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Research Article

Radiotherapy For Skull Base Tumors

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Abstract

Skull base meningiomas present significant therapeutic challenges due to their deep location and proximity to critical neurovascular structures. Although surgical excision remains the primary treatment modality for accessible lesions, complete resection is often not feasible in skull base tumors, leading to higher rates of residual disease and recurrence. Radiotherapy (RT) has therefore emerged as a crucial component in both adjuvant and definitive management. Conventional fractionated external beam radiotherapy has demonstrated long-term tumor control rates exceeding 75–90% at 10 years following subtotal resection. Recent advances in radiation oncology—including stereotactic radiosurgery (SRS), fractionated stereotactic radiotherapy (FSRT), intensity-modulated radiotherapy (IMRT), and stereotactic body radiotherapy (SBRT)—enable highly conformal dose delivery with improved sparing of surrounding organs at risk. Published data indicate 5-year local control rates of 85–97% with stereotactic techniques and a low incidence of late toxicity. Treatment selection is guided by tumor size, proximity to critical structures such as the optic apparatus and brainstem, histological grade, and surgical accessibility. While SRS is best suited for small lesions, fractionated approaches are preferred for larger tumors or those adjacent to sensitive structures. Overall, radiotherapy—particularly with modern stereotactic techniques—offers effective, safe, and durable tumor control for skull base meningiomas, though long-term prospective studies are required to establish the optimal modality and fractionation strategies.

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KEYWORDS: Skull base meningioma; Radiotherapy; Stereotactic radiosurgery; Fractionated stereotactic radiotherapy

INTRODUCTION

Meningiomas located in the skull base region are difficult to access. Complex combined surgical approaches are more likely to achieve complete tumor removal, but often come at a high treatment-related cost. Local control after subtotal excision of benign meningiomas can be improved with conventional fractionated external beam radiotherapy, with a reported 5-year progression-free survival rate of up to 95%. New radiotherapy techniques, including stereotactic radiosurgery (SRS), fractionated stereotactic radiotherapy (FSRT), and intensity-modulated radiotherapy (IMRT), have been developed as more accurate radiation techniques with more precise tumor localization and, consequently, a reduction in the volume of healthy brain irradiated with high radiation doses. Results from SRS studies suggest a high tumor control rate of 85% to 97% at 5 years, and similar results have been achieved with the use of FSRT and IMRT, with a low incidence of long-term complications. Single-fraction stereotactic radiotherapy is typically administered to relatively small tumors, while fractionated radiotherapy is useful for larger skull base meningiomas (>3-3.5 cm) and/or those involving critical structures, such as the optic chiasm and brainstem. The high tumor control rate and low incidence of radiation-induced toxicity, if confirmed with longer follow-up, clearly suggest that stereotactic techniques represent an effective treatment for most skull base meningiomas.

Surgical excision is the treatment of choice for accessible intracranial meningiomas. After apparently complete resection of benign meningiomas, reported control rates are approximately 95% at 5 years, 90% at 10 years, and 70% at 15 years. However, meningiomas located in the skull base region are often difficult to access, and only subtotal or partial resection is possible, with a high tendency for tumor regrowth.

Local control after incomplete excision of a benign meningioma can be improved with conventional fractionated external beam radiation therapy (RT), with a reported 10-year progression-free survival rate of 75–90%.

Advances in radiation oncology include intensity-modulated radiation therapy (IMRT), fractionated stereotactic radiation therapy (FSRT), and stereotactic radiosurgery (SRS), which allow for more localized and precise irradiation. Recent studies using these new techniques report apparently high local control rates and low morbidity for benign skull base tumors such as pituitary adenomas, craniopharyngiomas, and meningiomas. We performed a review of the published literature on fractionated RT and SRS for skull base meningiomas in an attempt to establish reasonably objective and comparative information on the safety and efficacy of each technique.

Radiotherapy is highly effective in the management of skull base meningiomas, and long-term data clearly indicate tumor control in over 80% of patients after 10 years, with an acceptable incidence of complications. More recently, new stereotactic techniques in patients with meningiomas suggest a higher tumor control rate and may represent an alternative to conventional radiotherapy. FSRT and SRS provide comparable long-term tumor control with low morbidity. Although SRS is an attractive treatment option for skull base meningiomas, it cannot be recommended for the treatment of lesions of any size. Hypofractionated stereotactic radiotherapy in patients with large skull base meningiomas adjacent to the optic pathway is a promising treatment, however, more robust data are needed to definitively evaluate the efficacy and long-term toxicity of hypofractionation. Due to the slow-growing potential of meningiomas, the superiority of individual techniques must be confirmed by prospective, methodologically rigorous studies with an adequate follow-up of 10–20 years.

