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Radiotherapy for vestibular schwannoma: Review of recent literature results

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ABSTRACT

Background: The management of vestibular schwannoma is still a quite controversial issue and can include wait and see policy, surgery and radiotherapy, mainly with stereotactic technique. The purpose of this study is to review the results of recent clinical series treated by radiotherapy.

Materials and methods: Literature search was performed by Pubmed and Scopus by using the words vestibular schwannoma, acoustic neuroma, radiotherapy, radiosurgery.

Results: Management options of VS include wait and see, surgery and radiotherapy. In case of small lesions, literature data report local control rates higher than 90% after radiosurgery (SRS) similar those of surgical techniques. Recent literature reviews show favourable functional outcome by using SRS. Several literature data support the use of fractionated stereotactic radiotherapy (FSRT) in case of large inoperable lesions.

Conclusion: Radiotherapy plays a relevant role in the treatment of VS. In small-size lesions, SRS can guarantee similar local control and potentially better function outcome compared to surgery. In case of large and irregularly shaped lesions, FSRT can be the used when surgery is not feasible.

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1. Background

Vestibular schwannoma (VS), or acoustic neuroma, is the most common tumour of the cerebellopontine angle.[1] It is a benign slow growing tumour with an incidence of about 10–20/million per year.[2] Symptoms at diagnosis commonly include hearing deficiency or loss, tinnitus, loss of balance and, more rarely, change in facial sensation and headache. Diagnosis is performed by magnetic resonance imaging showing a typical gadolinium-enhanced lesion.

The principal management options for VS are watchful waiting, surgery and radiotherapy.[3] The chance of tumour control and optimal functional outcome are very high, so a tailored clinical approach, based on tumour and patients' characteristics is often possible.

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Radiotherapy can be performed by various technical approaches, including in particular stereotactic radiosurgery (SRS) in a single shot and fractionated stereotactic radiotherapy (FSRT) with hypofractionation or conventional fractionation.

The present article aims at reviewing the most recent literature data of radiotherapy to describe the results in terms of local control and side effects in order to define the indication to radiation treatment and the optimal technical approach.

2. Materials and methods

Literature search was performed by using the databases of Pubmed and Scopus and the following keywords: vestibular schwannoma, acoustic neuroma, radiotherapy, radiosurgery. The time period was from 2009 to 2015. Most relevant historical articles from previous years were also included. Case reports were in principle excluded from the analysis. The relevance was assessed on the basis of the numerousness of the series, the length of follow-up and the completeness of analysis of technical data, outcome results in terms of local control and early and late side effects.

3. Results

In total, 324 articles were found and 32 were selected for the analysis. The most relevant clinical studies using radiotherapy and analyzing large series with adequate follow-up are summarized in Tables 1 and 2.

The different radiation therapy approaches can be divided into two principal modalities, according to the fractionation schedule: single fraction stereotactic radio-surgery (SRS) and fractionated stereotactic radiotherapy (FSRT), the latter with standard (1.8–2 Gy/fraction) or hypo-fractionated modality.

3.1. *Stereotactic radio-surgery (SRS)*

Historically, the first radiotherapy experience for VS was conducted by Leksell in 1969 at Karolinska Hospital.[4] He used gamma-knife irradiation by ^{60}Co photons, reporting encouraging results, with local control rates higher than 80% at 3.7 years and only 14% facial nerve impairment. Initially, indications for SRS included: elderly patients, medically inoperable, bilateral tumours and recurrence after previous surgery. After a few decades experience, many centres adopted SRS for treatment of primary VS as a valid alternative to surgery. However, no randomized studies have been conducted in order to compare outcomes from surgery and SRS. However, a recent meta-analysis reported a better hearing function (70.2% vs. 50.3%, $p < 0.001$) and a similar tumour control rate (96.2% vs. 98.7%, $p = 0.122$) comparing stereotactic radiation with microsurgery for treating small (<3 cm) VS.[2] Similar data come from recent reviews.[5,6]

