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Stereotactic radiation therapy for skull base recurrences: Is a salvage approach still possible?

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ABSTRACT

Aim: A literature review was performed to analyse the role of stereotactic radiotherapy given in a single shot or in a fractionated fashion for recurrent skull base tumours in order to ascertain if it can be a real salvage approach.
Background: The management of recurrent skull base tumours can have a curative or palliative intent and mainly includes surgery and RT.
Materials and methods: One-thousand-ninety-one articles were found in the search databases and the most relevant of them were analysed and briefly described.
Results: Data on recurrences of meningioma, pituitary adenoma, craniopharyngioma, chordoma and chondrosarcoma, vestibular schwannoma, glomus jugulare tumours, olfactory neuroblastoma and recurrences from head and neck tumours invading the base of skull are reported highlighting the most relevant results in terms of local control, survival, side effects and complications.
Conclusions: In conclusion, it emerges that SRS and FSRT are effective and safe radiation modalities of realize real salvage treatment for recurrent skull base tumours.

1. Background

The base of skull is a structure at the interface between the intracranial content and the rest of the body where a number of neoplasms can arise from tissues of various origin including bone, cartilage, soft tissues, muscles, lymphatic tissue, nerves and nerve sheets, and embryonic remnants. This explains the extremely large variety of benign and malignant tumours occurring at this anatomic site. A peculiar aspect of the skull base lesions is the proximity to structures deputed to relevant physiologic functions like temporal lobes, brainstem, cranial nerves, pituitary gland and inner and middle ears, limiting extensive surgical approaches directed to achieve a real radical oncologic result, otherwise possible in other body districts.

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For these reasons, only the most recent progresses of surgery and radiotherapy (RT) allowed to improve the results in terms of local control with acceptable rates of side effects and complications.

Endoscopic surgery and neuro-navigation and high-precision radiation techniques like stereotactic and intensity modulated radiotherapy using photons and also particles greatly contributed to the improvement of long term outcomes. Despite the progress of the treatment modalities, the issue of local recurrence still remains the main cause of failure in most of the skull base tumours.

The management of this type of tumour relapse can have a curative or palliative intent and may include surgery, RT and sometimes chemotherapy or a combination of them. A retreatment is a challenge and should carefully take into account a number of factors related to the general status of the patient, the extent of the disease, the previous treatments and the patient's preference.

In case of patient refusal or contraindications to surgery, a radiation treatment should always be considered even in case of previous irradiation. This can be a very challenging choice considering a number of factors: (a) some tumours are radioresistant like sarcoma and chordoma; (b) they are often located nearby dose-limiting critical structures such as brainstem and optic pathway; (c) the previously delivered treatments, surgery and RT, can have altered the vascular and microvascular bed of the region with hypo-oxygenation of the tissues including the tumour itself that can result more radioresistant.

When the tumour recurrence is of limited size, stereotactic RT techniques offer relevant advantages: rapid decrease of dose in the surrounding tissues, use of hypofractionation or single ablative dose able to overcome the radioresistance.[1] For these reasons, several authors employed radiosurgery (SRS), i.e. the single fraction, or fractionated stereotactic radiotherapy (FSRT) whenever possible.

2. Aim

In this review, we present a critical analysis of the most recent available literature for the management of patients with tumour recurrence at the skull base and treated by stereotactic RT techniques.

3. Materials and methods

The following tumours were considered for the present review: meningioma, pituitary adenoma, craniopharyngioma, chordoma and chondrosarcoma, vestibular schwannoma (VS), glomus jugulare tumours (GJT), olfactory neuroblastoma (ON) and recurrences from head and neck tumours invading the base of skull.

Literature search was performed by Pubmed and Scopus by using the following words: skull base, recurrence, stereotactic radiotherapy, radiosurgery and the name of tumour type. The time period was from 2000 to 2014. Articles reporting clinical series and review were included while case reports were in principle excluded from the analysis.

4. Results

In total, 1091 articles were found and 66 were selected for the analysis based on the relevance and the number of clinical cases in relation to the frequency of the specific tumour type.

