SCOPING REVIEW

Judicious and evidence-based use of radiosurgery - recommendations for low-middle income countries

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Abstract

Surgical removal remains the primary treatment for most brain tumours. However, radiosurgery presents an effective, less invasive alternative or additional treatment for certain types. Our goal was to explore radiosurgery's roles in treating various brain tumours, focussing on its application in low- and middle-income countries (LMICs). We reviewed all relevant systematic reviews, meta-analyses, and guidelines to determine the most effective radiosurgical approaches. Additionally, we consulted a panel of experts with over ten years of experience in LMICs, such as Pakistan. For brain tumours, stereotactic radiosurgery should generally follow a confirmed histopathological diagnosis. Exceptions include tumours identified through Magnetic Resonance Imaging (MRI), like Vestibular Schwannoma (VS), pre-diagnosed Neurofibromatosis type 2 (NF2), multiple typical meningiomas, and metastases with a known histology from another site. While radiosurgery is gaining traction as a primary and adjunct treatment in some LMICs, the lack of regional guidelines, trained personnel, and collaboration among specialists hinders its wider adoption. Addressing these gaps is crucial for expanding radiosurgical care in these regions.

Keywords: Meningeal neoplasms, neurofibromatosis, neuroma, acoustic, meningioma,

Radiosurgery, brain neoplasms, magnetic resonance imaging, pituitary tumour, glioma, vestibular schwannoma.

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Introduction

Despite the progress in neuroimaging, advanced radiosurgery facilities, and microsurgical techniques in recent decades, managing brain tumours remains a complex challenge. A multi-disciplinary, patient-centric approach is crucial. This approach involves collaboration between expert neurosurgeons, radiation and medical oncologists to improve outcomes such as local tumour control, progression-free and overall survival, minimal post-treatment complications, and enhanced quality of life. While surgical excision has been the standard for most primary brain tumours, stereotactic radiosurgery (SRS) using Gamma Knife (GK), CyberKnife (CK), or Linear Accelerator (LINAC) is increasingly favoured for specific tumours like pituitary adenomas (PA), vestibular schwannomas (VS), and gliomas (GM). Leksell's first SRS for VS in 1969 marked the beginning of evolving protocols for radiosurgery, now a preferred treatment for various brain tumours.[1]

SRS offers targetted cell death with submillimeter accuracy, reducing the impact on healthy brain tissue compared to conventional radiotherapy.[2] For PA, especially in cases of residual or recurrent tumours, or when surgical intervention is risky due to location or patient co-morbidities, SRS can be a primary treatment option.[3] Different radiosurgery types are tailored to specific tumour characteristics. However, potential complications like neurotoxicity, hearing loss, hypopituitarism, and cranial nerve deficits vary based on the tumour's type and location.[4,5] To mitigate these risks, recent studies have focussed on optimising fractionation, dosages, and target volumes for common brain tumours. The goal is to maximise efficacy while minimising post-SRS toxicity.[6] Continuous neuroimaging, vigilant monitoring, and long-term follow-up are vital for significant outcomes. International guidelines aim to standardise processes and minimise errors, ensuring more consistent and effective results.

In the Pakistan Brain Tumour Epidemiology Study (PBTES), among 2750 diagnosed brain tumour cases, the proportions of meningiomas, schwannomas, pituitary adenomas, and gliomas were 15.6%, 5.4%, 10%, and 28.4%, respectively. [7–10] Khalid MU et al. observed that out of 2750 cases, a significant percentage of 41.4% (n=1140)

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lost to follow-up due to various reasons.[11] Moreover, a very small percentage of these cases went for adjuvant or primary radiation therapy.[7–10] Due to resource-limited settings, there is an all-encompassing dearth of trained staff, equipment, and capital, which greatly impacts the quality of care. Considering a different set of working dynamics and unique challenges concerning LMIC, the lack of consensus guidelines potentiates the gravity of the situation. We conducted a scoping review to summarise radiosurgery recommendations from systematic reviews, meta-analyses, and guidelines as a guide for practicable implementation in LMICs.