The very first reports on SRS for VS used quite high dose schedules, ranging from 10 up to 25 Gy delivered in single fraction. Local control with this approach was high (90–100%) but a significant number of adverse effects were observed, first of all hearing loss.[7–10] Foote et al. treated 36 patients with acoustic neuromas with SRS using a gamma knife at a dose of 16–20 Gy to the tumour margin. No tumour progression was observed, but the 2-year actuarial rate of preservation of useful hearing was only 41.7%, and the 2-year actuarial incidence of facial or trigeminal neuropathy was 81.7%.[7] In a cohort of 29 patients treated with median marginal dose of 16 Gy, Suh et al. reported hearing deterioration in 74% of patients who had useful hearing prior to treatment and new or progressive trigeminal and facial nerve deficits with estimated 5-year incidence of 15% and 32%, respectively.[8] Kondziolka et al. reported on 162 consecutive patients treated with gamma knife to an average tumour margin dose of 16 Gy achieving 98% local control, but 49% deterioration in hearing ability after 5 years of follow-up. Normal facial function was preserved in 79% of the patients and normal trigeminal function was preserved in 73%.[10]

More recent experiences were published reporting better long term results after SRS for VS. In a retrospective analysis, a dosimetric evaluation was performed by Jacob et al. in order to identify the safe threshold for cochlear maximum tolerated dose.[11] Fifty-nine out of 105 patients treated with SRS (12–13 Gy) for VS were analyzed. A statistically significant association was found between pre-treatment hearing and marginal dose, and mean dose to the cochlear volume. However, in a multivariable model, only pre-treatment pure tone average was significantly associated with non-serviceable hearing after treatment, with serviceable hearing loss of 36% at a mean of 2.2 years after SRS. The authors suggested caution against undertreating the tumour in the distal fundus or further reducing the marginal prescription dose to achieve lower cochlear doses.

A large Italian experience was recently published by Boari et al.[12] They reported outcomes in 523 patients treated between 2001 and 2010. Gamma-knife SRS was delivered with a median margin dose of 13 Gy (range 11–15 Gy). Local control was 97.1% with 82.7% of the patients having a tumour volume downsizing after mean follow-up of 75.7 months. Treatment related complications were only a transient worsening of pre-existing symptoms. The overall rate of preservation of functional hearing at the long term follow-up was 49%.

A substantial analysis was recently published from Japan analyzing safety and effectiveness of Gamma Knife SRS after more than 10 years.[13] Three hundred forty-seven patients were treated with median tumour volume of 2.8 cc to a median marginal dose of 12.8 Gy. The actuarial 5 and ≥10 year progression-free survival rates were 93% and 92%, respectively. No patient developed treatment failure more than 10 years after treatment. The actuarial 10-year facial nerve preservation rate was 97% in the high marginal dose group (>13 Gy) and 100% in the low marginal dose group (≤13 Gy).

An interesting study was recently reported on tumour growth rate, hearing loss and quality of life of 237 patients with unilateral VS receiving either gamma knife SRS (12 Gy, 113 patients) or just observation (124 patients).[14] In this prospective study, Breivik et al. reported no significant difference in hearing preservation between the two approaches: hearing was lost in 76% of conservative management patients and 64% of SRS patients. There was a significant reduction in tumour volume over time in the SRS group. The need for treatment following initial SRS or observation differed at highly significant levels ($p < 0.001$). Development of symptoms and quality

Table 1 – Selected series of vestibular schwannoma treated by stereotactic radiosurgery (SRS), fractionated stereotactic radiotherapy (FSRT) and protons.

