

## Management of Meningioma invading Superior Sagittal Sinus: Surgery and Radiosurgery

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### Abstract

Parasagittal meningiomas that invade the superior sagittal sinus (SSS) pose a dual hazard: recurrence if tumour is left behind, and venous infarction if a functional sinus or bridging vein is compromised. The 2021 European Association of Neuro-Oncology guideline recommends observation for incidental, asymptomatic suspected meningiomas and surgery for growing or symptomatic tumours, while stereotactic radiosurgery (SRS) or fractionated radiotherapy may complement or substitute for surgery in selected settings. Contemporary series support invasion-graded decision-making radical resection with venous repair can achieve durable control in selected patients, but morbidity clusters around extensive invasion and loss of venous outflow. Radiosurgery offers high tumour control for small presumed WHO grade I lesions and for residual intra-sinus disease, with peri-tumoural oedema as the key toxicity signal. This review synthesizes key surgical and radio-surgical evidence and highlights practical decision anchors for treatment selection.

**Keywords:** Meningioma, Superior sagittal sinus, Surgery, Radiosurgery

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### Introduction

Tumours that extend into the superior sagittal sinus (SSS) challenge routine pursuit of gross total resection (GTR) because venous structures, not tumour margins, often define the limits of safety. Manipulating a patent sinus or its bridging veins can trigger venous congestion, infarction, haemorrhage, and malignant brain swelling, whereas conservative surgery risks leaving an intra-sinus remnant capable of regrowth.<sup>2-4</sup> The clinical question is therefore not simply “surgery versus radiosurgery” but how to sequence modalities based on (i) extent of sinus invasion, (ii) sinus patency and collateral drainage on venous imaging, (iii) tumour size/volume and mass effect, and (iv) the need for histology when higher-grade biology is suspected.<sup>1,3</sup> This article summarizes study-level evidence

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comparing these approaches.

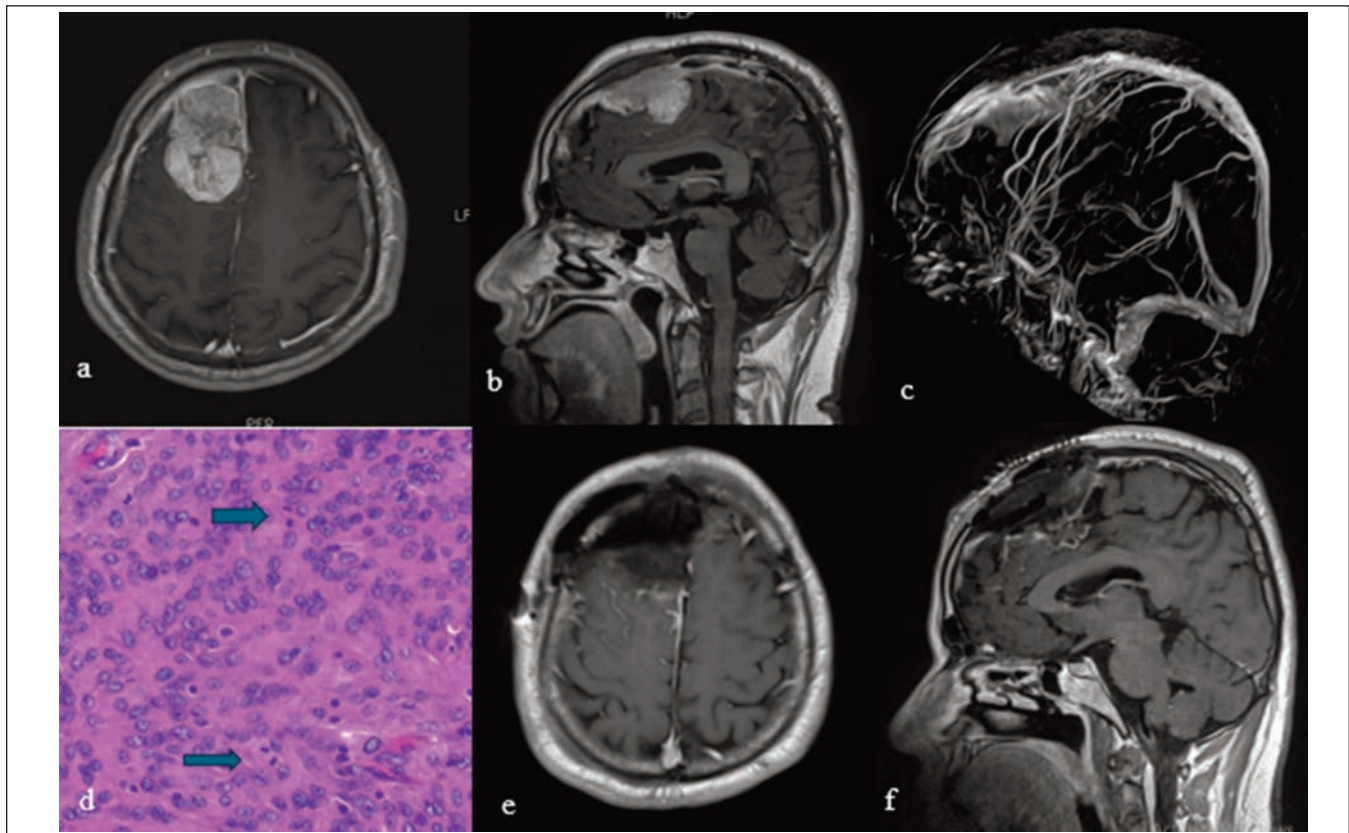
### Review of Literature

Current European Association of Neuro-Oncology guideline, emphasized that observation is the first option for incidental, asymptomatic suspected meningiomas, while surgery remains first-line for symptomatic or growing tumours. Radiosurgery or fractionated radiotherapy serves as either an alternative or adjunct in selected cases.<sup>1</sup> The guideline further supports combined concepts in which intended subtotal surgery is paired with radiosurgery or radiotherapy to reduce progression risk while limiting morbidity, an approach directly relevant to intra-sinus remnants where venous risk constrains option.<sup>1</sup>

Accurate assessment of venous anatomy is central to treatment planning. Bozzao et al. demonstrated that contrast-enhanced MR venography (CE-MRV) more reliably identifies sinus patency and collateral venous pathways compared to conventional techniques, significantly influencing surgical strategy.<sup>8</sup> Since tolerance to sinus manipulation depends on venous outflow and collateralization, preoperative venous imaging is essential when SSS invasion is suspected.<sup>8</sup>

Radical resection with sinus reconstruction can achieve excellent tumour control but carries significant risks. Sindou and Alvernia reported high rates of gross total resection (93%) with low recurrence (4%); however, mortality and permanent neurological deficits were primarily related to venous infarction and brain swelling, particularly when venous outflow was not restored.<sup>2</sup> Similarly, Nowak et al. highlighted that sinus ligation and resection in patent sinuses resulted in high rates of haemodynamic complications, whereas sinus repair reduced these risks. In contrast, leaving residual intra-sinus tumour avoided venous complications but was associated with higher recurrence rates.<sup>4</sup> Their cohort underscores a recurring theme: sacrifice of a patent sinus carries disproportionate venous risk, and non-radical strategies may be safer but require an explicit plan for surveillance or adjuvant treatment.<sup>4</sup>

Alternative surgical philosophies prioritize preservation of venous structures. DiMeco et al. demonstrated that selective sinus opening with preservation of bridging veins



**Figure:** A young gentleman presented with headache and seizures. Imaging revealed a right parasagittal extra-axial lesion. Figure a show an axial T1 post-contrast image demonstrating the lesion, while Figure b (sagittal T1 post-contrast) shows involvement of the superior sagittal sinus. In figure c, MR venography demonstrates that the superior sagittal sinus cannot be separately visualized in the region of the tumour, confirming sinus invasion. Figure d shows histopathology confirming the diagnosis of angiomatous meningioma. Figure e shows the postoperative axial T1 post-contrast image after excision of the large lesion. Figure f demonstrates a small residual enhancing area in the posterior part of the resection cavity. This residual lesion was treated with stereotactic radiosurgery, and on follow-up till 7 years, there has been no evidence of progression.

can achieve acceptable resection rates, Figure gement alone.<sup>3</sup> In this study, Simpson grade I–II removal was achieved in 100/108; 30 totally occluding tumours underwent complete resection of the encased sinus segment. Serious complications included brain swelling and postoperative haematoma.<sup>3</sup>

Sughrue et al. further showed that, in WHO grade I tumours, subtotal resection with residual tumour within the SSS may remain stable over time, with no significant difference in tumour control compared to gross total resection.<sup>9</sup> In these 135 resections of large, symptomatic, or growing parasagittal/falcine meningiomas (patients considered poor radiosurgery candidates), the SSS was invaded in 61 cases; complete occlusion was uncommon.<sup>9</sup> For WHO grade I tumours, they found no difference in tumours control between subtotal resection with observation and gross total resection, largely because no tumours remnant within the SSS demonstrated interval growth on serial imaging; across the series, 19% experienced at least one complication.<sup>9</sup> These findings support a more conservative approach in selected patients,

particularly when venous risk is high.

