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Role of Stereotactic Radiosurgery in Glial Tumors

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Abstract

Glial tumors are a relatively new indication for stereotactic radiosurgery (SRS). Traditionally, SRS has been considered to be an inadequate treatment for glial tumors as these are diffuse tumors, but SRS is a highly focused treatment. Tumor delineation can be challenging given the diffuse nature of the gliomas. It has been recommended to include the T2/fluid-attenuated inversion recovery (FLAIR) altered signal intensity areas in addition to the contrast enhancing part in the treatment plan of glioblastoma in order to increase the coverage. Some have recommended to include 5 mm margins to cover up for the diffusely infiltrative nature of the glioblastoma. The most common indication of SRS in patients with glioblastoma multiforme is tumor recurrence. SRS has also been used as a boost to the residual tumor or tumor bed after surgical excision before conventional radiotherapy. The addition of bevacizumab has been recently tried along with SRS in patients with recurrent glioblastoma to decrease radiation toxicity. Besides, SRS has also been used in patients with low-grade gliomas following recurrence. Brainstem gliomas, which are usually low-grade gliomas, are another indication for SRS. Outcomes following the use of SRS are comparable with external beam radiotherapy in brainstem gliomas, whereas the risks of radiation-induced complications is less. SRS has also been used in other glial tumors such as gangliogliomas and ependymomas.

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Full Text

Glial neoplasms are a relatively uncommon indication for stereotactic radiosurgery (SRS). Niranjan et al.[40] reported that more than 40,000 patients with glial neoplasms have received SRS as an adjuvant therapy worldwide till 2013. We will discuss the role of SRS in various glial pathologies individually in the following sections.

Role of SRS in Glioblastoma Multiforme

Glioblastoma multiforme (GBM) is the most common malignant brain tumor, with an estimated annual worldwide incidence of 3.21 persons per 100,000 population.[1] The standard treatment for a patient with GBM includes surgical excision or a biopsy (depending on the location of the lesion), followed by chemotherapy and concurrent fractionated radiotherapy.[2],[3] Nowadays, temozolamide is a commonly used chemotherapeutic agent.[2] Radiotherapy involves delivering 60 Gy in different schedules. However, 60 Gy fractionated radiotherapy (FRT) does not confer prolonged tumor control, and most patients experience tumor recurrence despite receiving other adjuvant therapies along with radiation.[4]

The role of stereotactic radiosurgery in GBM is yet not clear, and the literature on this is continuously evolving. SRS has been used in patients with GBM in various roles – in combination with chemotherapy, as a sole adjuvant agent, or as a boost in addition to chemotherapy and radiotherapy.[5] It has been used for both primary disease and recurrent disease. The results of trials describing the effect of adding SRS in addition to the routinely used adjuvant therapies are contradictory with some reporting a slight survival advantage (Nwokedi)[6–9] but others reporting no advantage.[10–13] Median survival times ranging from 7.5 to 30 months have been reported in various series following radiosurgery in GBM patients.[14],[15]

Rationale for the use of SRS in GBM

The main criticism of the use of SRS in GBM is the fact that SRS is a highly focused therapy, whereas GBM is a diffuse disease with the tumor cells spreading far from the contrast enhancing part as seen on magnetic resonance imaging (MRI).[16] Hence, the highly conformal treatment provided along with the volume restriction in SRS techniques may make SRS a poor choice in patients with GBM. Hence, SRS may offer an inadequate treatment.

It is not possible to excise the tumor completely in many patients because of the involvement of the eloquent regions of the brain, and residual tumor after surgery portends a poor prognosis. Focused high-dose radiation doses may be delivered using SRS to the residual lesion. Moreover, it has been observed that most of the recurrences of GBM occur within 2 cm of the initial tumor.[17] Moreover, many of the recurrences are focal. This may make SRS a good treatment option for these focal GBM recurrences. Moreover, while irradiating recurrent GBM using SRS, one may be able to control the dose to the parts of the brain which need a high dose, that is, the surrounding few centimeters while the radiation exposure of the surrounding brain which is already irradiated is limited, thus decreasing the radiation complications.[5]

Radiological targeting can be challenging in patients with GBM

SRS can be delivered using gamma knife radiosurgery (GKRS, Elekta Instruments AB, Stockholm, Sweden), linear accelerator (LINAC)-based photon therapy, or a Cyberknife Robotic Radiosurgical System (Accuray, Sunnyvale, CA, USA).