Author	Year	Institution	N. of pts	Median follow-up (months)	Median dose	Mean/Median volume (cc)	Local control	Hearing preservation	Toxicity		
									VII c.n.	V c.n.	Others
SRS											
Breivik[14]	2013	Bergen, Norway	113	55	12 Gy	3.9	94%	36%	12%	NA	0%
Hasegawa[13]	2013	Komaki, Japan	440	12.5 y	12.8 Gy	2.8	93% 5 y 92% 10 y	43% 5 y 34% 8 y	2.2%	0.5%	0.2–0.7%
Boari[12]	2014	San Raffaele, Italy	379	75.7	13 Gy	1.2	97.1%	49%	1.1%	1.8%	3.2% disequilibrium 3.2% tinnitus 1.8% headache 5.3% hydrocephalus
FSRT (conventional fractionation)											
Champ[19]	2013	Philadelphia, USA	154	35	46.8 Gy, 26 fxs	2.41/0.09	99% 3 y 93% 5 y	64% 3 y 54% 5 y	1.9%	1.9%	4.5% imbalance 1.9% hydrocephalus
Woolf[17]	2013	London, UK	93	5.7 y	52.5 Gy, 25 fxs	19.6 mm (mean diameter)	93% 5 y 92% 10 y	93%	1%	1%	NA
Litre[18]	2013	Reims, France	155	60	50.4 Gy, 28 fxs	2.45	99.3% 3 y 97.5% 5 y 95.2% >7y	54%	2.5%	3.2%	2.5% hydrocephalus 2.1% tinnitus
FSRT (hypofractionation)											
Hansasuta[20]	2011	Standford, USA	383	3.6 y	18 Gy, 3 fxs	1.1	97% 99% 3 y 96% 5 y	All, 76% T≥3cc 59% T < 3cc 80%	0.2%	1%	1% hydrocephalus
Tsai[21]	2013	Taipei, Taiwan	117	61.1	18 Gy, 3 fxs	4.7	99.1%	81.5%	NA	NA	NA
Vivas[22]	2014	Pittsburgh, USA	73	40	18 Gy, 3 fxs	0.81	83%	53.5%	NA	NA	NA
Vernimmen[23]*	2009	Tygerberg, South Africa	51	60	26 CGyE, 3 fxs	3.45	98%	42%	8.3%	8.3%	NA

SRS, radiosurgery (marginal dose); FSRT, fractionated stereotactic radiotherapy; y, years; NA, not available
*Proton radiotherapy

Table 2 – Selected series of vestibular schwannoma comparing stereotactic radiosurgery (SRS) and fractionated stereotactic radiotherapy (FSRT).

Author	Year	Institution	N. of pts	Median follow-up (months)	Median Dose	Mean/Median volume (cc)	Local control	Hearing preservation	Toxicity		
									VII n.c.	V n.c.	Others
SRS vs. FSRT											
Collen[25]	2011	Brussels, Belgium	78	56	SRS 12.5 Gy	1.7	95%	82% 4 y	16%	6%	5% hydrocephalus
			41	73	FSRT 50 Gy, 25 fxs 40–30 Gy, 10 fxs	6.3		59% 4 y	3%	3%	
Kopp[24]	2011	Munich, Germany	68	30	SRS 12 Gy	1.24	98.5%	85%	4.4%	13%	NA
			47	32	FSRT 54 Gy, 30 fxs	5.7	97.9%	79%	2.1%	4.2%	NA
Puataweepong[26]	2013	Bangkok, Thailand	39	61	SRS 12 Gy	0.9	95% 5 y	75% 5 y	<1%	0%	<1% hydrocephalus
			79	61	FSRT 25 Gy (range, 18–30), 5 fxs (range, 3–10)	3.9	100% 5 y	87% 5 y	<1%	0%	<1% hydrocephalus
			28		45–50 Gy, 20–25 fxs	9.5	95% 5 y	63% 5 y			
Anderson[27]	2014	Wisconsin, USA	48	83.6	SRS 12.5 Gy	0.66	97% 5 y 85% 10 y	60%	2.1% 5 y	10.5% 5 y	2.2% tinnitus
			19	53.6	FSRT 45–50.4 Gy, 25–28 fxs	2.94	100% 5 y	44.4%	0%	5.3%	5.6% vertigo 0% tinnitus
			37	43.1	20 Gy, 5 fxs, once a week	0.89	90.5% 5 y	63.2%	2.1%	20.5%	2.9% vertigo 2.9% tinnitus
Combs[28]	2015	3 centres, Germany	158	67	SRS 13 Gy	1	95% 5 y 94% 10 y	86%	< 1%	1.8%	3% gait uncertainty
			291	67	FSRT 57.6 Gy, 32 fxs	3.5	95% 5 y 94% 10 y	84%	1%	14%	

