, GKRS showed good control of different tumor growth, obliteration of AVM nidus and remission of trigeminal neuralgia pain, good overall and progression free survival rate, possible preservation of neurological functions, lesser number of complications, and improvement of quality of life. Therefore, GKRS is an important treatment option for patients with different benign intracranial tumors, AVM and trigeminal neuralgia. However, GKRS is not effective for recurrent malignant tumors in the brain.



Combining brain diagnosis and therapy in a single strategy: the safety, reliability, and cost implications using same-day versus separate-day stereotactic procedures.

Stereotact and Funct Neurosurg. 2011;89(6):346–56. DOI: 10.1159/000332057. Epub 2011 Nov 5.

Park KJ, Niranjana A, Kondziolka D, Kano H, Castillo P, Matchett JC, Flickinger JC, Lunsford LD.

Background

A therapeutic radiosurgery procedure usually follows a separate diagnostic stereotactic procedure after days or weeks. Objectives: To define the clinical reliability, safety, and cost implications of same-day diagnostic stereotactic biopsy and therapeutic radiosurgery.

Methods

During an 8-year interval, 26 patients underwent stereotactic brain biopsy followed by immediate therapeutic stereotactic radiosurgery in a single-day combined procedure. The intraoperative diagnosis was determined using standard histopathological techniques. Diagnostic accuracy, hospital costs, and contribution margins associated with this treatment strategy were compared to those of 26 case-matched patients (controls) who underwent a stereotactic diagnostic procedure followed by a separate-day outpatient SRS procedure within 6 weeks during the same time interval.

Results

The intraoperative diagnosis correlated with the final histopathological diagnosis in 96% of the patients. Biopsy-related morbidity did not occur in this series. The mean total costs of same-day patients was significantly lower than the costs of patients who had two-stage procedures (USD 9,077 +/- 2,366 vs. 11,284 +/- 3,025; $p = 0.008$). The net contribution to the hospital margin of USD 13,736 was not significantly different between the two management strategies.

Conclusions

The advantages of the same-day approach included a single stereotactic head frame application, reduced total admission time, consecutive histopathological diagnosis and therapy in a single hospital admission, and reduced total hospital costs. For patients who are highly suspected to have a brain tumor for which SRS is likely to be an effective therapeutic strategy, same-day diagnostic stereotactic biopsy followed by therapeutic SRS proved to be a safe, reliable, and cost-effective management strategy.



Socioeconomic costs of open surgery and gamma knife radiosurgery for benign cranial base tumors.**Neurosurgery. 2006;58(5):866–73; discussion 866–73.**

Cho DY, Tsao M, Lee WY, Chang CS.

Objective

The aim of this study was to evaluate the relative socioeconomic costs of benign cranial base tumors treated with open surgery and gamma knife radiosurgery.

Methods

In a retrospective study, we studied 174 patients with benign cranial base tumors, less than 3 cm in diameter (or volume less than 30 ml), admitted in the past 5 years. Group A (n = 94) underwent open surgery for removal of the tumors, whereas Group B (n = 80) underwent gamma knife radiosurgery. The socioeconomic costs were evaluated by both direct and indirect cost. The direct costs comprised intensive care unit cost, ward cost, operating room cost, and outpatient visiting cost. The indirect costs included loss of workdays and mortality. The length of hospital stay, the number of lost workdays, surgical complications, mortality, and cost-effectiveness analysis were calculated as well. Student t test and chi test were used for statistical analysis.

Results

The mean length of hospital stay for open surgery was 18.2 +/- 30.4 days including 5.0 +/- 14.7 days of intensive care unit stay and 13.0 +/- 15.2 days of ward stay, P < 0.01. The mean hospital stay for gamma knife was 2.2 +/- 0.9 days with no need of intensive care unit stay, P < 0.01. The mean loss of workdays for open surgery was 160 +/- 158 days and 8.0 +/- 9.0 days for gamma knife, P < 0.01. The gamma knife cost per hour (1435 US dollars) is higher than the open surgery cost per hour (450 US dollars), P < 0.01. The direct cost for gamma knife (9677 US dollars +/- 6700 US dollars) is higher than that for open surgery (5837 US dollars +/- 6587 US dollars), P < 0.01. Open surgery had more complication rates (31.2%) than gamma knife (3.8%). Open surgery had a mortality rate of 5.3%; there was no mortality for gamma knife. The indirect costs, including loss of workdays and mortality, were significantly higher for open surgery than for gamma knife, P < 0.01. Finally, the socioeconomic cost (34,453 US dollars +/- 97,277 US dollars) is higher for open surgery than for gamma knife (10,044 US dollars +/- 7481 US dollars), P < 0.01. The CEA is significantly higher in gamma knife (3762 US dollars/quality-adjusted life year) than in open surgery (8996 US dollars/quality-adjusted life year), P < 0.01.