INDICATIONS: Meningiomas

Meningiomas are the most common benign intracranial tumor, occurring in the convexity and falx cerebri, the cerebellar tentorium, the cerebellopontine angle, and the sphenoid region. Most meningiomas have a good prognosis, with a 5-year survival rate of >80%.

Surgical removal is the treatment of choice, and the decision to perform surgery is guided by the patient's clinical history, severity of symptoms, histological grade, location, and risk-benefit assessment. Some studies have shown that asymptomatic and small meningiomas (<30 mm) can be initiated with close follow-up and surgery and/or radiation treatment can be postponed until radiological progression or the onset of neurological symptoms.

RT is performed:

- Grade I in case of clinical-radiological progression
- Grade II atypical meningioma and Grade III anaplastic meningioma after surgery or after clinical-radiological progression

Treatment:

For meningiomas with a diameter of less than 30 mm, radiosurgery may be performed, or hypofractionated stereotactic radiotherapy may be performed in the case of nearby OARs.

For meningiomas larger than 3 cm that are "not amenable to surgical treatment" and/or in the vicinity of nearby OARs, radiation treatment is performed with conventional fractionation.

PROCEDURES

a) Positioning

Patient supine with arms at the sides, immobilization: BrainLab thermoplastic mask, or Qfix

b) Simulation CT imaging with and without contrast medium, 1 mm step. Simulation MRI, T1-weighted sequence with contrast medium.

c) Contouring:

- Adjuvant RT in anaplastic meningioma: The CTV includes the signal alteration of the preoperative T1-weighted MRI with contrast medium, the surgical bed, and the postoperative T1-weighted MRI with contrast medium; the PTV is determined by

a 10-mm expansion of the CTV. The prescribed dose is 60 Gy in 30 fractions.

- **Adjuvant RT:** The CTV includes the signal alteration of the preoperative T1-weighted MRI with contrast medium, the surgical bed, and the postoperative T1-weighted MRI with contrast medium; the PTV is determined by a 3-mm expansion of the CTV. The prescribed dose is 54 Gy in 27 fractions.
- **Radiosurgery:** CTV includes T1-weighted MRI with contrast medium. The PTV is determined by a 3 mm CTV expansion. The prescribed dose for the PTV is 14 Gy.
- **SBRT:** CTV includes T1-weighted MRI with contrast medium. The PTV is determined by a 3 mm CTV expansion. The prescribed dose for the PTV is 30 Gy in 5 fractions.
- **Exclusive RT:** CTV includes signal alteration of MRI with contrast medium. The PTV is determined by a 3 mm CTV expansion. The prescribed dose is 50 Gy in 25 sessions.

d) Constraints

PTV coverage

RapidArc technique: V95>99% Dmax < 110% V107%<3%

Organo	RT convenzionale	RT ipofrazionata	RS
Tronco encefalico	Dmax≤	Dmax≤ 20 Gy	Dmax≤ 12 Gy
N. Ottici e N.cranici	Dmax <	Dmax ≤ 15Gy	Dmax≤8Gy
Chiasma	Dmax <	Dmax ≤15 Gy	Dmax≤8 Gy
Cristallino	Dmax <10Gy	Dmax≤10 Gy	Dmax≤10 Gy
Coclea	Dmax <45 Gy	Dmax≤15 Gy	Dmax≤12Gy

e) IGRT

Exac Trac the first week, then twice a week; CBCT the first week, then twice a week.

ONGOING VISITS

a) Visit timing: once a week.

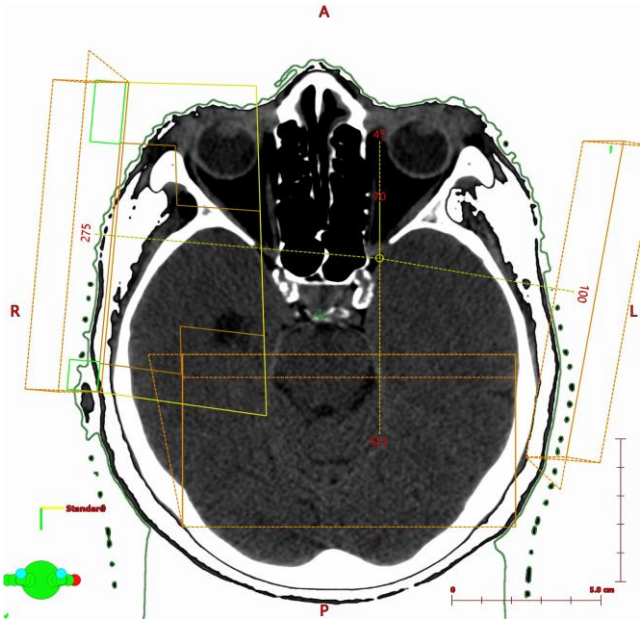
b) Toxicity scale (CTCAE v.4.0)

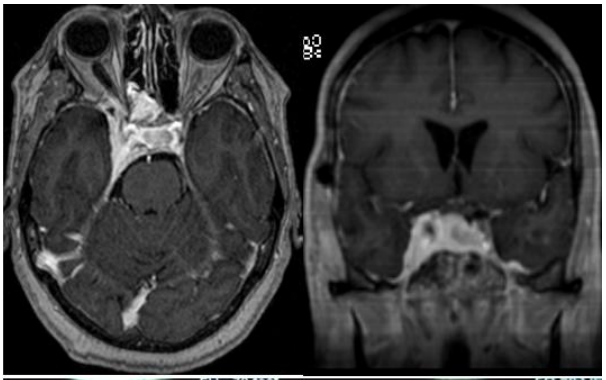
c) Medications to be evaluated/prescribed: Dexamethasone 4 mg from the first day of RT combined with a gastroprotective agent.

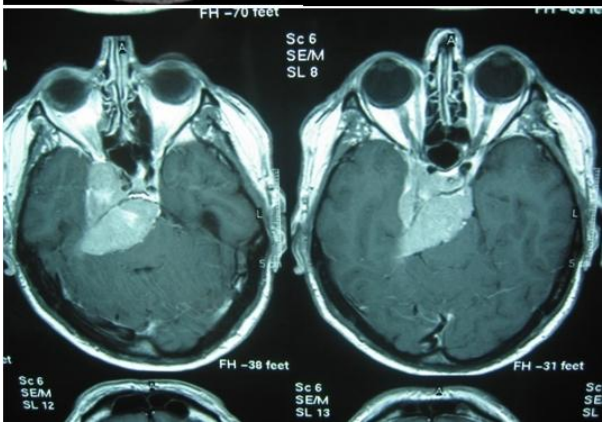
FOLLOW-UP

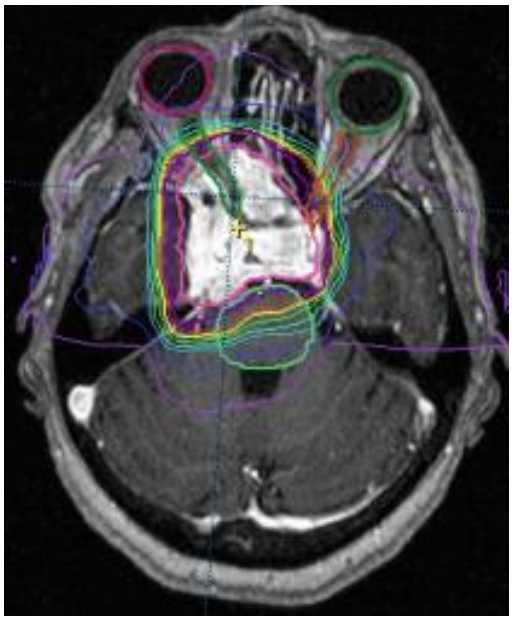
a) 3 months after the end of RT, contrast-enhanced brain MRI

b) Contrast-enhanced brain MRI every 6 months.



