

OP-1. The Role of Stereotactic Radiosurgery as a Postoperative Adjuvant Treatment for the Patients with Multiple Metastatic Brain Tumors

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Introduction: Brain metastases are the most common of intracranial tumors. Surgical resection followed by whole brain radiation therapy (WBRT) has been a standard therapy in the patients with brain metastasis. We evaluate if, as an adjuvant treatment, stereotactic radiosurgery (SRS) can replace WBRT for the metastatic brain tumor patients who underwent surgery.

Methods: The authors retrospectively reviewed the records from an 8-year period at a single institution for consecutive patients with brain metastases treated via surgical resection and adjuvant gamma knife radiosurgery (GKRS) for the other remained metastases. In this study, 25 patients underwent surgical resection, and consecutive GKRS was performed to 111 tumors. Patients had an average age of 59.4 years (range, 36-81 years), and 63.6% were male. At GKRS, the mean tumor volume was 2.23 cc (range, 0.01-15.7 cc) and the mean dose of 21.0 Gy was prescribed to the tumor margin. The Kaplan-Meier method was used to calculate both progression-free and overall survival.

Result: The clinical and radiologic follow up was performed in 22 patients with 102 tumors. The median progression-free survival was 168 days, and the median overall survival after GKRS was 257 days. The rate of local control is 86.3%. The management for local recurrence were gamma knife (N=3), WBRT (N=2) and palliative therapy (N=2). The rate of surgical site recurrence was 9.1% (N=2, 2 tumors). The management for surgical site recurrence were GKRS (N=1) and WBRT (N=1). The management for new metastases were gamma knife (N=7), WBRT (N=4), surgery (N=1) and palliative therapy (N=7). Although survival rate was very low as 4%, we could not find any brain related death cases. The rate of local recurrences was 12.7% (N=8, 13 tumors).

Conclusion: SRS could be one of the postoperative adjuvants in selected patents with both totally resected tumors(s) and the other oligometastases.



OP-2. Long Term Results of Gamma Knife Radiosurgery for Vestibular Schwannoma

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Objective: Radiosurgical effects for the benign brain tumor have been established. Among benign brain tumor, vestibular schwannomas is adequate indication for the radiosurgical treatment because the tumor have the characteristics of anatomical uniformity, mostly diagnosed in small volume. In the current study, we analyzed the result of radiosurgery for vestibular schwannoma during follow up periods.

Methods: A total of 327 patients with vestibular schwannoma were treated with gamma knife radiosurgery at our hospital during the past 22 years, and the patients were followed up for 6 to 180 months (mean 51.2 months). We retrospectively reviewed the medical records, radiological results, and radiosurgical records, of the patients. We then performed a detailed analysis of factors that affects tumor control and hearing preservation.

Results: The tumor volume control was achieved in 84% of patient by only initial gamma knife radiosurgery. In case the treatment was failed, the secondary treatment was performed by operation in 10 cases and secondary gamma knife radiosurgery in 19 cases. The tumor control rate had not showed the statistical difference by age (younger than and older than 55 years); gender (female or male); treatment software (KULA or Gamma plan); operation history (first line treatment or secondary treatment). But by the treatment volume (larger than or smaller than 2.5 cc), there was no significance, but by '5.0 cc', the treatment outcome showed statistical difference. As for the hearing preservation, there was no significant difference by gender, age. But even if the tumor control had been established, the worsening of the hearing preservation had been persisted in many cases for the long time.

Conclusion: Radiosurgical treatment outcome for the tumor control during long time observation was satisfactory. But the more long term follow up than 5 years is needed for the assessment of the functional hearing preservation.



OP-3. Gamma Knife Radiosurgery for Cerebral Metastases from Non-small Cell Lung Cancer during a 10-year Period

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Objective: Non-small cell lung cancer (NSCLC) is the most frequent cancer that metastasizes to brain. Stereotactic radiosurgery (SRS) has become the management of choice for most patients with such metastatic tumors. Therefore, the authors endeavored to elucidate the survival and SRS outcomes for patients with NSCLC metastasis at their center.

Methods: In this single-institution retrospective analysis, the authors reviewed their experience with NSCLC metastasis during a 10-year period from 2001 to 2010. Seven hundred twenty patients underwent Gamma Knife radiosurgery. A total of 1004 SRS procedures were performed, and 3143 tumors were treated. The NSCLC subtype was adenocarcinoma in 386 patients, squamous cell carcinoma in 111 patients, and large cell carcinoma in 34 patients. The median aggregate tumor volume was 4.5 cm³ (range 0.1-88 cm³).

Results: The median survival time after diagnosis of brain metastasis from NSCLC was 12.6 months, and the median survival after SRS was 8.5 months. The 1-, 2-, and 5-year survival rates after SRS were 39%, 21%, and 10%, respectively. Postradiosurgery survival was decreased in patients treated with prior whole-brain radiation therapy compared with SRS alone ($p=0.003$). Aggregate tumor volume was inversely related to survival after SRS ($p<0.001$), and the histological subgroups demonstrated significant survival differences ($p=0.023$). The overall local tumor control rate in the entire group was 92.8%. One hundred seventy-four patients (24%) underwent repeat SRS for new or resistant metastatic deposits.

Conclusions: Stereotactic radiosurgery is an effective means of providing local control for NSCLC metastases. Neurological function and survival benefit from serial patient monitoring and repeat SRS for new tumors.



OP-4. Gamma Knife Radiosurgery for Central Neurocytomas

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Objective: Central neurocytomas (CN) are rare benign tumor that located in lateral ventricles in young adults. Treatment of choice of CN is surgical resection but radiosurgery showed favorable outcomes also. We assessed treatment effect of Gamma Knife Radiosurgery (GKS) for central neurocytomas in our center.

Methods: Between October, 1994 and March 2015, 11 patients with CN were treated with GKS. Of these patients, We assessed 8 patients that could followed up CT or MRI. The mean age of patients was 34.5 years old (range 25.4-64.6). 6 patients were male and 2 patients were female. The mean radio- surgical tumor volume was 18.1 mL (range 3.8-34.3). The mean dose delivered to the tumor margin was 12.8 Gy (range 8-18.9).

Results: 8 patients underwent follow-up CT or MRI scanning and median duration of imaging follow-up was 90.9 months (range 21-199). 1 patient was performed GKS after resection, and other patients treated with GKS only. 2 patients underwent ventriculoperitoneal shunt pre or post GKS state. Follow-up images showed complete response in 1 patients (12.5%), partial response in 3 patients (37.5%) and no change of tumor size in 2 patients (25.0%). 2 patients was recurred tumor (25%) and these patients was performed 2nd GKS. After 2nd GKS, tumor size was reduced in all patients.

Conclusion: GKS is safe and effective treatment of CN, but tumor recurrence is not infrequent. So, long term surveillance is required after GKS to detect recurrence.

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OP-5. Gamma Knife Radiosurgery for Large Sized Arteriovenous Malformation: Staged Surgery

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Objective: Radiosurgery has been well established as a safe and effective treatment for small to medium sized cerebral arteriovenous malformations (AVMs). But, treatment of large AVMs remains a great challenge due to the size of nidus, location, low obliteration rate after radiation therapy, unacceptable treatment-related deficit. So, we introduce our experience about staged Gamma Knife radiosurgery (GKS) for large sized AVMs, herein.

Cases: 38 years old male patient presented with seizure who had large sized AVM underwent staged GKS after endovascular embolization. Volume of AVM was 45.8 mL. 10 Gy marginal dose (50%) was delivered to AVM in 1st GKS, and 3 months later, same radiation dose was delivered in 2nd GKS. 4 years after GKS, AVM was complete obliteration on follow up images. 47 years old male patient with large sized AVM underwent staged GKS. Primary symptom of patient was seizure. Volume of AVM was 43.8 mL. Prescription dose was 10 Gy (marginal dose, 50%) in 1st GKS, and 2 months later, the patient underwent 2nd GKS as same radiation dose. 5 years after GKS, AVM was complete obliteration on follow up images, also.