Methods

A systematic search strategy comprising of a combination of search terms, ((guidelines)) AND (radiosurgery)) [Mesh] OR (robotic radiosurgery)) [Mesh] OR (stereotactic radiosurgery)) [Mesh] OR (gammaknife)) [Mesh] OR (cyberknife)) [Mesh] OR (conventional radiosurgery)) [Mesh] OR (fractionated radiosurgery))] [Mesh] AND [(brain tumours)) [Mesh] OR (brain masses)) [Mesh] OR (central nervous system tumours)) OR (CNS tumours) OR (CNS malignancies)) OR (intracranial tumours)) [Mesh] OR (brain malignancies)) [Mesh] OR (pituitary tumour)) [Mesh] OR (pituitary adenoma)) [Mesh] OR (sellar tumour)) [Mesh] OR (parasellar tumour)) [Mesh] OR (acoustic neuroma)) [Mesh] OR (vestibular schwannoma)) [Mesh] OR (cerebellopontine angle lesion)) [Mesh] OR (cerebellopontine angle tumour)) [Mesh] OR (glioma)) [Mesh] OR (oligodendroglioma)) [Mesh] OR (astrocytoma)) [Mesh] OR (medulloblastoma)) [Mesh] OR (posterior fossa tumour)) [Mesh] OR (glioblastoma)) [Mesh] OR (brain mets)) [Mesh] OR (brain metastasis)) [Mesh]OR (secondary brain tumours))] AND [(LMIC OR low income country OR middle income country OR low to middle income country OR developing country)), and Boolean modifiers was applied on the PubMed (MEDLINE) database (Figure 1). Search was limited to studies published in English or with available English translations and selected guidelines, systematic reviews, and meta-analyses with specified recommendations for radiosurgery in brain tumour management. Single center studies, case series, case reports, opinion papers, and conference abstracts were excluded. In January 2023Two reviewers independently screened the extracted database papers published till before December 2022 by titles and abstracts for eligibility. Full-text articles were obtained for those that matched the pre-specified criteria. Data were extracted from studies and categorised according to radiosurgery technology and tumour subtypes. We further discussed this review with experts from different expertise and backgrounds with more than ten years of experience in treating mainly brain tumours and are regularly involved in neuro-oncology tumour board (NOTB) meetings in LMICs like Pakistan. Recommendations were summarised and tabulated.

Results

A thorough literature review was undertaken and 372 articles related to radiosurgery guidelines for various brain tumours were identified. Following a detailed title and abstract evaluation conducted independently by two reviewers, 53 articles were shortlisted. One manuscript was inaccessible, and another was excluded for not being in English. Consequently, 21 articles were selected for this study after an in-depth full-text review (Figure 1). This review encompassed guidelines, systematic reviews, and meta-analyses, providing comprehensive recommendations for radiosurgery in different types of brain tumours. We meticulously analyzed 21 manuscripts, extracting and summarising the recommendations for skull base and meningiomas, pituitary adenomas, vestibular schwannomas, and gliomas shown in Tables 1 to 4. Furthermore, an implementation algorithm and summary of recommendations were developed, drawing on expert opinions from clinical specialists and the synthesized evidence (Table 5, Figure 2).

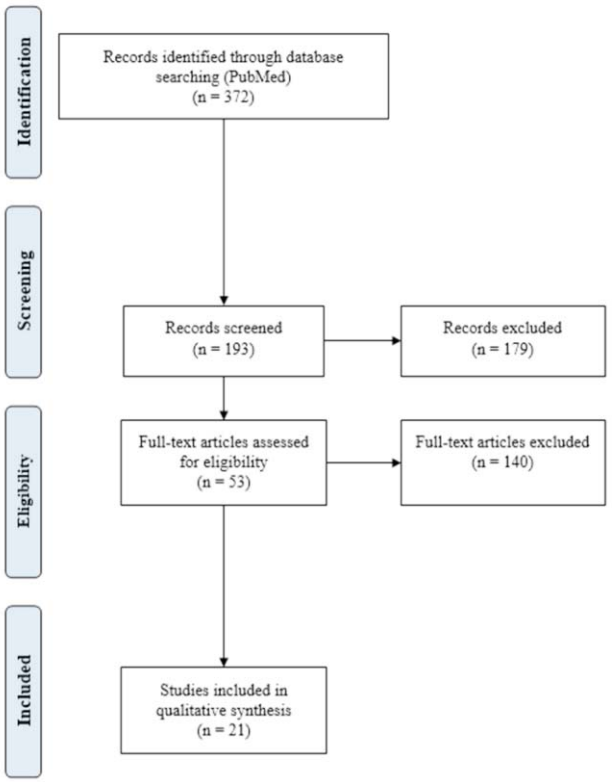

Figure-1: Workflow of Scoping Review.

Table 1: Skull Base Tumours and Meningiomas.