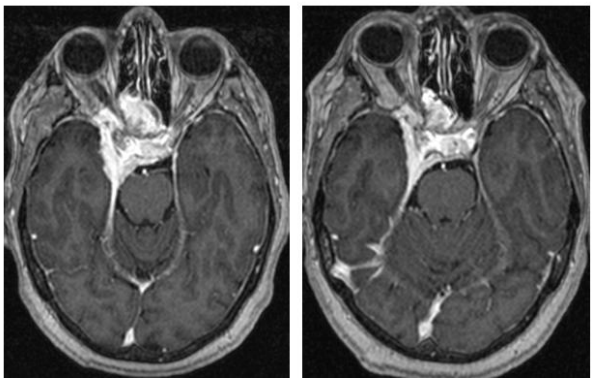




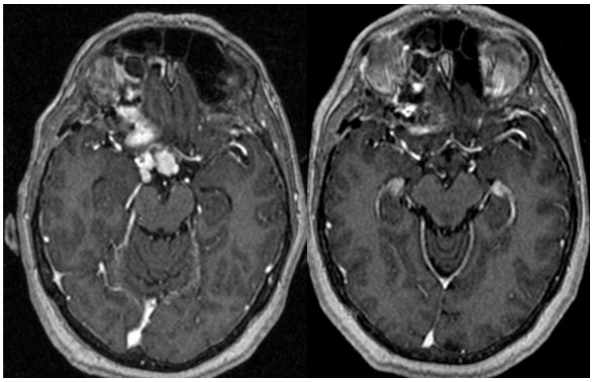


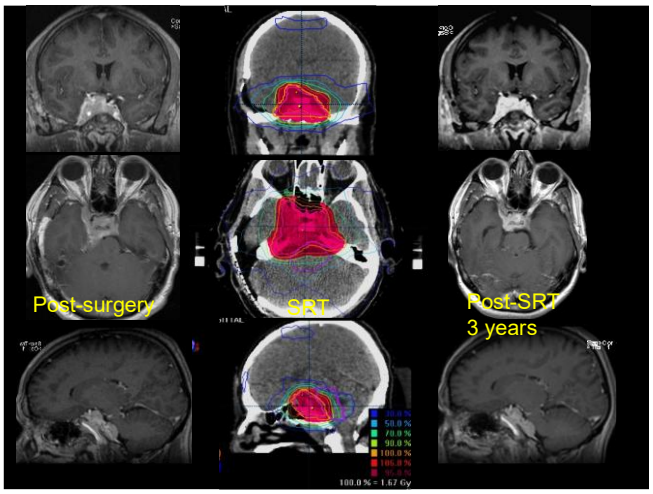
PIANO DI CURA RT

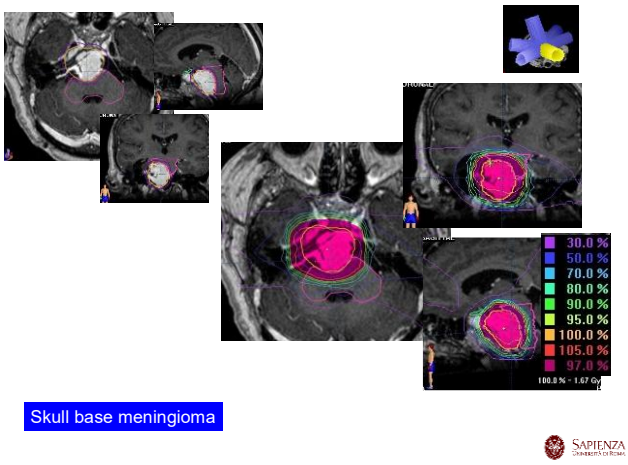
Pre FSRT



Post FSRT







Skull base meningioma

Late Toxicity

- A development of new or worsening of pre-existing hypopituitarism occurred in 10 (19%) patients after a median follow-up of 32 months, requiring hormone replacement therapy
- New clinically apparent neurocognitive dysfunction (Grade II RTOG memory impairment) was reported in one patient.
- No radiation necrosis, cerebrovascular accidents and second tumors were reported.

CONCLUSION

- Radiation is highly effective in the management of skull base meningioma and long-term data clearly indicate a tumour control in more than 80% of cases after 10 years, with an acceptable incidence of complications.
- FSRT and SRS allow a comparable long-term tumor control with lower morbidity. Although SRS is an attractive therapeutic option for skull base meningiomas, it cannot be recommended as the treatment of meningiomas of any size.

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