4.1. *Meningioma*

The majority of intracranial meningiomas are benign (90–95%), mainly arising from the base of skull and the others are atypical and malignant mostly located in the convexities.[2]

Standard of care for benign meningioma is complete surgery or subtotal resection followed by post-operative RT. Several studies suggest that resected atypical and malignant meningiomas should be treated with adjuvant RT, because of the high recurrence rate.[2,3] Actually, benign meningiomas have long-term control rates up to 90% and atypical meningiomas up to 70% after combined approach.[2]

Most clinical series of skull base meningiomas report results of SRS and FSRT for either adjuvant or salvage treatment.[4–12]

Studies on SRS report local control rates of 90–100% and cranial neuropathies in less than 8% of the cases.[6,8,12] Interestingly, local control decreases with tumour size while radiation toxicity increases.[8] One of the largest studies is from Flannery et al. who analysed 168 patients treated with SRS for residual/recurrent meningiomas obtaining local control and overall survival rates >90% at 5 years with relatively low incidence of complications[6] (Table 1).

FSRT offers a potential advantage for meningioma involving or directly adjacent to organs at risk and for larger tumour volumes. Clinical data on FSRT show local control rates of 92–100% and toxicity in up to 9.8% of the cases[4,7,9,10] (Table 1). Cyberknife was used to deliver hypofractionated radiotherapy in a series of 16 cases of skull base meningioma with similar rates of local control and toxicity.[11]

Data on recurrent atypical and malignant meningiomas are sparse with heterogeneous series. Mattozo et al. treated 25 recurrences with SRS and Sughrue et al. analysed 45 patients with recurrent meningioma after surgery and adjuvant RT who underwent a second surgery and brachytherapy implants or gamma-knife SRS. These studies failed to show local control or survival benefits.[5,13] El-Khatib et al. analysed 14 patients after incomplete resection or recurrence treated with SRS. Tumour control rate at 3 years was 91% for atypical and 74% for malignant meningiomas.[14] Mori et al. studied 30 patients with recurrent or residual atypical and malignant meningiomas treated with SRS. Local control rate was 34% at 3 years.[15] Pollock et al. treated 15 skull base atypical/malignant meningiomas with SRS (15 Gy) achieving a local control rate of 85%.[16] Two studies described the use of stereotactic proton radiotherapy for previously untreated and recurrent meningiomas with local control rates of 88% and 94%, respectively.[17,18]

4.2. *Pituitary adenoma*

Pituitary adenomas represent 10–20% of all intracranial tumours, and surgical resection is the preferred treatment for functioning and large non-functioning pituitary adenomas,

Table 1 – Selected series of recurrent skull base tumours treated by stereotactic radiotherapy.

Author, years	No. patients (recurrent/total)	Prior therapies	SRS/FSRT	Median F/U	Local control	Survival	Toxicity
Benign meningioma							
Flannery 2010[6]	71/168 (residual-recurrent)	R	SRS 13 Gy	72 mos	All 91% (5 yrs) 86% (10 yrs) Residual-recurrent 91%	All, OS 95% (5 yrs) 78% (10 yrs) All, PFS 91% (5 yrs) 86% (10 yrs)	2% cranial neuropathies 4% hydrocephalus
Minniti 2011[7]	34/52	R	FSRT 50 Gy, 30 fxs	42 mos	All 93% (5 yrs)	All, OS 100% (5 yrs)	19% hypopituitarism 5.5% cranial nerve deficits
Shen 2012[10]	69/224	R, RT	FSRT 54 Gy, 27–30 fxs	4.4 yrs	Recurrent after R 77% (5 yrs) Recurrent after RT 44% (5 yrs)	NA	2.2% optic neuritis 2.2% radiation necrosis
Pituitary adenoma							
Jagannathan 2007[24]	90/90 (residual-recurrent) (ACTH-secreting)	R, RT	SRS 25 Gy	45 mos	54% endocrine remission 94% radiological response	NA	22% hormone deficiencies 5.5% cranial nerve deficits
Sheehan 2011[25]	418/418 (functioning and non-functioning)	R, RT	SRS 24 Gy	31 mos	Endocrine remission: 53% acromegaly 54% Cushing's disease 26% prolactinoma 90% radiological response	NA	24.4% hormone deficiencies 3.1% cranial nerve deficits
Sheehan 2013[23]	512/512 (residual-recurrent) (non-functioning)	R, RT	SRS 16 Gy	36 mos	95% (5 yrs) 85% (10 yrs)	No pts died as a result of tumour progression	21% hypopituitarism 9% cranial nerve deficits
Craniopharyngioma							
Kobayashi 2009[32]	38/100	R, RT, CHT	SRS Gy	66 mos	All 79.5%	All, OS 94% (5 yrs) 91% (10 yrs) All, RFS 74% (5 yrs) 60% (10 yrs)	6% complication (hypopituitarism and visual deterioration)
Niranjan 2010[33]	43/46	R ± RT, P-32	SRS 13 Gy	62 mos	All 67.8% (5 yrs)	All, OS 97% (5 yrs) All, PFS 92% (5 yrs)	2% panhypopituitarism
Chordoma and chondrosarcoma							
Liu 2008[44]	31/31 chordomas (residual-recurrent)	R, RT	SRS Gy	28 mos	64% (3 yrs) 21% (5 yrs)	OS 91% (3 yrs) 76% (5 yrs)	No serious radiation-related complication