Caroli et al. described 328 surgically treated meningiomas infiltrating the SSS and reported segment-based strategies (including descriptions of more aggressive treatment for some anterior sinus lesions), reflecting the anatomical variability of collateral venous pathways and perceived venous risk along the sinus.<sup>10</sup> In parallel, Giordan et al. synthesized the surgical literature in a systematic review and highlighted heterogeneity in strategies and outcome reporting across series, reinforcing anatomy-driven individualization rather than a uniform mandate for radical sinus surgery.<sup>11</sup>

Radiosurgery has emerged as an effective modality for both primary and adjuvant treatment. Kondziolka et al. proposed an early multimodality paradigm that remains clinically recognizable: radiosurgery alone for smaller parasagittal meningiomas (<3 cm) with patent sinuses, resection for larger tumors or those causing progressive neurological deficit, and planned second-stage radiosurgery for any residual tumour nodule or neoplastic

dural remnant.<sup>12</sup> This staged framing presaged current practice in which the intrasinus component is often the “residual at risk” and can be targeted without forcing venous sacrifice.<sup>12</sup>

Schmutzer et al. reported favourable outcomes in a large cohort of SSS-involving meningiomas treated with robotic radiosurgery, with a 5-year recurrence rate of 15.8% and no cases of acute sinus thrombosis or venous bleeding.<sup>5</sup> Conti et al. similarly demonstrated high tumour control rates (94%) with acceptable rates of radiation-induced oedema, which were primarily influenced by tumour volume and tumour–brain interface characteristics.<sup>6</sup>

Advances in imaging have further improved safety. Sahoo et al. demonstrated that MR venography-guided planning reduces radiation dose to the SSS and cortical veins, potentially minimizing complications such as venous congestion and oedema.<sup>7</sup>

Given the risks associated with aggressive sinus resection, a multimodal approach is increasingly favoured. Planned subtotal resection followed by radiosurgery allows for tumour debulking while preserving venous structures, with residual disease effectively controlled using focused radiation. This strategy is particularly useful for tumours involving a patent sinus or critical bridging veins, where radical resection may carry disproportionate risk. Systematic reviews highlight significant heterogeneity in surgical strategies, reinforcing that management should be individualized based on tumour characteristics and venous anatomy rather than adhering to a single uniform approach.<sup>11</sup>

## Conclusion

Available evidence supports anatomy-driven, multimodal management rather than a single universally superior modality. Radical resection with venous repair can achieve excellent control in selected patients, but venous infarction and brain swelling cluster when extensive invasion is treated without preserving or restoring venous outflow. When the sinus is patent or bridging veins are critical, maximal safe resection with intentional intra-sinus residual plus adjuvant radiosurgery provides a pragmatic balance between symptom relief, venous safety, and durable local control

## References

1. Goldbrunner R, Stavrinou P, Jenkinson MD, Sahm F, Mawrin C, Weber DC, et al. EANO guideline on the diagnosis and management of meningiomas. *Neuro Oncol.* 2021;23:1821-34.
2. Sindou MP, Alvernia JE. Results of attempted radical tumor removal and venous repair in 100 consecutive meningiomas involving the major dural sinuses. *J Neurosurg.* 2006;105:514-25.
3. DiMeco F, Li KW, Casali C, Ciceri E, Giombini S, Filippini G, et al. Meningiomas invading the superior sagittal sinus: surgical experience in 108 cases. *Neurosurg.* 2004;55:1263-72.
4. Nowak A, Dziedzic T, Czernicki T, Kunert P, Marchel A. Surgical treatment of parasagittal and falcine meningiomas invading the superior sagittal sinus. *Neurol Neurochir Pol.* 2014;48:174-80.
5. Schmutzer M, Skrap B, Thorsteinsdottir J, Fürweger C, Muacevic A, Schichor C. Meningioma involving the superior sagittal sinus: long-term outcome after robotic radiosurgery in primary and recurrent situation. *Front Oncol.* 2023;13:1206059.
6. Conti A, Pontoriero A, Siddi F, Iati G, Cardali S, Angileri FF, et al. Post-Treatment Edema after Meningioma Radiosurgery is a Predictable Complication. *Cureus.* 2016;8:e605.
7. Sahoo SK, Ahuja CK, Dhandapani S, Madan R, Tomar P, Kumar S, et al. MR Venography in Gamma Knife Radiosurgery for Parasagittal Meningiomas: A Technical Note with the Rationale of Venous Protection and a Review of Literature. *Asian J Neurosurg.* 2021;16:307-11.
8. Bozzao A, Finocchi V, Romano A, Ferrante M, Fasoli F, Trillò G, et al. Role of contrast-enhanced MR venography in the preoperative evaluation of parasagittal meningiomas. *Eur Radiol.* 2005;15:1790-6.
9. Sughrue ME, Rutkowski MJ, Shangari G, Parsa AT, Berger MS, McDermott MW. Results with judicious modern neurosurgical management of parasagittal and falcine meningiomas. *Clinical article. J Neurosurg.* 2011;114:731-7.
10. Caroli E, Orlando ER, Mastronardi L, Ferrante L. Meningiomas infiltrating the superior sagittal sinus: surgical considerations of 328 cases. *Neurosurg Rev.* 2006;29:236-41.
11. Giordan E, Sorenson TJ, Lanzino G. Optimal surgical strategy for meningiomas involving the superior sagittal sinus: a systematic review. *Neurosurg Rev.* 2020;43:525-35.
12. Kondziolka D, Flickinger JC, Perez B. Judicious resection and/or radiosurgery for parasagittal meningiomas: outcomes from a multicenter review. *Gamma Knife Meningioma Study Group. Neurosurgery.* 1998;43:405-13.