Conclusions

Most of the socioeconomic loss with open surgery for benign cranial base tumors comes from the indirect costs of workdays lost and mortality. Gamma knife radiosurgery is a worthwhile treatment to our patients and to our society because it may shorten hospital stays and workdays lost and reduce complications, mortality, socioeconomic loss, and achieve better cost-effectiveness.



Direct costs of microsurgical management of radiosurgically amenable intracranial pathology in Germany: An analysis of meningiomas, acoustic neuromas, metastases and arteriovenous malformations of less than 3 cm in diameter.

Acta Neurochir (Wien). 2003;145(4):249–55.

Wellis G, Nagel R, Vollmar C, Steiger HJ.

Background

The purpose of the analysis was to appreciate and compare the effective direct costs of microsurgical treatment of intracranial pathology potentially amenable to radiosurgery as they arose in 1998-99.

Method

Treatment costs of 127 microsurgically treated patients harbouring an arteriovenous malformation (AVM), acoustic neuroma, meningioma or brain metastasis potentially amenable to radiosurgery were reviewed. Costs for the surgical procedure, ICU care, medical and nursing care on the ward, interclinical bills (ICB) for services provided by other departments and the overhead for basic hotel service were added. For comparison Gamma Knife costs were calculated by dividing the global operating cost of the Gamma Knife centre by the number of patients treated in 1999.

Findings

Average hospitalisation time for the entire microsurgical patients was 15,4+/-8,6 days. The patients spent an average of 1,2+/-2,8 days on ICU. Average operating time for all patients, including preparation, was 393+/-118 minutes. Average costs for the microsurgical therapy were Euro10.814+/-6.108. These consisted of Euro1417+/-426 for the surgical procedure, Euro1.188+/-2.658 for ICU care, Euro2.333+/-1.582 for medical and nursing care on the ward, Euro1.671+/-1.433 for interclinical bills and Euro 4.204+/-2.338 for basic hotel service (overhead, Euro273/day). 70% of the microsurgically treated patients needed ancillary inpatient rehabilitation or radiotherapy resulting in an average additional cost for all patients of Euro2.744. Furthermore 20% of the microsurgically treated patients required an unplanned readmission after discharge, resulting in an average additional costs for all patients of Euro1.684. Average overall costs per patient including ancillary therapy and unplanned readmissions amounted to Euro15.242. For comparison, Gamma Knife treatment costs per patient amounted to Euro7.920 in 1999.

Interpretation

The current analysis showed that for established radiosurgical indications the primary costs of microsurgery exceeded the costs of radiosurgery. Differences with regard to additional expenses as a consequence of disability were not addressed in this study. Microsurgical management as well as Gamma Knife radiosurgery have potential for economic improvement.



The costs of radiosurgical treatment: Comparison between gamma knife and linear accelerator.

Acta Neurochir (Wien). 1998;140(11):1101–10; discussion 1110–1. DOI: 10.1007/s007010050223.

Königsmaier H, de Pauli-Ferch B, Hackl A, Pendl G

Abstract

Radiosurgical treatment can be carried out by means of a Gamma Knife or a Linear Accelerator. The Linear Accelerator may be either a single-purpose appliance, exclusively employed in radiosurgery, or an adapted appliance, which is used primarily for fractionated radiotherapy, and only additionally for radiosurgical purposes. The first alternative will be referred to briefly as a “dedicated Linac”, the latter as an “adapted Linac”. Cost accounting data for these alternatives will be discussed under three main categories: investment costs, operating costs, and finally staffing costs. Costs are only considered to the extent that this is necessary to facilitate a comprehensive cost comparison. Factors for which the costs remain the same or at least broadly the same will from the outset not be taken into consideration. These include, for instance, the

costs of general or special administration, diagnosis, and image processing. The results and conclusions of this study therefore cannot be employed immediately in the evaluation of cost reimbursement schemes of the type carried out by agencies responsible for social insurance. Here, appropriate complete cost analyses especially for this purpose are required. The final comprehensive cost comparison reveals that the adapted Linac is the most favourable alternative with small annual quantities of patients. With larger numbers of patients the Gamma Knife represents the most favourable from a cost accounting angle. The dedicated Linac accordingly does not have a cost advantage for any of the examined numbers of patients. Clearly the lowest treatment costs per patient can be achieved by employing a Gamma Knife and using it to capacity.



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Elekta AB

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SE-103 93
Stockholm, Sweden

T +46 8 587 254 00
F +46 8 587 255 00

Europe

T +46 8 587 254 00
F +46 8 587 255 00

Turkey, India, Middle East & Africa

T +90 216 474 3500
F +90 216 474 3406

North & Central America including the Caribbean

T +1 770 300 9725
F +1 770 448 6338

South America & Cuba

T +55 11 5054 4550
F +55 11 5054 4568

Asia Pacific

T +852 2891 2208
F +852 2575 7133

Japan

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