Author	Type of radiosurgery/ tumour	Recommendations
Minniti et al [6]	GK, LINAC, CK/skull base meningiomas	SRS is convenient, safe and has tumour control at 5 and 10 years comparable to fractionated radiotherapy (FRT). Both SRS and FSRT are effective for benign skull base meningiomas and the choice of stereotactic technique depends on tumour characteristics. SRS is reserved for tumours < 3 cm in size and > 3-5 mm away from the optic chiasm, whereas FSRT is employed for tumours not amenable to SRS. Reported toxicity of SRS is low when doses of 13-15 Gy are used. Although the risk of a second tumour after SRS is of concern. The maximum dose for optic chiasm is 8 Gy. the difference between tumour margin and optic apparatus should be 2-3mm to avoid visual deterioration.
Combs et al [22]	SRS, FSRT, IMRT/skull base tumours	For invasive frame-based SRS; 1–2 mm margin expansion is generally used and in patients receiving frameless SRS up to 3 mm. If IGRT techniques are not available, larger margins up to 5 mm should be employed. Single-fraction SRS, fractionated SRS (2–5 fractions) or conventionally fractionated SRT are commonly used, depending on tumour types, target volumes and involvement of critical structures. SRS doses of about 13–22 Gy in single fraction and 21–25 Gy in 3–5 fractions are typically utilized according to the different histology. Doses up to 74–76 Gy in 1.8–2.0 Gy fractions can be used for chordomas; lower doses for chondrosarcomas.
Combs et al [23]	Type of radiosurgery not specified/skull base meningioma	Independent of technique, radiosurgery approaches are comparable with respect to clinical outcome and toxicity. Radiosurgery is a safe alternative for skull-base meningioma, independent of location, however, limitations must be kept in mind with proximity to sensitive organs at risk as well as with increasing volumes. Thus, smaller volumes are preferred. Patients with asymptomatic lesion and typical imaging can be offered wait and scan policy with periodic neurological and radiological assessment. When the tumour reaches optimal size for irradiation, it can be ideal for radiosurgery/radiotherapy.If the tumour size reaches a resectable size, and patient prefers immediate treatment, surgery remains the best choice. However, in the lesions where treatment option via surgery or radiosurgery remains equivocal o each other, consider patient's preference. With the tumour invading critical areas. for example, cavernous sinus, radiosurgery remains a better choice.
Marchetti et al [24]	SRS and HSRT/meningioma (WHO grade 1)	SRS can be a primary treatment modality for an asymptomatic or mildly symptomatic meningioma and should be considered when a complete surgical excision is not possible. After surgery, when a residual tumour is not evident or is minimal, a wait-and-scan approach is reasonable with a regular radiological follow-up. At the time of recurrence or progression, SRS should be considered as a treatment modality. Recurrence/progression rate can be lower when SRS is delivered as the primary treatment as compared to adjuvant treatment.Single-fraction SRS with 12 to 15 Gy is sufficient to manage benign intracranial meningioma. A prescription dose of at least 14 Gy would be advisable. HSRT may be considered for the treatment of large or/and critically located meningioma. Optimal practice has yet to be defined; however, 25 Gy in 5 fractions is a common approach. SRS has a low risk of neurological deterioration and can lead to clinical improvement without tumour shrinkage.
Lee et al [25]	SRS (GK and LINAC)/cavernous sinus (CS) meningioma	SRS/SRT is recommended as a primary treatment option for an asymptomatic, or mildly symptomatic CS meningioma. The recurrence rate is not appreciably different between primary or adjuvant therapy for a CS meningioma and resection should be considered for the treatment of larger and symptomatic CS meningioma in patients for open surgery.CS meningioma treated with SRS/SRT have lower risk of complications.When no residual tumour is observed, or only a small tumour lining on the dura of the CS exists postoperatively, serial neuroimaging studies can be done. SRS/SRT should be considered for recurrence or

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		progression.For rapidly and substantially recurring tumours, after prior treatment, a subtotal surgical resection or biopsy may be considered. More aggressive features of the tumour should be ruled out. These tumours tend to progression and postoperative SRS/SRT with a higher dose is recommended.Technique for SRS or SRT delivery depends on tumour histology, volume and proximity to adjacent critical structures. SRS using single session marginal doses of 11 to 16 Gy offers a local tumour control rate of 90% or higher at 5 yr post-SRS.
Corniola et al [26]	SRS/cavernous sinus meningioma	SRS, SRT, or f-SRT, have similar rates of tumour control and improvement of pre-existing CN deficits as open surgery.The tumour control rate after SRS/RT using a median margin dose to the lesion of 13–15 Gy is up to 95%. SRS or SRT (either single-dose or fractionated) should be considered in the following cases, insofar as the distance to the ON is superior to 3 mm:- Asymptomatic, > 40 years old patients with a purely intracavernous CSMs <2.5 cm showing growth on serial imaging after initial conservative treatment- Asymptomatic patients with partly extracavernous CSMs showing growth on serial imaging after initial conservative treatment- Symptomatic patients with CSMs <2.5 cm, given that the symptoms are not related to optic nerve (ON) compression- Symptomatic patients with partly extracavernous CSMs in whom surgery is contraindicated.Fractionated RT should be considered in cases that require treatment if the distance to the ON is < 3 mm and ipsilateral visual function is good.

Table-2: Pituitary Adenomas.

Author	Type of radiosurgery/ tumour	Recommendations
Sheehan et al [27]	SRS/Non- Functional Pituitary Adenoma (NFPA)	Radiation therapy, including radiosurgery, is recommended to treat residual or recurrent NFPAs for lowering the risk of tumour progression. Radiosurgery with single-session doses of 12 Gy or radiation therapy with fractionated doses of 45 to 54 Gy is recommended for a greater local tumour control rate of 90% at 5 years after treatment.
Heringer et al [5]	SRS/Pituitary Adenoma	SRS is recommended as a treatment for residual or relapsed pituitary tumours due to fewer side effects. The severity of a relapsed tumour in this meta-analysis revealed that at a mean marginal dose of 19.6 Gy, SRS was associated with a better tumour control rate (95%) and hormonal control rate (67%). However, hypopituitarism and visual deterioration were the two main post-SRS complications encountered.
Mathieu et al [13]	SRS/Secretory Pituitary Adenoma	Dose of SRS should safely protect surrounding structures (optic pathways, brainstem); higher margin doses can be used.Withdrawal of antisecretory medications is preferred, typically for 4–12 weeks prior to radiosurgery, if safely possible considering endocrinologic status of patient. Timing of temporary cessation of medications and their reinstatement should be based on pharmacology of medication and patient's ability to tolerate brief withdrawal of medical management. SRS can be used as a primary therapy for medically unfit for surgical resection and as an alternative to surgical resection for medically refractory prolactinomas.
Gupta et al [28]	SRS/Pituitary adenoma	SRS is usually reserved for small adenomas (typically <2–3 cm) which are well defined and are located away from the optic chiasm (≥3 mm). Medical management should be withheld temporarily prior to SRS/RT in functioning/secretory adenomas. The recommended dose of SRS given in a single fraction is 12–14Gy for nonfunctioning adenomas and 16–20Gy for secretory tumours. Late toxicity of pituitary RT includes hypopituitarism, neurocognitive impairment, neuropsychological dysfunction, optic neuropathy, cerebrovascular accidents, and second malignant neoplasms. Hence, RT in pituitary adenoma should be offered only to patients with residual, recurrent, progressive, or high-risk tumours with careful assessment of the benefit-risk ratio by an experienced multidisciplinary neuro-oncology team.

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Lucas et al [29]	Type of radiosurgery not specified/Non-Functioning Pituitary Adenoma	Surgical resection is recommended as the primary treatment of symptomatic patients with NFPA. Limited class III evidence showed inconsistent benefits for observation alone, primary radiation-based treatment, or primary medical treatment (8 studies) for improving vision, headaches, hypopituitarism, or tumour volume for symptomatic NFPAs. There was insufficient evidence to make a recommendation regarding the primary treatment strategy for asymptomatic lesions.

Table 3: Vestibular Schwannomas.

Author	Type of radiosurgery/tumour	Recommendations
Kondziolka et al [16]	SRS mainly GK/ Vestibular Schwannoma (VS)	They suggested that in the absence of clinical symptoms of mass effect, newly diagnosed VS can be treated primarily with GKSRS, that in 98% of the cases do not require further treatment and as compared to surgery has similar or even better outcomes. Moreover, hearing is preserved in max 85% of such cases. However, wait and scan policy with no treatment is reserved for patients with medical co-morbidities and treating with SRS outweighed risk over benefit in the next 5 years. Matched cohort studies show that radiosurgery has either better or similar outcomes to resection, depending on the outcome measured.
Rotter et al [30]	SRS/Facial nerve schwannoma(FNS)	Unfavourable facial nerve function outcomes are associated with surgical treatment of intracranial FNS, whereas stable facial nerve function outcomes are associated with SRS. Therefore, SRS should be recommended to patients with FNS who require treatment, and surgery should be reserved for patients with another indication, such as decompression of the brainstem. Treatment-related morbidity, and complications are almost universally lower following radiosurgery.
Germano et al [31]	SRS/Vestibular schwannoma	For intracanalicular vestibular schwannomas and small tumours (<2 cm) without tinnitus can there is no negative impact on tumour growth or hearing preservation compared to non-radiosurgical treatment. There is no difference in radiographic control using different doses, it is recommended that for single fraction SRS doses, <13 Gy be used to facilitate hearing preservation and minimize new onset or worsening of preexisting cranial nerve deficits. Follow-up imaging should be obtained at intervals after SRS based on clinical indications, a patient's personal circumstances, or institutional protocols. Long-term surveillance with serial magnetic resonance imaging to look for recurrence is advised. SRS can be safely and effectively employed for retreatment in case of the progression of tumour after SRS. There is minimal risk of malignant transformation of vestibular schwannomas after SRS. Radiosurgery is a treatment option for patients with neurofibromatosis type 2 who's VS are enlarging and/or causing hearing loss.
Carlson et al [32]	SRS/Vestibular schwannoma	Greatest risk to hearing occurs with surgery, but if the hearing ability is initially preserved, the results tend to be durable. The risk of hearing loss increases with time during conservative management. The two strongest prognostic factors for the development of non-serviceable hearing are tumour growth and poorer hearing at the beginning of observation.
Starnoni et al [17]	SRS/Vestibular schwannoma	A combined approach of STR followed by SRS was shown to have excellent clinical and functional outcomes while still achieving a tumour control rate comparable to that obtained with a total resection. Longer-term follow-up and larger patient cohorts are necessary to fully evaluate the rate of tumour control achieved with this approach. Our pooled preserved serviceable hearing rate of 59.9% after the combined STR/SRS approach used for large VSs

Discussion

Stereotactic radiosurgery is a newer technique preferred over conventional radiation, delivering a large dose of highly focused radiation to the target with sub-millimeter accuracy. This is achieved while sparing surrounding structures, thanks to stereotactic image guidance.[2]

Table 4: Gliomas, including GBM.

Author	Type of radiosurgery/tumour	Recommendations
Tsao et al.[33]	SRS or FSRT (boost after surgery and external beam radiotherapy)/High Grade Glioma	Use of radiosurgery boost followed by external beam radiotherapy and BCNU does not confer benefit in terms of overall survival, local brain control, or quality of life as compared with external beam radiotherapy and BCNU. The use of radiosurgery boost is associated with increased toxicity. For malignant gliomas, there is evidence regarding the benefits/harms of using radiosurgery at the time of progression or recurrence. There is insufficient evidence regarding the benefits/harms in the use of stereotactic fractionated radiation therapy for patients with newly diagnosed or progressive/recurrent malignant glioma.
Ziu et al[34]	CRT, FSRS, SRS/ Progressive and recurrent GBM	Given the complex clinical nature of patients with progressive GBM, multidisciplinary assessment is vital to effective patient management. This paper has concluded class III evidence that re-irradiation can achieve tumour control, and improve PFS, neurological and functional status in **selected group of patients.** Prospective trials are required to systematically determine the advantage of re-irradiation
Ziu et al[19]	SRS/Newly diagnosed GBM	RT is important for treatment of GBM with the standard dose of 60 Gy fractionated in 2 Gy per day for 5 days a week. SRS boost to external beam RT has not been shown to be beneficial and is not recommended in patients undergoing routine management of newly diagnosed malignant glioma.
Germano et al [18]	SRS/Progressive GBM	Re irradiation can solely be used in elderly patients whereas, repeat cytoreductive surgery adds maximum survival benefit in patients with progressive glioblastoma.
Scoccianti et al [35]	SRS/Recurrent GBM	Retreatment of recurrent glioma must be tailored to each single patient in order to have an acceptable risk of severe toxicity (< 3.5%). Prospective trials are required to further clarify the role of SRS or fractionated radiation in recurrent gliomas. Due to scarcity of literature, two local modalities i.e. redo surgery and re-radiation comparison is not available limiting the use of SRS in recurrent disease.

Radiosurgery is traditionally delivered in a single session but can be delivered in three or five sessions or fractions, to mitigate radiation-induced toxicity to the normal vital structures. There are several types of radiosurgeries, including the GK, LINAC-based, CK, or proton beam units.

Compared to traditional radiotherapy, stereotactic procedures offer a more localised radiation dose, potentially reducing the risk of long-term radiation-induced morbidity. SRS lowers the dangers associated with open surgical procedures, maintains cranial nerve function in most patients, and halts the progression of tumours. Larger tumours may be effectively managed with adjuvant gamma knife radiosurgery for long-term tumour growth control.[12] To reduce the long-term late effects of radiation, proton irradiation could be considered for younger individuals or patients with large and complex-shaped tumours, such as extensive meningiomas. However, proton beam therapy is not widely available globally.

Skull base tumours are operated using advanced techniques derived from a comprehensive understanding of the challenging skull base anatomy. Yet, total resection of these tumours can often be difficult, with significant risks related to critical neurovascular structures, especially in areas such as the cavernous sinus, the petrous apex, and the jugular bulb.[12] For skull base tumours such as meningioma, radiation therapy is highly effective, with long-term statistics showing that after 10 years, over 80% of patients have tumour control with a manageable rate of sequelae.[6]

Our review shows that pituitary adenomas can be safely and maximally treated with SRS with results comparable to surgery. They can also be a primary treatment option in many tumours, provided the extension of the tumour does not invade critical surrounding areas. SRS has also been an established treatment option for residual or recurrent pituitary tumours with a significant tumour control rate, better clinical and hormonal outcomes, and progression-free survival.[5] Additionally, dose fractionation enables the safe delivery of radiation doses near critical areas without harming normal tissue. The usual recommended dose to the optic nerve varies from 8 Gy to 10 Gy, achievable safely through fractionation.[13] However, treatment with SRS requires planning with a CT scan, MRI brain with contrast, complete hormonal profile, and assessment of visual parameters.[14] Due to this extensive set of investigations, SRS remains a secondary treatment option in LMICs, where neuroimaging and basic medical investigations are scarce.

Table 5: Summary of radiosurgery recommendations for LMICs.

• Management of CNS tumours requires a multidisciplinary approach therefore decision for radiation therapy should be made by or in consultation with NOTB.
• Histopathological diagnosis is essential for decision making about specific treatment plans in cancer care therefore it is mandatory to take every measure to establish histological diagnosis before embarking on any treatment including radiation therapy. Upfront radiation therapy has no role in brain tumours except for a few cases. These include:

1. small vestibular schwannoma (<3 cm)
2. Typical shape of VS
3. pre-diagnosed NF2
4. multiple meningiomas
5. metastasis with proven histology from some other site.

• Peer review of radiation treatment plans by site-specific specialists is an integral and essential component of quality assurance and should be a part of radiation therapy services to improve patient care.

Type of tumour	Recommendations
Meningioma	• Standard of care is surgery as first line of treatment regardless of the grade, with mandatory histopathology. • SRS for skull base meningioma's can be used for recurrence or progression after proven histopathology if: o The tumour is invading critical areas such as cavernous sinus and complete surgical resection is not possible. o Tumour size is <3 cm. o The difference between tumour margin and optic apparatus, brain stem or other sensitive areas is between 2-3 mm to avoid radiation toxicity. • Single session marginal doses of 12-20 Gy depending on size & grade. • Fractionated radiotherapy should be the treatment option when the distance between tumour and optic apparatus is < 3mm and visual function is good.
Pituitary adenoma	• Surgery should be the first line of treatment for every symptomatic pituitary adenoma except prolactinomas (first line medical management). • SRS is second-line therapy for residual after surgery, unresectable, recurrence after surgery, or refractory to medical management. • The common dose of single fraction SRS is 12-14 Gy for non-functional adenomas and 16-25 Gy for functional adenomas. • Fractionated SRS dose is 25-30 Gy in 5 fractions. • Fractionated conventional radiation therapy is indicated if tumour >3 cm or <3–5 mm from chiasm due to risk of visual deficits.
Vestibular schwannoma	• SRS alone is appropriate for patients in whom the tumour is <3 cm in size. • Single fraction SRS dose of <13 Gy can help preserve hearing due to minimal toxicity. • For residual and recurrent VS, along with surgical resection, SRS single fraction or fractionated may be the safe alternative to surgery.
Glioma & GBM	• SRS is not recommended primarily for newly diagnosed malignant glioma. • Recommendations of SRS for gliomas: o First line of treatment: never o Adjuvant: no o Recurrence and <3cm in size: yes o Recurrence and >3cm in size: yes, but only after surgical resection of recurrence. o SRS is not recommended as first line of treatment or adjuvant therapy. • SRS can be considered at recurrence along with CCRT. • Peer review treatment planning, previous radiation treatment details and current disease volume are essential components required for re-irradiation decision making process. • Standard doses to be decided by subject expertise.

LMIC: Low-middle income countries, NOTB: Neuro-Oncology tumour board, VS: Vestibular schwannoma, NF2: Neurofibromatosis type 2, SRS: Stereotactic radiosurgery, Gy: Gray, 3DCRT: 3-dimensional conformal radiation therapy, IMRT: Intensity-modulated radiation therapy, VMAT: Volumetric modulated arc therapy, SRS: Stereotactic radiosurgery, SRT: Stereotactic radiotherapy, GBM: Glioblastoma multiforme, CCRT: Concurrent chemo radiation therapy.

In this scoping review, we observed that the treatment results of vestibular schwannomas with SRS are comparable to, if not better than, surgical resection for smaller lesions. In their retrospective study, Tatagiba et al. analyzed the effectiveness of SRS and microsurgical resection for sporadic VS across two specialized

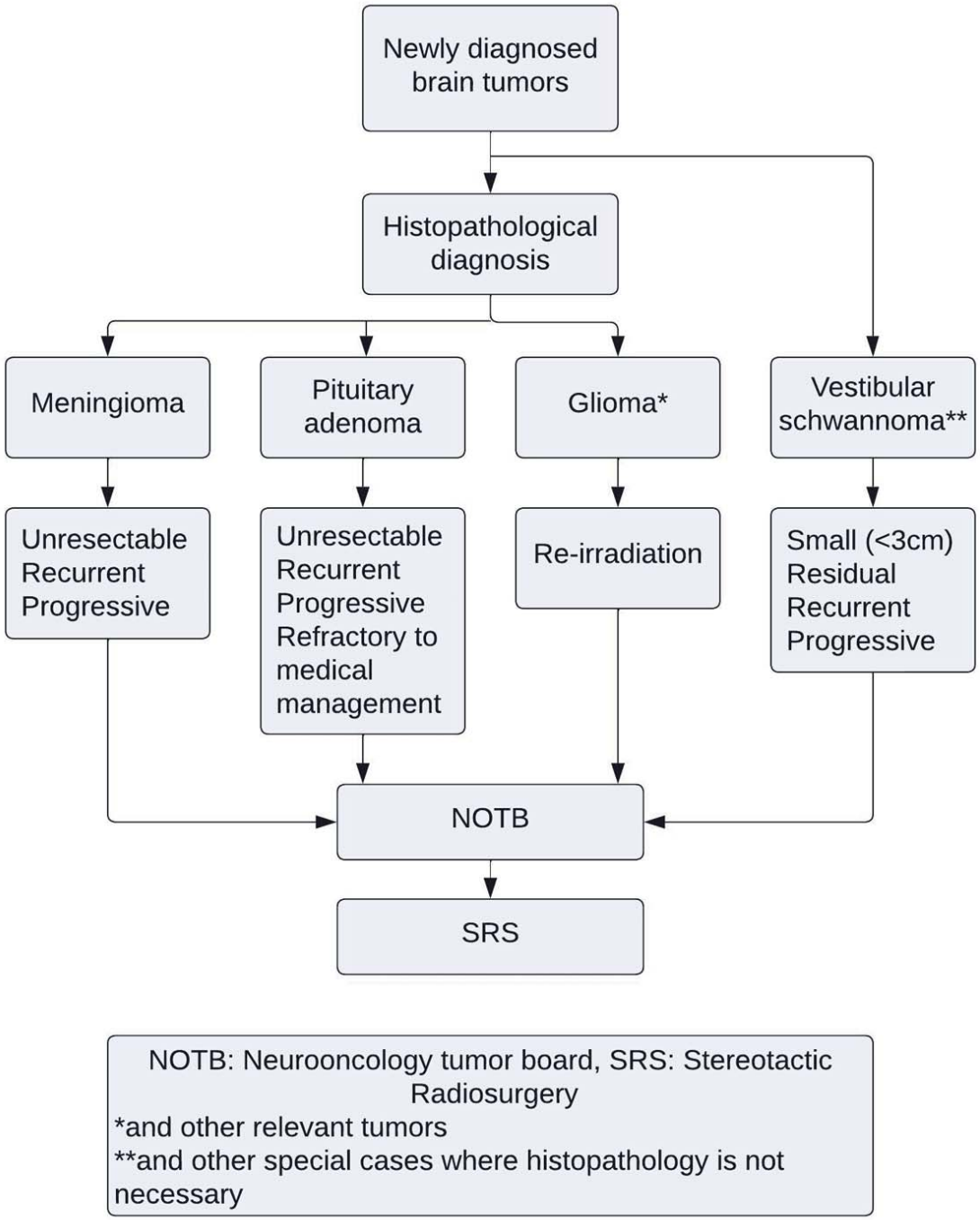

Figure-2: Management of brain tumours via radiosurgery algorithm.

neurosurgical centres, using data from 901 patients between 2005 and 2011.[15]

They employed the Koos classification, finding that microsurgery was more effective overall, particularly for larger tumours (Koos III and IV), with a lower recurrence rate, and better long-term control, compared to SRS. Both treatments were similarly effective for smaller tumours (Koos I and II). Not all lesions require immediate surgical decompression and can be considered for primary treatment with SRS for serviceable hearing preservation if treated early.[16] VS, similar to Pituitary adenoma, requires a complete set of investigations for SRS planning and

treatment. Moreover, the longer follow-up along with the neuroimaging and investigations is absolutely necessary to compare the tumour and hearing control and achieve a tumour control rate comparable to gross total surgical resection.[17] However, this is a major concern in resource-limited settings and should be stressed to diagnose post-SRS radionecrosis and follow a better course of management.

Since gliomas are infiltrative lesions, safe surgical resection has always been the primary treatment for them. However, for progressive and recurrent GBMs, re-irradiation adds greater benefit in elderly patients, whereas cytoreductive surgery offers the maximum survival benefit in progressive glioblastoma, preserving neurological status and improving quality of life.[18] However, there has been no significant benefit of SRS for newly diagnosed malignant gliomas.[19] Moreover, re-irradiation and higher radio-surgical doses are associated with greater risks of radiation-induced toxicity.[18] A complete set of recommendations has been summarized in Table 4.

Our review shows that radiosurgery is a highly safe and effective method capable of treating a wide range of brain tumours. Although the technique is becoming more widely available globally, limited access to CNS imaging and insufficient treatment equipment restricts the availability of radiosurgery as a therapeutic option in various parts of the world.[20] Epidemiologic data on CNS cancers in low-income countries are scant and significantly less thorough than in more developed nations, thus underestimating the need for radiosurgery. In PBTES, it was observed that among the treatment-receiving group, only 14 patients with VS, 26 patients with PA, and 27 cases of gliomas received radiation therapy.8–10 Moreover, PBTES identified meningioma as the second largest group of brain tumours found in Pakistan. Among those with the low-grade type (WHO grade 1), only a small percentage, 6.29% (n=27), received radiation therapy as part of their treatment.[7] This limited use may be attributed to the high financial burden, lack of proper knowledge, and increased waiting times at cost-effective centers.[11]

Moreover, it can be costly to construct ample radio-surgical centres, and properly trained staff is required to operate safely. Access to care is limited by socioeconomic and political dynamics.[20] There is a lack of procedures to implement novel medicines, and a failure to adhere to well-established international norms. The focus should be on developing and implementing adequate obligatory procedures to guarantee correct equipment use. LMICs and their healthcare facilities must adopt and deploy new technology in a manner suitable for their institutions. Adhering to international protocols, which often require the infrastructure and resources of a HIC, can lead to higher costs and inefficient use of limited resources.[21]

Conclusion

Radiosurgery has become a significant alternative to surgical intervention for various brain tumours, offering a noninvasive approach that circumvents the risks and expenses typically associated with traditional surgeries. This method is particularly valuable in LMICs due to its cost-effectiveness and reduced invasiveness. However, its application should be approached with caution and a full understanding of international standards rather than relying solely on anecdotal evidence. In most cases, a histopathological diagnosis is essential before employing radiosurgery to ensure accurate treatment planning, patient safety, and choosing the right adjuvant treatment based on histopathology. Despite its increasing use in some LMICs, there is a pressing need for structured training, patient-centric care, and education, coupled with a multidisciplinary team approach, to optimize the management of brain tumours. This comprehensive approach will enhance the effectiveness of radiosurgery and ensure it aligns with global best practices in oncological care.

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