SRS, radiosurgery (marginal dose); FSRT, fractionated stereotactic radiotherapy; y, years; NA, not available.

of life (QoL) did not differ significantly between the groups. SRS reduced the tumour growth rate and, thereby, the incidence rate of new treatment about tenfold. Hearing was lost at similar rates in both groups. Symptoms and QoL were not significantly affected by SRS.

3.2. *Fractionated stereotactic radiotherapy (FSRT)*

FSRT was first used as an adjuvant treatment for non-radically removed VS.[15] Without a clearly visible gross tumour volume (GTV) or because of large volume or irregular shape of the target, a fractionated schedule was chosen to better spare OARs. A standard fractionation of 1.8–2 Gy a day, and a total dose >45 Gy was found to be able to obtain a local control in VS.

A significant difference between SRS and FSRT seems to be not only the incidence but also the time between radiation delivery and appearance of adverse effects. Fractionation seems to increase latency for late toxicity rather than reduce its incidence.[16]

A retrospective analysis conducted at the Royal Free Hospital from a 15 year cohort of 93 patients treated with FSRT (52.5 Gy in 25 fractions) obtained an overall control rate of 92%. Data on complications were available for 90 patients, with 7% experiencing a reduction in hearing, 1% developing trigeminal nerve dysfunction and 1% a deterioration in facial nerve function. Four percent developed hydrocephalus and 1% developed radiation brainstem necrosis.[17]

A recent French experience reported oncologic outcomes of 158 acoustic neuromas treated by FSRT between January 1996 and December 2009. Patients received a dose of 50.4 Gy in five fractions of 1.8 Gy weekly, on a median tumour volume at 2.45 cc (range, 0.17–12.5 cc). Local tumour control rates were, respectively, 99.3%, 97.5% and 95.2% at 3, 5 and more than 7-year follow-up. Neurological sequelae consisted in radiation-induced trigeminal nerve impairments (3.2%), facial neuropathies (2.5%) and new or aggravated tinnitus (2.1%).[18]

In a recent report from Thomas Jefferson University, Champ et al. demonstrated that a further reduction in total dose for FSRT to 46.8 Gy in 1.8-Gy fractions resulted in improved preservation of functional hearing status, without compromising long term local control. On 154 patients analyzed, tumour control rate was 99% and 93% at 3 and 5 years, respectively. Eighty-seven patients had serviceable hearing at the time of FSRT and evaluable audiometric follow-up. Hearing preservation rates at 3 and 5 years were 66% and 54%, respectively. These results, according to authors' conclusion, may lay the foundation for further attempts at dose de-escalation.[19]

Hypofractionated radiotherapy schedules have also been used, even if only small series are available with this approach.

One of the largest experiences was conducted at the Stanford University Medical Centre: 383 patients were treated from 1999 to 2007 with hypofractionated FSRT (18 Gy in 3 sessions), targeting a median tumour volume of 1.1 cc (range, 0.02–19.8 cc). Local control rates at 3 and 5 years were 99% and 96%, respectively. On 200 evaluable patients with pre-FSRT, serviceable hearing preservation rate was 76%. Smaller tumour volume was associated with better hearing preservation ($p = 0.001$). There was no case of post-FSRT facial weakness. Trigeminal dysfunction arose in 8 patients (2%), half of which was transient.[20]