Kano 2011[46]	68/71 chordomas (residual-recurrent)	R, RT	SRS 15 Gy	5 yrs	All 66% (5 yrs) 61% (7 yrs)	All, OS 80% (5 yrs) 69% (7 yrs)	9% AREs
Iyer 2012[47]	15/22 chondrosarcomas (residual-recurrent)	R, RT	SRS 15 Gy	75 mos	All 72% (5 yrs) 54% (10 yrs)	All, OS 70% (5 yrs) 56% (10 yrs)	10% symptomatic AREs
Vestibular schwannoma (acoustic neurinoma)							
Hasegawa 2005[57]	72/317 (residual-recurrent)	R	SRS Gy	7.8 yrs	All 93%	All, PFS 93% (5 yrs) 92% (10 yrs)	42.2% hearing deterioration 3.5% persistent facial numbness/palsy
Hsu 2010[58]	14/75	R	SRS 14 Gy	98 mos	93%	NA	12% neurological deficits
Glomus jugulare tumours							
Pollok 2004[64]	23/42	NA	SRS Gy	44 mos	All 98%	All, PFS 75% (10 yrs)	15% neurological deficits
Gerosa 2006[65]	17/20	R, EE	SRS Gy	51 mos	All 100%	All 100%	10% hearing deterioration
Olfactory neuroblastoma							
Van Gompel 2013[68]	7/8	R ± RT ± CHT	SRS 15 Gy	42 mos	All 92%	All, OS 88% (2 yrs)	No complications
Recurrence from head and neck tumours invading the base of skull							
Wu 2007[72]	90/90 NPC	RT ± CHT	FSRT 18 Gy, 3 fxs 48 Gy, 6 fxs	20 mos	90%	DSS 58% (3 yrs) PFS 55% (3 yrs)	19% late complications
Chua 2009[70]	86/86 NPC	RT ± CHT	SRS Gy FSRT 34 Gy, 2–6 fxs	32 mos	SRS 51% (3 yrs) FSRT 83% (3 yrs)	SRS, OS 66% (3 yrs) FSRT, OS 61% (3 yrs)	Severe late complications 33% SRS 21% FSRT

SRS, radiosurgery (marginal dose); FSRT, fractionated stereotactic radiotherapy; yrs, years; mos, months; R, resection; RT, radiotherapy; CHT, chemotherapy; P-32, intracavitary phosphorus-32 brachytherapy and cyst aspiration; EE, endovascular embolization; OS, overall survival; PFS, progression-free survival; DSS, disease specific survival; RFS, recurrence free survival; AREs, adverse radiation effects; NCP, nasopharyngeal carcinoma; NA, not available.

except for prolactinomas, which are usually treated medically. Surgical resection achieves tumour control in 50–80% of cases. RT has a well-established role when surgical and medical approaches have been exhausted.[19]

Salvage RT can be delivered by SRS or FSRT used in different settings. FSRT has the advantage of limiting radiation damage to nearby radiation-sensitive structures such as the optic apparatus, whereas SRS can be conveniently performed in a single session with more rapid biochemical remission.[20]

The majority of current research has been focused on SRS and two large reviews including also recurrent disease were recently published.[21,22] The median margin dose of the 25 major SRS series on non-functioning adenomas, studying 1935 patients, was 16 Gy. These studies achieved a mean tumour control rate of 95.2% (range 83–100%). The occurrence of hypopituitarism was observed in a mean 8.8% of patients (range 0–40%). Among these studies, the multicentre trial of Sheehan et al.,[23] on residual/recurrent non-functioning adenomas treated with gamma-knife SRS found a tumour control rate >90% (Table 1).

Clinical series on secreting adenomas considered patients with Cushing's disease, acromegaly and hypersecretion of prolactine.[24,25] Series on Cushing's disease analysing 646 patients treated with a median dose of 24 Gy (range 15–35), reported endocrine remission in a mean 51% of the patients.[21,22] Series on acromegaly analysing 1459 patients treated with a median dose of 22 Gy (range 14–35), observed endocrine remission in a mean 45% of the cases.[22] Series on prolactinomas, analysing 573 patients treated with a median dose of 24 Gy (range 15–49), achieved endocrine remission in a mean 35% of the patients.[22] Endocrine remission in these series required a time period from 3 months to 8 years. The mean incidence of hypopituitarism was 18% (range 0–69%) while cranial nerve dysfunction was observed in 4% of the cases treated with gamma-knife with an increased risk correlated with the number of isocentres.

Data on proton SRS are also available. In a series of 22 patients with persistent acromegaly treated to a median dose of 20 Gy (range 15–24 Gy), biochemical remission was observed in 59% of the patients with median time to response of 42 months (range 6–62 months).[26] Another series of 33 patients with Cushing's disease to a median dose of 20 Gy (range 15–20 Gy) showed hormone normalization in 52% of patients with a median time of 18 months (range 5–49 months).[27] Toxicity was represented by pituitary deficits in up to 52% of the patients. Hypofractionated radiotherapy by Cyberknife was used in patients with acromegaly reporting similar control rates.[28]

4.3. *Craniopharyngioma*

Craniopharyngiomas are rare tumours arising from Rathke's pouch. Treatment strategy includes gross total resection, limited resection combined with RT, cystic drainage and intratumour chemotherapy.

Gross tumour resection, achieving higher local control rate compared with limited surgery (65–90% vs. 10–50%) is preferably performed in adults and children >5 years old, with small tumours without hypothalamic invasion. Younger children and patients with larger tumours should benefit from a conservative/partial surgical resection followed by postoperative RT, in order to minimize neurological damage.[29] Outcome of multimodality approach is good, with 10-year local control rates of 77–100% and 20-year overall survival of 66–92%.[30]

Even after radical surgery, local recurrence often occurs, requiring additional treatments. Repeat surgery, however, is associated with a greater risk of complications and a lower cure rate,[31] therefore the optimal approach for recurrent craniopharyngioma is RT. In case of residual/recurrent tumours, local control rates of 37% in larger lesions and of 87–94% in smaller lesions are reported by using FSRT with 50–60 Gy and SRS with a median marginal dose of 12–14 Gy, respectively.[32–34] Neurological toxicity related to SRS, including visual deterioration, endocrine morbidity and seizures, ranges from 0 to 19%[32,33] (Table 1).

Cyberknife was used both in a single and in hypofractionated modalities for residual/recurrent craniopharyngioma with a control rates of 91% at 2 years and 85% at 3 years and a neurological toxicity in 0–4% of the patients.[35,36]

4.4. *Chordoma and chondrosarcoma*

Chordomas and chondrosarcomas are rare and slow-growing tumours arising in the skull base in 25–35% and 6% of cases, respectively.[37,38] A functional conserving surgery followed by particle therapy is the most recommended treatment option, and a recent review showed a local control and survival rates at 5 years of 70% and 80% for chordomas and 75% and 99% for chondrosarcomas.[39] The patients, who experience recurrent disease, are considered a challenge to physicians.

The published results, on the effectiveness of SRS in patients with residual/recurrent chordomas and chodrosarcomas of skull base, have been recently reviewed.[40] The authors[41–47] of these articles on chordoma (158 patients) and chondrosarcoma (48 patients) used a mean SRS margin dose of 14 Gy (range 9–20 Gy). They achieved a mean tumour control rate at 5 years of 46% (range 15–72%) and of 87% (range 72–100%), and a survival rate at 5 years of 76–84% and of 70–100%, respectively for chordoma and chondrosarcoma. The occurrence of adverse effects is reported in less than 10% of the cases (Table 1).