It has been recommended to include the T2/fluid-attenuated inversion recovery (FLAIR)-altered signal intensity areas suggesting hyper-cellularity, in addition to the contrast enhancing part, in the treatment plan of GBM in order to increase the coverage.[18] Some have recommended to include 5 mm margins to cover up for the diffusely infiltrative nature of the GBM.[19] Positron emission tomography (PET) has also been used by a few authors in target delineation.

C-methionine-PET has been used to identify the metabolic active parts of the tumor, which can be fused with MRI images to plan SRS treatment.[20],[21] However, the clinical advantage of this technique remains to be proved yet.

White matter adjacent to GBM has been considered to be the pathway for spread of GBM. Hence, including the non-enhancing white matter adjacent to the GBM in the tumor, termed as leading-edge radiosurgery, has been recommended to reduce the risk of tumor recurrence.[18]

Radiation dose

The radiation dose used in patients with GBM depends on many factors and varies from patient to patient. These factors include the volume of the tumor, if previous radiation therapy was received by the patient, if yes

then the dose and time interval between the repeat radiotherapies, eloquent tissues in close proximity, and the performance status of the patient.[5] Based on these factors, larger tumors or those who have received prior irradiation are given less dose as compared to small tumors and those being irradiated for the first time. Hypo-fractionated radiosurgery is also an option in the first category. The most commonly used median radiation dose in the literature is 16 Gy (range 9–25 Gy).[14],[22],[23]

Adverse effects of SRS in recurrent GBM

It is difficult to assess the accurate rates of adverse events and radiation necrosis because of variation in the definitions and follow-up protocols among the different institutes.[5] Adverse events in patients with recurrent GBM who received SRS were reported in nearly 26% of patients, whereas nearly 24% of these patients developed radiation necrosis.[14],[22],[23],[24],[25],[26]

Role of SRS in recurrent glioblastoma multiforme

Despite advances in surgical techniques and molecular targeted therapies, the outcome of patients with GBM remains dismal, with a median survival of 9–20 months.[27] The various radiotherapy options for recurrent glioblastomas include external beam radiotherapy, fractionated or hypo-fractionated stereotactic radiotherapy (SRT), 125-Iodine brachytherapy brachytherapy, or SRS.[28],[29],[30],[31],[32] Recurrent GBM is the most common indication for SRS in patients with GBM.

Literature review

Primary GBM

One randomized phase III trial assessed the role of initial SRS boost before standard FRT and carmustine (RTOG 93-05). It revealed that there is no benefit of an initial SRS boost.[33] However, carmustine was used in this trial against temozolomide. Hence, the general applicability of these results is questionable.[1] No level 1 study has evaluated the role of SRS in the clinically relevant situations till date.

Einstein described the experience of SRS boost in 35 patients with biopsy-proven GBM in addition to standard radiotherapy.[34] The target was chosen on the basis of increased biological activity as determined by magnetic resonance spectroscopy (MRS) imaging within 2 cm of the post-operative enhancing surgical bed. Only 16 out of 35 patients received temozolamide in this study. The median overall survival (OS) in the entire cohort and patients who received temozolamide was 15.8 months and 20.8 months, respectively. The latter is higher as compared to the OS of 14.6 months in the historical controls who received radiotherapy and temozolomide in the European Organization for Research and Treatment of Cancer trials.[35] Eleven percent of patients developed grade 3 or 4 toxicities, possibly attributable to GKRS in this study.

Nwokedi et al.[9] described their experience of treating 64 patients with GBM. All patients received external beam radiotherapy (EBRT), whereas 31 patients received a GKRS boost in addition to the EBRT. The median OS in the patients who received SRS boost was 25 months as compared to 13 months in the patients who received EBRT alone (p value - 0.034). No patient in the study group experienced grade 3 or 4 radiation side effects.

Kong et al. used SRS boost before EBRT in ten patients with unresectable GBM. The median OS in the patient who received SRS boost before EBRT was 52 weeks (22–110.6 weeks) as compared to 28 weeks in those who received EBRT alone. This difference was not statistically significant. However, post-treatment Karnofsky Performance Scale (KPS) scores were significantly better maintained in the SRS group as compared to the patients who received EBRT alone ($p = 0.004$).

Duma et al.[18] described their results of upfront GK boost to the leading edge of GBM in 174 patients. The leading edge was defined on the FLAIR MRI sequence and was outside the contrast enhancing tumor. Thus, the clinical tumor volume included the entire FLAIR volume (even 4–5 cm away from the enhancing tumor edge) plus the enhancing tumor. Diagnosis of GBM in the included patients was made on the histopathological specimen obtained during tumor excision or stereotactic biopsy. SRS was given after an initial diagnosis of GBM and prior to or during standard radiation therapy and carmustine or temozolomide chemotherapy. The

median interval between the diagnosis of GBM and SRS was 18 days. The irradiated target, the volume of which ranged from 2.5 cc to 220 cc (median 48.5 cc), received a median prescription dose of 8 Gy (range 6–14 Gy). The median OS after diagnosis in the patients included in this study was 23 months (43 ± 0.78 months). The 2-, 3-, 5-, 7-, and 10-year actual OS rates after leading edge radiosurgery in this series were 39%, 26%, 16%, 10%, and 4%, respectively. This suggested that the patients who received SRS to the leading edge had better survival as compared to what was described in the landmark trial by Stupp et al.[4] Treatment-related imaging changes were seen in 9% of patients with 6% of patients experiencing permanent complications attributable to SRS. These patients were managed with dexamethasone, whereas 4% of patients required surgical intervention for symptoms arising out of radiation-induced changes. Moreover, 10% of patients experienced fall in KPS by 1 to 3 grades, which was temporally related to the development of radiation-induced changes and not progression of GBM. None of the patients in this series received bevacizumab.

Another trial evaluating the role of early stereotactic GKRS boost to residual tumor after surgery. in patients with GBM with post-operative residual tumor is ongoing.[36]

In a recent study, Yakar et al.[37] compared patients with sub-total resection of high-grade glioma (WHO grade 3 and 4) who received either EBRT alone (group 1, 68 patients) or GKRS boost post-surgery to the residual followed by EBRT (group 2, 32 patients). OS and progression free survival (PFS) were significantly higher in group 2. The authors concluded that boost GKRS during the early post-operative period is beneficial for increasing PFS and OS.

Recurrent GBM

Factors which independently predict better survival in patients with recurrent GBM following SRS include a lesser volume of the tumor to be irradiated, younger patients, a marginal dose of SRS used, use of multiple chemotherapy agents before SRS, less homogeneous treatment plans, time interval between surgery and SRS, and MGMT methylation status.[22],[24],[38],[39]

Sharma et al.[39] reported their experience of treating 53 patients with recurrent GBM with SRS. Seventy-five lesions were targeted in these patients with a median volume of 8.80 cubic cm (cc). The radiation dose prescribed varied from 12 to 24 Gy (median 18 Gy). They reported the median OS and PFS after SRS in recurrent GBM to be 11.0 months (95% CI 7.1–12.2) and 4.4 months (95% CI 3.7–5.0), respectively. The prognostic predictors of longer OS and PFS were tumor volumes less than 15 cc and heterogenous treatment plans. A KPS score more than 80 was associated with longer OS but not PFS.

Niranjan et al.[40] described their experience of treating 297 patients with unresected residual or progressive biopsy-proven GBM with adjuvant or salvage radiosurgery in the pre-bevacizumab era. Ninety-six patients had deep-seated unresectable GBMs and had undergone biopsy of the lesion and constituted the unresected residual group. The progressive GBM group included 68 patients who had undergone gross total excision of the lesion and 133 patients who had sub-total excision. The median tumor volume and prescription dose were 14 cc (range 0.26–84.2 cc) and 15 Gy (range 9–25 Gy), respectively. The median follow-up duration was 8.6 months (range 1.1–173 months). They reported the median survival after the diagnosis of GBM and after SRS to be 18.1 and 9.0 months, respectively. The 1-year and 2-year OS after SRS were 37.9% and 16.7%, respectively. Factors found to be associated with improved OS after diagnosis on multi-variate analysis were a younger age (<60 years) at the time of diagnosis, a tumor volume less than 14 cc, use of prior chemotherapy, and radiosurgery at the time of recurrence. The rate of adverse effects in this series was 23% at a median interval of 1.7 months.

Imber et al.[14] published their experience of treating 174 patients with recurrent GBM with GKRS. The median interval between the diagnosis of GBM and SRS was 8.7 months. The median volume of the target and the median marginal dose prescribed were 7.0 cc (range 0.3–39.0 cc) and 16.0 Gy (range 10–22 Gy), respectively. They reported the median OS after SRS to be 10.6 months after SRS. The predictors of improved outcome on multi-variate analysis were found to be younger age at time of SRS, a higher prescription dose, and a longer interval between original surgery and SRS. Twenty-six percent of these patients required redo-craniotomy after SRS. Recurrent tumor without radionecrosis was seen in 35% of these patients, whereas the histopathological examination in the majority (63%) of the patients revealed either radionecrosis alone or

mixed recurrent tumor/radionecrosis. The latter group had a larger mean treatment volume and a lower mean isodose prescription compared with the former group. They concluded that GKRS can be beneficial for young patients with smaller recurrent GBM.

Bir et al.[41] identified KPS >70, an age less than 50 years, the absence of neurological deficits, and initial post-operative RT to be associated with improved survival following GKRS in patients with recurrent GBM. They also observed that adjuvant therapy with GKRS following GBM recurrence yielded a longer OS (7.9 months vs 3.5 months) than when GKRS was used to give post-operative boost therapy.

A recent meta-analysis analyzed the effect of Cyberknife SRS in patients with malignant gliomas (both grade 3 and grade 4).[42] The median OS from initial diagnosis and CyberKnife treatment for both grade 3 and 4 gliomas combined was 22.6 months and 8.6 months, respectively. The median OS from CyberKnife treatment was 8.4 months for WHO grade IV gliomas, compared to 11 months for WHO grade III gliomas. The radiation-induced necrosis was seen in 4.3% of the patients.

GKRS with bevacizumab in patients with recurrent GBM

Bevacizumab has been approved for the treatment of recurrent GBM to control tumor growth.[43] Moreover, it has a role in treatment of radiation necrosis.[44] Given these roles, the advantages of administration of bevacizumab following GKRS have been evaluated in many studies.

A single fraction SRS dose up to 22 Gy was found to be safely tolerated with no radiation-induced adverse effects when a single dose of bevacizumab was administered before SRS in patients with recurrent GBM in a Phase I Trial of Radiosurgery Dose Escalation.[45] Another study involving 45 patients delivered a single fraction SRS dose up to 24 Gy in patients with initial recurrences along with bevacizumab and found no radiation-induced adverse effects.[46] They used a slightly lower dose, up to 19 Gy, for subsequent recurrences along with bevacizumab; again, no radiation-induced adverse effects were seen. The authors in this study observed that when SRS is given along with bevacizumab in patients with recurrent GBM, the factors associated with poor outcome are a KPS of less than 70, an SRS dose lesser than 18, and use of less than two chemotherapeutic agents. No radiation-related adverse events were recorded in this series.

Park et al.[25] studied 11 patients with recurrent GBM (seven had first recurrence, and four had two or more recurrences), who were subjected to GKRS, followed by bevacizumab combined with chemotherapy. The treatment outcomes were compared to 44 case-matched controls who underwent GKRS without additional bevacizumab. The median volume was 13.6 cc, and the radiation dose prescribed varied from 13 to 18 Gy (median 16 Gy). Irinotecan and temozolomide were used along with bevacizumab in nine patients and one patient, respectively, whereas bevacizumab was used alone in one patient. The median OS in this study was found to be 18 months (95% CI, 10.1–25.7 months), whereas the 1-year OS rate was 73%. Radiation adverse effects were seen in one patient. These patients had statistically significantly longer OS (18 vs 12 months) and PFS (15 vs 7 months) as compared to the case-matched controls who underwent SRS but did not receive bevacizumab. At a median of 13.7 months (range 4.6–28.3 months) after radiosurgery, tumor progression was evident in seven patients. More importantly, the risk of adverse radiation effects was also lower in the patients who received bevacizumab (9% vs 46%).

Morris et al.[46] treated 45 patients with recurrent GBM with GKRS and bevacizumab. They observed the median OS and PFS to be 31 months and 9.3 months following the diagnosis of GBM and 13.3 months and 5.2 months after SRS, respectively. No patient in their study group developed radiation-induced adverse effects.

Low-grade Gliomas

Low-grade gliomas (LGGs) are WHO grade 1 or 2 tumors and account for 20% of all gliomas.[47] LGGs are more commonly seen in young adults. Surgical resection of LGGs is the preferred treatment, whereas some non-resectable lesions are subjected to radiotherapy.[47] The role of radiotherapy is well proven in LGGs. It has also been observed that patients receiving upfront radiotherapy for residual LGG have better PFS than

patients who receive radiotherapy only when there is tumor progression.[48]

Gagliardi et al.[47] published their experience of performing 42 GKRS treatments in 39 patients with supratentorial and infratentorial LGGs. Twelve patients underwent GKRS as first-line therapy, whereas the rest 27 underwent GKRS as a rescue therapy after surgery, RT, or chemotherapy. The median marginal dose used was 15 Gy (range 12–20 Gy). The actuarial PFS at 1, 5, and 10 years observed in this study was 74.9%, 52.8%, and 39.1%, respectively. The actuarial OS at 9 months, 1 year, and 5 years observed in this study was 97.4%, 94.6%, and 91.8%, respectively. 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 the median volume decreased by 33.3%. More than half of the patients reported improvement in clinical symptoms. Radiation-induced adverse complications were seen in nine patients, whereas one patient had permanent complications.

Henderson et al.[49] treated 12 LGGs with GKRS. The lesions in their series included pilocytic astrocytomas in eight patients, subependymal giant cell astrocytoma, and fibrillary astrocytoma in two patients each. The median volume of the target and the median marginal dose prescribed were 4.4 cc (range 1.0–16.5 cc) and 13.0 Gy (range 12–20 Gy), respectively. The median follow-up in this study was 48.2 months. The 4-year tumor control and OS observed in this study were 77 and 83%, respectively. Symptomatic radiation-induced adverse complications were seen in two patients. They concluded that GKRS can provide local control in cases of unresectable or recurrent LGGs with acceptable complication rates.

Another study including 49 patients of LGG reported complete radiological remission in 29% patients.[50] The 5-year radiological PFS was 37% in this series. GKRS-induced adverse complications were seen in 8% of patients in this series. Complete disappearance of a right caudate head grade astrocytoma has also been reported in a child following 14 Gy marginal dose delivered by GKRS.[51]

Tuleasca et al.[52] reported their experience of treating four patients of ganglioglioma with GKRS. All four patients had undergone gross total excision of the tumor and received GKRS at the time of tumor recurrence. The median volume of the target and the median marginal dose prescribed were 0.5 ml (range 0.23–2.3 ml) and 18.0 Gy (range 16–18 Gy), respectively. The tumor size decreased in three patients and remained stable in one patient at a median follow-up of 54 months (range 6–120).

No patients had worsening seizures or any radiation-induced adverse effects.

Brainstem LGG

Brainstem LGG accounts for 10% and 2% of central nervous system tumors in the pediatric and adult patient populations, respectively.[53] These lesions, especially tectal plate gliomas, are most of the time surgically inaccessible. The common treatment strategies for these patients are observation and cerebro-spinal fluid diversion if there is hydrocephalus. Many patients who demonstrate tumor progression are subjected to EBRT.[54] Nowadays, SRS is being commonly used in these patients in place of external beam radiotherapy.[55–57]

Yen et al.[55] described the management of 20 patients with focal brainstem glioma. Tumor was located in the mid-brain in 16 patients, in the pons in three patients, and in the medulla in one patient. Out of the ten tumors which were biopsied, five were pilocytic astrocytoma and the rest were non-pilocytic astrocytomas. Diagnosis in the rest ten was based on imaging alone. The mean volume was 2.5 cc, and the radiation dose prescribed varied from 10 to 18 Gy, except in three patients who were getting GKRS as a boost to EBRT. Tumor control was achieved in 16 patients, with complete tumor disappearance in four patients, at a mean follow of 78 months. Tumor progressed in the remaining four cases.

Another case series described the role of SRS in 11 patients with tectal plate glioma (five were pilocytic astrocytoma, and six were non-pilocytic astrocytomas).[58] The median volume was 4.5 cc (1.2 cc to 14.7 cc), and the radiation dose prescribed varied from 11 to 14 Gy (median 12 Gy). Tumor control was achieved in all

patients, with complete tumor disappearance in six patients, at a median follow of 40 months (range 13 months to 114 months). Four patients experienced transient tumor swelling, and an equal number of patients developed tumor cysts. One patient required cyst aspiration.

In a recently published meta-analysis comparing RT with GKRS in patients with brainstem gliomas, it was found that GKRS is associated with significantly higher rates of complete and partial response as compared to RT, whereas the rate of stable disease was found to be significantly higher after RT.[54] OS and PFS were similar in both the groups. However, the actuarial OS and PFS rates in the SRS-GK group were more strongly maintained over time compared to RT. The rates of clinical improvement were comparable in both the groups. However, radiation-related adverse events were more commonly seen in patients who received GKRS. This may be ascribed to the bias in reporting adverse events and more frequent use of advanced imaging techniques to detect these in the patients undergoing GKRS.

Ependymoma

Ependymomas are a type of glial tumors which are most commonly seen in the fourth ventricle and spinal canal. Supratentorial ependymomas are common in children. The standard treatment for grade 2 and grade 3 ependymomas is surgical excision followed by EBRT.[59] Recurrences are common after the standard treatment, especially in grade 3 lesions, and are difficult to manage.[60] SRS can be a suitable option for focal recurrent ependymomas as demonstrated by many studies published in the literature.[61]

The International Gamma Knife Research Foundation reported the results of SRS in 89 patients with 113 intracranial ependymomas who underwent SRSs from seven centers across the world.[62] Forty-two patients had 51 grade 2 ependymomas, whereas 48 patients had 61 grade 3 tumors. All patients had received surgical therapy and RT before developing recurrence. The median tumor volume was 2.2 cc (range 0.03–36.8), and the radiation dose prescribed varied from 9 to 24 Gy (median 15 Gy). The OS in these patients after SRS was 86%, 50%, 44%, and 34% at 1 year, 3 years, 5 years, and 10 years, respectively. The PFS in these patients after SRS was 71%, 56%, 48%, and 40% at 1 year, 3 years, 5 years, and 10 years, respectively. OS was more in patients with a small tumor volume to be irradiated, whereas PFS was significantly better in adult patients, females, and small tumors. Radiation-induced adverse complications were seen in seven patients (8%). Another study found homogeneous contrast enhancement to be a prognostic factor.[63],[64]

Oligodendroglioma

Oligodendrogliomas are the third most common glial tumors and can be WHO grade 2 or grade 3. The presence of 1p19q is classical of an oligodendroglioma.[65] Treatment of patients with oligodendrogliomas involves maximal safe surgical excision and radiotherapy. Kano et al.[66] reported the results of SRS in 30 patients with oligodendrogliomas. Twelve patients had grade 2 oligodendrogliomas, whereas 18 patients had grade 3 oligodendrogliomas. Tumor excision was performed in 24 patients, whereas six patients had undergone only biopsy. Twenty-five patients had progression on imaging before administration of SRS, and 22 of these patients had received prior EBRT. The median tumor volume was 15.4 cc (range 0.07–48.7), and the radiation dose prescribed varied from 11 to 20 Gy (median 14.5 Gy). The OS in patients with grade 2 lesions after SRS was 90.9% and 68.2% at 5 years and 10 years, respectively, whereas for patients with grade 3 lesions, it was 52.1% and 26.1% at 5 years and 10 years, respectively. PFS was more in patients with a small tumor volume to be irradiated and lower grade tumors. Radiation-induced adverse complications were seen in two patients. The authors concluded that SRS is a safe option for patients with residual or recurrent oligodendroglioma.

Sarkar et al.[67] reported the OS after SRS for oligodendrogliomas and oligoastrocytomas to be 78, 61, and 44% at 1, 2, and 4 years, respectively. They concluded that SRS may provide some survival benefit to patients with oligodendrogliomas and oligoastrocytomas after recurrence.

Our Data

We treated 13 GBM patients with GKRS in place of external radiotherapy within 4 weeks of surgical excision along with lifelong temozolomide. These patients were compared with 24 patients who received EBRT along with six cycles of temozolamide. Patients were followed up every 3 months with CEMRI brain and PET-CT. At a mean follow-up of 13.7 months, the median overall survivals in GKT and EBRT groups were 11.07 and 13.03 months, respectively (HR = 0.59; P value = 0.19; 95% CI: 0.27–1.29). The median PFS for the GKRS group was 7.03 months (95% CI: 4.17–17.3) as compared to 11.07 months (95% CI: 5.33–14.03) for the EBRT group. There was no statistical difference in the PFS or OS between the GKRS and EBRT groups. This suggests that GKRS can be used in place of EBRT in GBM patients following surgery.

Conclusions

The role of SRS in gliomas is evolving. Recurrent gliomas can be a good indication for SRS. The addition of bevacizumab may decrease the risk of radiation-induced complications associated with SRS.

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Conflicts of interest

There are no conflicts of interest.

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