In a retrospective series of 117 VS patients treated with 18 Gy over 3 fraction of Cyberknife, 99.1% had excellent tumour control rates, with a mean imaging follow-up of 61.1 months. Eighty percent of them maintained hearing after radiotherapy, with a mean audiometric follow-up of 64.5 months. In this report, patients with larger tumour volumes, smaller cochlear sizes and higher prescribed cochlear doses had poor hearing prognosis.[21]

In a recent retrospective analysis of 73 cases (63 primary and 10 postsurgical radiosurgery), Vivas et al. described linear accelerator (LINAC) based FSRT for VS (18 Gy over 3 fractions at 80% isodose).[22] Analysis for tumour growth was positive for 17% using linear (maximum diameters) and 26% using volumetric measurements. Serviceable hearing preservation was obtained in 53.5%.

Proton beam was also used as hypofractionated stereotactic radiotherapy for acoustic neuromas. Fifty-one cases treated with hypofractionation (3 fractions) and followed-up for a minimum of 2 years were reported by Vernimmen et al.[23] Mean dose prescribed to ICRU reference point (isocentre) was 26 cobalt grey equivalent (CgyE) in 3 fractions. Mean minimum tumour dose was 21.4 CgyE/3. With a mean radiological follow-up of 60 months, the 5-year results showed a 98% local control, with a hearing preservation of 42%, a facial nerve preservation of 90.5% and a trigeminal nerve preservation of 93%.

3.3. *SRS and FSRT: compared schedules*

In a recent German study, a retrospective analysis was performed comparing functional and oncologic outcomes from both treatment modalities, SRS and FSRT, for VS.[24] Forty-seven patients with larger tumours (>1.5 cm) received FSRT to a total dose of 54 Gy at 1.8 Gy per fraction and 68 patients with smaller tumours (<1.5 cm) received a total dose of 12 Gy at the 100% isodose. Tumour control rate was 97.9% in the FSRT group and 98.5% in the SRS group. Hearing function was preserved in 79% after FSRT and in 85% after SRS. Nine out of 68 patients (13%) had a new trigeminal neuropathy after SRS.

Collen et al. reported compared outcomes for 119 patients treated in a single institution with linac-based SRS (median single dose of 12.5 Gy, 78 patients) or by FSRT (10 fractions of 3–4 Gy, or 10 25 fractions of 2 Gy, 41 patients). Five-year local tumour control was 95%. A higher facial nerve toxicity rate after linac-based SRS was observed ($p = 0.04$). Neither 5-year trigeminal nerve preservation, nor useful hearing preservation probability was significantly different between the patients treated by SRS and FSRT.[25]

In a mono-institutional experience from University of Bangkok, a comparing analysis from 139 consecutive patients was performed. SRS (12 Gy) was given in 39 lesions ≤ 3 cm, hypo-fractionated FSRT (5 Gy × 4–5, 6 Gy × 3, and 3 Gy × 10) in 79 lesions and FSRT (50 Gy in 25 fractions) in 28 lesions. The 5-year local control rate was 95%, 100% and 95% in the SRS, hypofractionated FSRT and FSRT groups, respectively. Hearing preservation was observed after SRS in 75%, after hypo-fractionated FSRT in 87% and after FSRT in 63% of the patients. No statistically significant difference in local control, hearing preservation or complication between the treatment schedules was reported.[26]

In a study from the University of Wisconsin, the long-term outcome and toxicity of FSRT and SRS for 100 VS were described. SRS was delivered to 48 patients (median prescription dose of 12.5 Gy, range 9.7–16 Gy), FSRT (at the dose of 45–50.4 Gy in 1.8 Gy per fraction) in 19 patients, while hypofractionated FSRT (4 Gy/F for 5 fractions to a total dose of 20 Gy) in 37 patients. The 5-year local control rate was 97% after SRS, 90.5% after hypofractionated FSRT, and 100.0% after FSRT. Serviceable hearing preservation was obtained in 60% of the SRS patients, 63.2% of the hypofractionated FSRT patients and 44.4% of the FSRT patients ($p = 0.6$). No differences in 5-year cranial nerves toxicity was registered, confirming the equivalence of the three schedules.[27]