Only few experiences[48,49] evaluated FSRT. Bugoci et al. treated 12 patients affected by skull base chordoma with adjuvant or salvage FSRT. Median isocentre dose of 74 Gy (range 54–76 Gy) with conventional fractionation was delivered. Overall survival rate was 76.4% at 5 years.[49]

4.5. *Vestibular schwannoma*

VS are benign slow-growing tumours arising from the eighth cranial nerve. The current treatment options are wait and see, resection and RT.[50]

Actually there are no randomized studies evaluating comparative outcomes of surgery and RT. A recent meta-analysis compared hearing and tumour outcome after treating small (<3 cm) VS with SRS and microsurgery: a better hearing function with SRS approach (70.2% vs. 50.3%, $p < 0.001$) and a similar tumour control rate (96.2% vs. 98.7%, $p = 0.122$) was found.[51]

The conservative approach (wait and see and RT at progression) is considered for patients almost asymptomatic with <25 mm tumours or with poor physical conditions.[52]

Residual tumour rate ranges between 2.6% and 6%, without significant differences among the different surgical approaches. A "less-than-total" resection of VS can be advocated in order to preserve facial outcomes. Particularly for patients with large (>3 cm maximum diameter) VS, a subtotal resection is often performed, since RT can optimally arrest eventual tumour regrowth.[53] Even if partially resected, VS are often quiescent and inactive lesions, a significant recurrence rate up to 44% has been reported in studies with long follow up.[54,55] The volume of residual tumours is the most important prognostic variable for tumour regrowth.[56]

Two relevant studies on residual/recurrent VS employed SRS with single doses of 13.2 Gy and 14 Gy and reported a local control and rate >90%[57,58] with progression free rate higher for recurrent than for residual disease.[58] Worsening of hearing function was observed in up to 42% of patients[57] (Table 1). A series of 386 patients treated by gamma-knife in single fraction or cyberknife with hypofractionation is reported by Wowra et al.[59] with a failure rate in 7% and a serviceable hearing in 75% of patients.

4.6. *Glomus jugulare tumours*

GJT are rare, indolent and highly vascularized lesions arising from the paraganglionic tissue of the IX–X cranial nerves. Treatment options include surgery, endovascular embolization and RT alone or in combination with surgery.

Due the anatomic location of GJT, surgery is often suboptimal and needs postoperative RT in case of persistence and recurrence. RT with standard fractionation schedule at a dose of 45–50 Gy is considered as an optimal approach for primary treatment or in case of residual/recurrent tumour after surgery.[60] Several studies reported tumour control outcomes using SRS similar or superior to those of standard fractionated RT, and with lower toxicity rate.[40]

Two metanalyses and a systematic review highlighted the effectiveness of SRS in the treatment of GJT, although methodological limitations due to the heterogeneity of the available studies limited the statistical significance.[61–63]

Data on two relevant series are reported in Table 1 showing that SRS is able to achieve local control in 97–100% of residual/recurrent tumours with limited neurological toxicity.[64,65]

4.7. *Olfactory neuroblastoma*

ON is a rare neuroendocrine malignancy arising from the olfactory neuroepithelium. The most frequently used treatment approach is surgery followed by postoperative RT.[66,67] Despite this aggressive management, approximately 50% of patients develop local recurrence and may require additional treatments including surgery, RT and chemotherapy. Only few experiences on stereotactic RT are available for locally recurred ON.

In the study of Van Gompel et al., 8 patients were treated by SRS with a median dose to the tumour margin of 15 Gy achieving local control in 92% of the lesions[68] (Table 1).

4.8. *Recurrences from head and neck tumours invading the base of skull*

Head and neck carcinomas are treated with aggressive multimodality therapies. However, about 50% with locally advanced tumour experience a recurrent disease that may require new treatments consisting of surgery, RT or chemotherapy or a combination of them.[69] Head and neck recurrences invading the skull base are a clinical challenge due to radiation doses previously administered in proximity of critical structures. Stereotactic RT can be adopted as a salvage treatment depending on the size and the location of the disease.

Chua et al. compared FSRT with SRS in a matched cohort analysis.[70] Fractionated SRT achieved better outcome especially for recurrent nasopharynx tumour in skull base and less severe late complications: 33% in SRS group vs. 21% in FSRT (Table 1). A few studies reporting different subsites of relapse analysed overall 82 skull base recurrences.[71–76] Total dose ranged 20–59 Gy with daily fraction of 2.5–13 Gy. Overall survival rates at 1 year were 38–78%. Severe late toxicity was reported in some studies, but less frequently than in other patients re-irradiated with conventional RT techniques.[77] Of note, Roh et al. reported 2 cases of skull base necrosis in 36 re-irradiations with FSRT with 3 fractions of 10–13 Gy.[74]

5. Discussion

Stereotactic RT is a very precise and conservative treatment modality used in several treatment settings including recurrent tumours at difficult sites.[78,79] Thanks to the narrow gradient dose at the periphery of the target volume, it can safely deliver high RT dose to the target while sparing the surrounding healthy tissue and critical organs nearby. Stereotactic RT can be delivered in a single shot, as SRS, or in a fractionated fashion as FSRT. The main difference resides in the dose per fraction delivered to the target and to the surrounding non-target tissues. We know from radiobiology that a single high dose can be very effective in achieving tumour control[1] but, on the other hand, the repair of the sublethal damage can be more effective when a fractionated RT is delivered to an healthy tissue compared to a single high dose. This fact can be crucial for minimizing the damage to late-responding tissues such as the nervous structures that have a low alpha/beta value in the linear-quadratic model. Clinical data have confirmed these theoretic assumptions showing that the side effects of SRS are more severe than those of FSRT especially when the target volume is abutting or compressing a dose-sensitive critical structure. These data should drive the choice of the best treatment option when a tumour recurrence has to be considered for RT, especially in case of re-irradiation (Figs. 1 and 2). In this regard, different dose constraints for healthy structures can be used for SRT and FSRT, according to the Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC).[80] Maximum dose should not exceed 10 Gy for SRS and 55 Gy for FSRT to the optic pathway, 12–14 Gy for SRS and 3–10 Gy for FSRT (3–10 fractions) to the inner ear and cochlea, and 12.5 Gy for SRS and 54 for FSRT to the brainstem.

The data from the present literature review show that both SRS and FSRT, when appropriately used, can be very

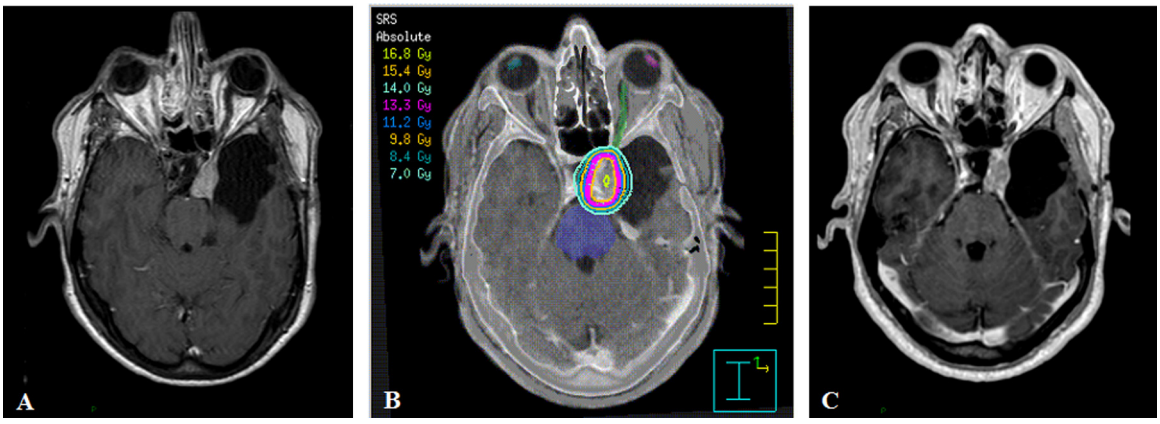

Fig. 1 – Recurrent benign meningioma in a 47 years old male previously treated with partial surgery. (A) MRI in axial view of the residual meningioma after surgery at the level of the left cavernous sinus. (B) Axial view of the treatment plan showing the isodose distribution of SRS to a dose of 14 Gy (prescribed to the 95% isodose). (C) MRI in axial view 3 years after completion of SRS.

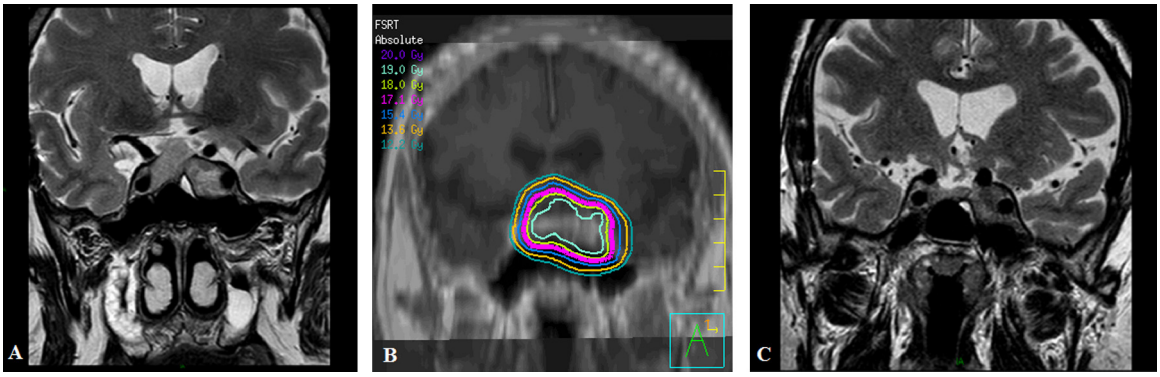

Fig. 2 – Pituitary adenoma in a 61 years old, male already treated with partial surgery. (A) MRI in coronal view showing a lesion extending to the parasellar region and abutting the chiasm. (B) Coronal view of the treatment plan showing the isodose distribution of FSRT to a total dose of 18 Gy in 3 fractions of 6 Gy (prescribed to the 95% isodose). (C) MRI in coronal view 4 years after completion of FSRT.

effective and safe treatments in many cases of tumour recurrence located in the base of skull.

SRS has been mainly used for small size residual/recurrent meningioma, pituitary adenoma, craniopharyngioma, VS and GJT (Table 1). In these cases, local control can be achieved in more than 90% of the patients especially in case of small meningioma and VS.[6,9,60] Neurological deficits range from 0% to about 10% depending on the anatomic location and the size of the recurrence. As far as pituitary adenomas, SRS can achieve more favourable results in non-functioning rather than hormone secreting tumours, that seem to be more radioresistant.[20,21] Less favourable result have been obtained in case of chordoma and chondrosarcoma, most likely related to the irregular shape and the larger size of the recurrence.[42,43]

FSRT usually with hypofractionated regimens has been mainly employed in selected series of large size residual/recurrent meningioma and craniopharyngioma often presenting with irregular shape. In these series local control can have large variations depending on the tumour characteristics.[7,10,30] In VS, FSRT is potentially better for ear preservation compared to SRS, especially in case of large tumours.[46] FSRT can be conveniently employed also in selected cases of recurrent head and neck tumours invading the base of skull.[65,67] In general, FSRT should be preferred in case of larger and irregularly shaped lesions when the preservation of dose-limiting healthy tissues is the priority whereas SRS can be conveniently used in case of small even radioresistant lesions not abutting or compressing critical structures.

The main limitation of this literature review is related to the available studies which are often retrospective and only in few cases focused on recurrent tumours. In this regard, most authors describe the results of the first treatment line and report limited details about the pattern of recurrence, the subsequent treatment modalities and the final outcome.

6. Conclusions

SRS and FSRT are effective and safe radiation modalities to realize a real salvage treatment for several recurrent skull base tumours. The management of these challenging treatments should be performed in centres where all the competences

are well represented including surgeons, radiation oncologists and medical oncologists and also pathologists and radiologist with a special expertise in skull base tumours. The decision about the final choice of treatment should always be taken after multidisciplinary discussion taking into account the previous medical history of the patient and his conditions and symptoms, the tumour characteristics and last but not least the preference of the patient.

Conflict of interest

None declared.

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