Conclusion: Staged Gamma Knife Radiosurgery is a feasible and safe method for treatment of large AVMs.

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OP-6. Time-Versus Volume-staged Stereotactic Radiosurgery for Large Cerebral Arteriovenous Malformations

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Objective: There have been debates on time-staged stereotactic radiosurgery (TS-SRS) and volumestaged SRS (VS-SRS) for large cerebral arteriovenous malformations (cAVMs), which still remains challenging due to their complexity and large surrounding normal brain tissue. We performed this study to compare outcomes after these two different radiosurgical methods treating large cAVMs.

Methods: A total of 173 patients with large cAVMs were treated with TS-SRS at Seoul National University Hospital, Seoul, Korea. Their clinical and radiological outcomes were compared with them of 54 large-cAVM patients, who were managed with VS-SRS at University of California San Francisco, CA, USA. TS-SRS was performed with a mean marginal dose of 13.2 ± 3.68 Gy to a mean volume of 21.9 ± 13.1 cm³ in a single session. VS-SRS was performed with two or three sessions separated by an interval of 3 to 6 months, and the volume and marginal dose per session were about 8 cm³ and 17 Gy. The mean volume of the VS-SRS group was 25.0 ± 13.5 cm³. The mean follow-up durations were 1790 ± 1219 days in the TS-SRS and 1616 ± 1515 days in the VS-SRS groups, respectively ($p=0.389$; Student-T test).

Results: Post-SRS bleeding was developed in 26 (15.0%) in the TS-SRS and 16 (29.6%) in the VS-SRS groups ($p=0.026$; chi-square test). TS-SRS showed higher complete obliteration rate in 49 (30.1%) than VS-SRS of 5 (10.0%) ($p=0.005$). However, near-complete obliteration rates were similar in the two groups [68 (41.7%) in the TS-SRS and 17 (34.0%) in the VS-SRS groups; $p=0.410$]. Changes on follow-up T2 and/or fluid attenuated inverse recovery magnetic resonance images were found in all patients of 35 (100%) in the VS-SRS group, whose data were available; the signal-change rate was 61.6% in the TS-SRS group ($p<0.001$; chi-square test). In the multivariate analysis for post-SRS bleeding, 'embolization before SRS' and 'AVM volume over 30 cm³' were found independent significant variables ($p<0.001$, OR=



3.433, 95% CI, 1.809-6.514; $p=0.010$, OR=2.458; 95% CI, 1.237-4.887, respectively), but 'VS-SRS vs. TS-SRS' did not reach the statistical significance ($p=0.120$, OR=1.700, 95% CI, 0.871-3.317). After propensity score matching (PSM) for 'embolization before SRS' and 'AVM volume over 30 cm³', 'VS-SRS' showed a trend of negative effect on post-SRS bleeding compared with TS-SRS ($p=0.051$, OR=2.598, 95% CI, 0.997-6.770). VS-SRS, AVM volume, and follow-up duration were all negative independent factors on complete obliteration ($p=0.015$, OR=0.277, 95% CI, 0.098-0.781; $p<0.001$, OR=0.929, 95% CI, 0.893-0.967; $p<0.001$, OR=0.999, 95% CI, 0.999-1.000, respectively), thus PSM for 'embolization before SRS' and 'AVM volume' was conducted. After this PSM, 'VS-SRS' still showed a significant negative effect on complete obliteration ($p=0.008$, OR=0.200, 95% CI, 0.061-0.656). In terms of near-complete obliteration, 'VS-SRS' also has a negative effect compared with 'TS-SRS' in the PSM results, conducted with the same manner of analysis for complete obliteration. However, it did not reach the statistical significance ($p=0.089$, OR=0.518, 95% CI, 0.243-1.106).

Conclusion: VS-SRS seems to have no benefit over TS-SRS in terms of AVM obliteration after SRS, rather it may increase post-SRS bleeding rate compared with TS-SRS. These results should be reevaluated in a large size of cohort considering the modest size of the population of this study.

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OP-7. Gamma Knife Radiosurgical Management in AVMs Containing Nidal Aneurysm

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Objective: To evaluate the therapeutic effects and complications in patients treated with SRS

Methods: AVM patients treated with SRS from October, 2008 to November, 2014, were reviewed retrospectively. We investigated the result of SRS in the field of clinical characteristics, radiological image, symptomatic changes and interval progress of the nidus. 34 patients were included in this study. We reviewed the candidates according to the therapeutic modality, such as craniotomy, endovascular embolization, stereotactic radiosurgery. MRI and MRA was taken at 3, 6, 12 months post-operatively. Follow-up trans-femoral cerebral angiography was taken at 12 or 24 months after SRS. Additional image study was taken at the time of unexpected events.

Results: The average age of 34 patients was 43.06 yrs (range from 6 to 67). The sex ratio was 2.09:1 (Male:23, Female:11). The number of patients with Spetzler-Martin grade 1 was six, grade 2 was eleven, grade 3 was nine, grade 4 was four, grade 5 was four. Average nidus diameter was 3.06 cm (range from 1.1cm to 6.8 cm). The mean follow-up duration was 29.91 months (range from 4 months to 108 months). 7 post-operative complication cases were noted. Complications included AVM rupture (8.69%), seizure (13.04%), edema (4.34%), and hydrocephalus (4.34%). Among the patients with nidal decrement, the number of patients who only underwent SRS was eleven. In average, complete obliteration was observed in 27.5 months (range from 20 to 38 months). Unfortunately, in one case of AVM, massive rebleeding occurred 10 months after SRS. Ictal tragedy led the patient to coma and decease.

Conclusion: Concerning the patients' mortality, morbidity and treatment efficacy, SRS can be said to be a good therapeutic option. In AVM patients, hemodynamic change or vessel structural change after the radiosurgery might cause re-bleeding, seizure, edema and hydrocephalus. Short-term follow-up and small population parameters were limiting factors in our study. Further studies should be continued.

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OP-8. Gamma Knife Radiosurgery for Metastatic Brain Tumor Exposed to Cerebrospinal Fluid Space: Is it Really Contraindicated ?

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Objective: Gamma Knife Radiosurgery (GKRS) offers similar local control rates for metastatic brain tumor and fewer neurocognitive risks compared with WBRT. But in case of metastasis exposed to cerebrospinal fluid (CSF) space, it could mimic leptomeningeal carcinomatosis (LMC) and led clinician to choose whole brain radiation therapy with or without intrathecal chemotherapy. The authors analyzed our experiences of GKRS for metastatic brain tumor exposed to CSF space.

Methods: We performed a retrospective review on 223 patients with brain metastasis who were treated by GKS from 2010 to 2012 at Yonsei gamma knife center. Their lesions occupied CSF space such as cerebral cortex, periventricular ependymal layer, choroid plexus, intraventricular space. Among them, 45 patients were excluded due to leptomeningeal carcinomatosis before GKS or previously performed GKS or brain radiation therapy. Multiple factors were analyzed including survival rate, patient related factors and treatment related parameters.

Results: A total of 178 patients enrolled this study. The 2 year overall survival rate was 39.9%. During the follow up period, 21 (11.8%) patients were diagnosed as LC. Non-small cell lung cancer is the most common lesion related to brain metastasis (50.5%) as well as LC (52.4%). Age younger than 65 years old and surgical procedures after GKRS were factors related to development of LC ($p < 0.05$).

Conclusions: GKRS could achieve durable tumor control rates for CSF occupying lesions and relatively low failure rate, especially in patients older than 65 years old. This treatment method may also potentially offer the chance to delay the WBRT. Further studies are mandatory for the criteria of optimal candidate.

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