A recent German study evaluated the long term clinical outcome in 451 VS treated with SRS ($n = 169$, median dose 13 Gy) or FSRT ($n = 291$, 57.6 Gy in median single doses of 1.8 Gy).[28] After a median follow-up of 67 months, local control rate was 97% at 36 months, 95% at 60 months, and 94% at 120 months, with no difference between FSRT and SRS ($p = 0.39$). Loss of useful hearing was observed in 14% of the FSRT group and in 16% of the SRS group. No difference between FSRT and SRS in trigeminal and facial nerve toxicity was observed. In the light of these findings, the two approaches (with dose ≤ 13 Gy for single fraction SRS) proved equally safe and effective.

Radiotherapy is often used to treat residual and recurrent VS after surgery. Studies on SRS with single doses of 13.2 Gy and 14 Gy for recurrent VS reported a local control and rate >90%, with a worsening of hearing function observed in up to 42% of patients.[29]

3.4. *Comparison of radiotherapy with other approaches*

Small size VS (up to 2 cm in diameter) can be managed by different approaches: conservative management (wait and see), surgery and radiotherapy (radiosurgery or FRS).[3] Recent studies undertake a cost-effectiveness analysis comparing these three approaches.[30,31]

Using a Markov decision analysis model, the benefit derived from each management strategy in quality-adjusted life years (QALYs) was measured.

Conservative management of small size and slow growing VS proved to be both cheaper and more effective (0.136 and 0.554 quality-adjusted life years) than both radiosurgery and surgery, respectively. A conservative strategy can therefore be considered as highly cost-effective.

In the case of rapidly growing tumours, after a period of observation, the higher benefit derives from radiosurgery rather than microsurgery. QALY totals for the two immediate treatment approaches are actually significantly lower than those for observation.

4. Discussion

During the last decades, the role of radiotherapy in the management of VS has been progressively established thanks to improved technology and the availability of long term follow-up data regarding local control and adverse effects.[32,33]

Table 3 – Recommended radiation dose limits for hearing preservation.

Author, year	Structure	Recommended dose limits
SRS		
Linskey, 2013[31]	Ventral cochlear nucleus	≤9 Gy
	Modiolus and the basal turn of the cochlea	Ideally < 4–5.3 Gy
	Tumour margin dose prescription	≤12 Gy
Jacob, 2014[11]	cochlear volume	<5 Gy
Bhandare, 2010[32]	Suggested tumour margin dose prescription	12–14 Gy
FSRT (conventional fractionation)		
Honoré, 2002[33] [a]	Cochlea	Mean dose < 35 Gy
Van der Putten, 2006[34] [b]	Cochlea and Eustachian tube	<50 Gy
Bhandare, 2010[32]	Cochlea	Mean dose < 45 Gy (or more conservatively < 35 Gy)
Jereczek-Fossa, 2011[35] [b]	Cochlea	Mean dose 19.2 Gy (not permanent hearing impairment at this dose level)
FSRT (hypofractionation)		
Bhandare, 2010[32]	Suggested schedule	21–30 Gy in 3–7 Gy per fraction over 3–10 days

[a] Radiotherapy for nasopharyngeal carcinoma.
[b] Radiotherapy for parotid gland tumours.

Modern radiotherapy allows using highly collimated photon beams, through the use of extremely precise multileaf collimators for shaping the dose, optimizing the coverage of the target and minimizing exposure of surrounding healthy tissue. Recently, many experiences of radiotherapy for VS using proton beams were conducted. The rapid dose falloff of protons offers theoretical advantages for VSs, arising in areas strictly surrounded by organs at risk.

SRS and FSRT have been extensively used for the treatment of VS. