JOURNAL OF NEUROSURGERY:
Case Lessons

J Neurosurg Case Lessons 9(15): CASE2530, 2025
DOI: 10.3171/CASE2530

Optimizing outcome in radiosurgery for spheno-orbital meningioma: the critical role of planning quality. Illustrative case

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BACKGROUND Spheno-orbital meningiomas (SOMs) pose significant challenges due to their proximity to critical structures, such as the optic nerve. This report underscores the pivotal role of meticulous planning in achieving favorable outcomes with Gamma Knife radiosurgery (GKRS).

OBSERVATIONS A 54-year-old woman with a left SOM encasing the optic nerve underwent GKRS after being deemed unsuitable for surgery. The radiosurgical plan was meticulously tailored to balance effective tumor control with optic nerve sparing. A prescribed dose of 10 Gy at the 50% isodose line ensured a maximum optic nerve dose of 9.6 Gy, remaining within safe limits. Metrics such as high target coverage (0.96) and conformity (Paddick index: 0.83) highlighted the precision of the approach. A 12-year follow-up demonstrated stable tumor volume and preserved visual function without adverse effects, confirming the long-term efficacy and safety of this strategy. This case underscores the critical importance of comprehensive dose planning, particularly for perioptic lesions, where the therapeutic margin is narrow.

LESSONS GKRS offers a minimally invasive alternative for SOMs ineligible for surgery, emphasizing the need for individualized treatment strategies. This case highlights how tailored radiosurgical planning can optimize outcomes, preserve function, and improve quality of life for patients with complex skull base tumors.

https://thejns.org/doi/abs/10.3171/CASE2530

KEYWORDS spheno-orbital meningioma; Gamma Knife radiosurgery; dose planning; optic nerve sparing

Spheno-orbital meningiomas (SOMs) are a rare subset of skull base meningiomas often associated with optic nerve involvement and visual impairment. While surgery is the primary treatment for SOMs with visual deficits, achieving complete tumor resection poses challenges, including preserving visual function, minimizing recurrence, and avoiding complications.

Stereotactic radiosurgery (SRS) has emerged as a crucial method for treating such complex pathologies by offering a noninvasive alternative to traditional surgery, especially in patients who are not candidates for more invasive surgical interventions. However, for tumors in close contact with the optic nerves, it is very difficult to both preserve vision and inhibit tumor progression while remaining within safe dose ranges, especially for single-session SRS. To achieve this, it is essential to perform radiosurgical planning with the utmost caution.

In this case report, we present a unique and successful outcome of a patient with an SOM that completely encased the left optic nerve. Our aim is to demonstrate how meticulous radiosurgical planning, especially using Gamma Knife radiosurgery (GKRS), can successfully manage complex SOMs by focusing on 2 main goals: protecting the optic nerve from radiation-induced injury and ensuring the long-term stability of the tumor.

Illustrative Case

A 54-year-old right-handed woman was evaluated at another center for headaches and, following a diagnosis of left SOM, was referred to our clinic for SRS. The patient's neurological examination, including normal visual acuity and visual field, was unremarkable (Fig. 1). Laboratory results were within normal limits. GKRS was chosen due to the patient's medical comorbidities, which precluded safe surgical intervention, and the tumor's location, which required precise treatment to avoid optic nerve damage.

Imaging

MRI revealed a homogeneously enhancing mass with a volume of 6.6 cm^3, originating from the left sphenoid wing, extending to the

ABBREVIATIONS ARE = adverse radiation effect; Dmax = maximum dose; GKRS = Gamma Knife radiosurgery; SOM = spheno-orbital meningioma; SRS = stereotactic radiosurgery.

INCLUDE WHEN CITING Published April 14, 2025; DOI: 10.3171/CASE2530.
SUBMITTED January 11, 2025. **ACCEPTED** February 14, 2025.
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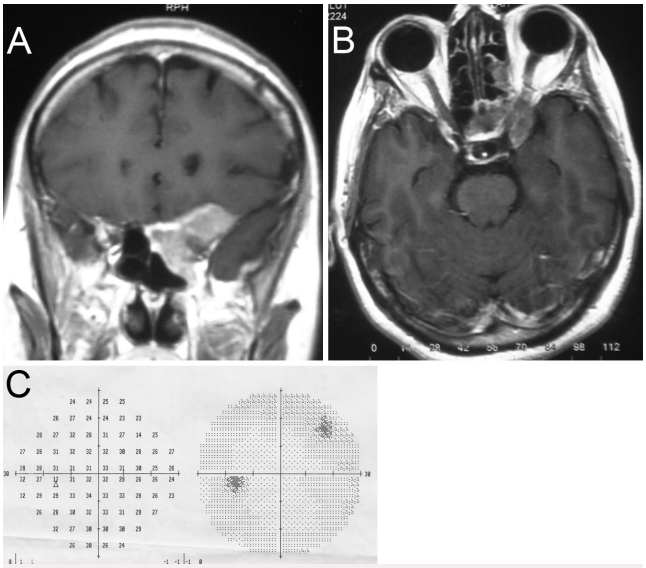


FIG. 1. Contrast-enhanced coronal (**A**) and axial (**B**) T1-weighted MR and visual field (**C**) images of SOM on treatment day.

orbital apex, and exhibiting a characteristic dural tail consistent with SOM. The tumor has completely encased the left optic nerve at the orbital apex. No sign of enhancement of the optic nerve is observed, indicating the preservation of its integrity. However, the encasement potentially compromises the nerve for future impairment, depending on tumor progression (Fig. 1).

Radiosurgery

SRS was performed using a Leksell G frame (Elekta), MRI-guided dose planning, and the 4C model Gamma Knife unit. The radiosurgical dose was meticulously tailored to protect the left optic nerve while effectively targeting the tumor. A 10-Gy dose was prescribed at the 50% isodose line, by carefully shaping the radiation field to target the tumor while minimizing exposure to the optic nerve. This precise approach was critical in maintaining tumor control while protecting the patient's visual function (Fig. 2).

The radiosurgical plan utilized multishot dose delivery with various collimator sizes to shape a toroidal isodose contour, effectively covering the tumor while sparing the optic nerve (Fig. 3). Fine adjustments to shot placement and weighting ensured precise dose distribution, achieving high target coverage (0.96), reasonable selectivity (0.88), and a Paddick conformity index of 0.83. The optic nerve dose was carefully limited, with a maximum dose (Dmax) of 9.6 Gy and only 0.03 cm^3 receiving ≥ 8 Gy, remaining within established safety thresholds. Treatment was delivered in 16 shots over 63 minutes, with a dose rate of 1.7 Gy/min.

Follow-Up

The patient's immediate postoperative course was uncomplicated, and her headaches gradually improved over the first 6 months following treatment. MRI at 24 months posttreatment confirmed stable tumor volume, indicating effective meningioma control. Remarkably, 12 years post-GKRS, the patient remains asymptomatic, with stable tumor size and no visual deficits or signs of progression (Fig. 4).

Informed Consent

The necessary informed consent was obtained in this study.

Discussion

Observations

Perioptic tumors, especially those involving the optic nerve, as in our case, remain a challenge for both open surgical and radiosurgical management due to the risk of visual sequelae. The main goal of treatment is to manage the tumor without increasing visual loss. These inherent risks associated with both approaches highlight the importance of tailored treatment strategies that prioritize minimizing neurological deficits.

SOMs are characterized by significant bone invasion with hyperostosis and potential invasion of the orbit, infratemporal fossa, and/or cavernous sinus, complicating complete surgical excision. Either direct compression of the optic nerve or external occlusion of the circulation to the optical apparatus is responsible for the tumor's effect on vision.[1]

SOMs are frequently treated surgically utilizing microsurgical or endoscopic procedures. However, vision impairment following surgery

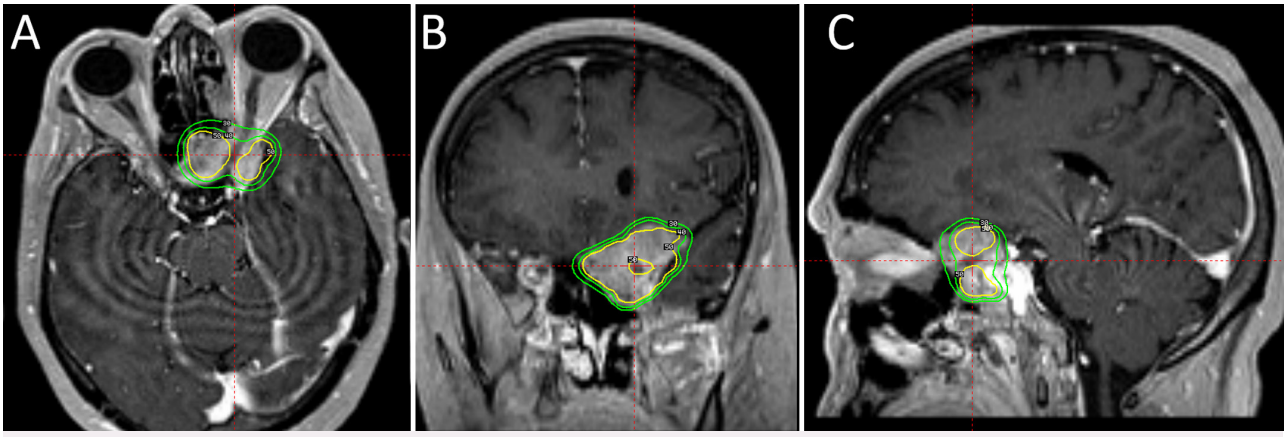


FIG. 2. Axial (**A**), coronal (**B**), and sagittal (**C**) radiosurgical planning images on treatment day. The *yellow contours* represent the 50% isodose lines, and the *green contours* represent the 40% and 30% isodose lines.

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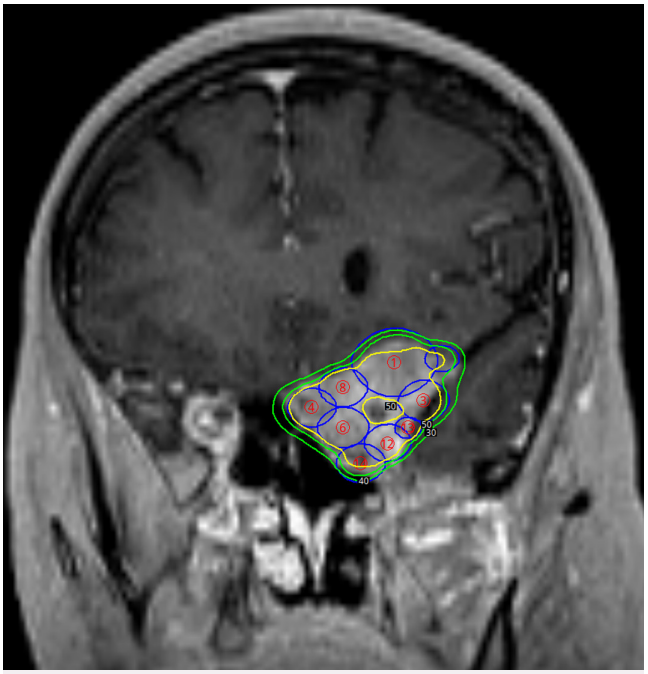


FIG. 3. Radiosurgical planning image demonstrating isodose distribution. The *yellow contours* represent the 50% isodose line, and the *green contours* represent the 40% and 30% isodose lines. Each shot is outlined in *blue*, and the number of the shot is shown in *red*.

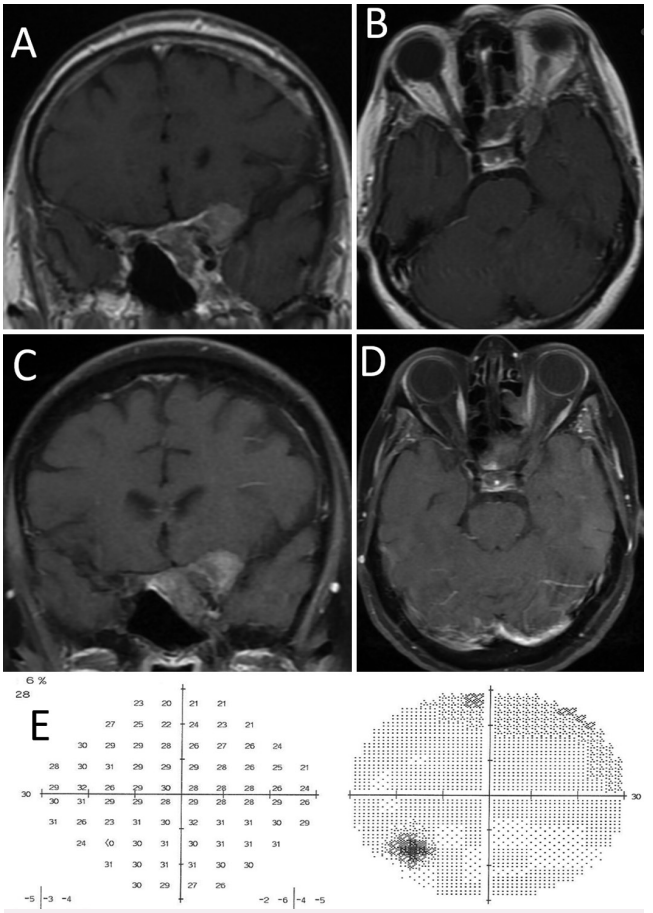


FIG. 4. Contrast-enhanced coronal (**A**) and axial (**B**) T1-weighted MR images obtained at the 24-month follow-up. Contrast-enhanced coronal (**C**) and axial (**D**) T1-weighted MR images obtained at the 12-year follow-up. The visual field (**E**) of the patient at the 12-year follow-up assessment.

has been reported in 2.6%–13.7% of patients.[2,3] In addition to the risk of visual loss progression, the surgical approach can also result in complications such as cranial nerve deficits. In a series of 47 SOMs treated surgically, the authors reported a postoperative oculomotor nerve palsy rate of 23% and a trigeminal nerve palsy rate of 40%.[4]

Alternative treatment strategies include radiation therapy or SRS.[5] SRS is frequently considered as a treatment option for residual skull base meningiomas.[6] Additionally, it is being utilized more frequently as a preventative measure for patients who are not appropriate candidates for surgery due to advanced age or major medical comorbidities.[7] However, the sensitivity of the anterior visual pathway to radiation is the primary challenge to safely delivering radiosurgery to lesions adjacent to the optic nerves. Following radiosurgery, the risk of developing optic neuropathy is dose-dependent, and the cumulative radiation dose to the optic nerves and chiasm should not exceed 8–12 Gy in a single session.[8,9] Hypofractionated SRS and fractionated SRS have shown lower rates of visual impairment, with some studies reporting no cases of radiation-induced optic neuropathy.[5,10,11] In our case, the Dmax to the optic nerve was limited to 9.6 Gy, and a volume of 0.03 cm^3 receiving ≥ 8 Gy was within this safety interval.

Temporary adverse radiation effects (AREs) are also observed in some patients. In a study of 175 patients with large perioptic meningiomas treated with single-session SRS, 12% experienced temporary AREs, although only 4% were symptomatic.[12] This highlights the need for ongoing monitoring and management of radiation-induced side effects.

Bunevicius et al. recently published the findings of a multicenter study in which they used GKRS to treat 438 patients with perioptic meningioma.[7] They reported that 10% of patients experienced visual function decline after SRS at a median interval of 52 months, with actuarial 5-year and 10-year post-SRS visual decline rates of 9% and 21%, respectively. The majority of perioptic meningiomas remained stable or regressed, and 33 patients (8%) experienced radiological progression at a median interval from SRS to the progression of 94 months. In another recently published multicenter study, Asuzu et al. reported clinical and radiological outcomes after GKRS for meningiomas in direct contact with the optic apparatus in 328 patients.[13] The rate of visual impairment was similarly reported as 9.6%. Tumor growth was seen in 8.7% of patients after SRS, which was also similar. These findings underscore the importance of carefully balancing the dose to achieve tumor control while minimizing the risk to the optic pathway.

In another study on visual outcomes in SOM surgery, Kim et al. reported a worsened postoperative vision rate of 10%, which is comparable to the results of the multicenter SRS studies reported above.[14] In contrast, our patient demonstrated no visual deficits or progression over a 12-year follow-up period, which underscores the success of our approach.

The decision to prescribe a dose of 10 Gy in our case was carefully made to prioritize patient safety, given the tumor's complete encasement of the optic nerve. While a dose of 12 Gy is standard for

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meningiomas, this would have posed an unacceptable risk of optic neuropathy. Limiting the optic nerve Dmax to 9.6 Gy and ensuring that only 0.03 cm^3 of the nerve received ≥ 8 Gy allowed us to remain within established safety thresholds for single-session radiosurgery. The tumor's long-term stability and the patient's preserved visual function over 12 years validate this tailored approach. Although fractionated SRS can now be considered an alternative, this option was not available with the Gamma Knife platform at the time of treatment (2012), and LINAC systems at that time lacked the precision to spare the optic nerve effectively. These considerations reinforce the value of individualized treatment planning in achieving optimal outcomes for perioptic meningiomas.

Lessons

SRS provides a minimally invasive option to resection, especially for patients with SOMs that are difficult to access, close to vital structures, and have major contraindications to surgery. The process involves creating a detailed map of the target area, determining the optimal radiation dose and delivery technique, and considering patient-specific factors such as anatomy. Proper planning helps maximize the therapeutic benefit and minimize the risk of side effects.

Our case highlights the unique technical importance of meticulous radiosurgical planning in managing a challenging neurosurgical task with long-term efficacy and safety. Additionally, it shows the potential for effective treatment of parasellar or perioptic meningiomas through optic nerve sparing.

Although our patient demonstrated stable tumor size and preserved visual function over 12 years, it is important to note that meningiomas can have the potential for delayed progression even after long-term stability. Continued follow-up with periodic imaging remains essential to promptly identify and manage any signs of tumor regrowth or other late effects of radiosurgery.

Acknowledgments

ChatGPT-4o was used for proofreading.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributuions

Conception and design: Peker, Samanci. Acquisition of data: Peker, Düzkalir, Askeroglu. Analysis and interpretation of data: Peker, Düzkalir, Samanci. Drafting the article: Samanci. Critically revising the article: Peker. Reviewed submitted version of manuscript: Peker, Düzkalir, Samanci. Approved the final version of the manuscript on behalf of all authors: Peker. Administrative/technical/material support: Düzkalir.

Supplemental Information

Previous Presentations

This paper was presented as an oral presentation at the European Association of Neurosurgical Societies (EANS) 2024 meeting, Sofia, Bulgaria, October 13–17, 2024.

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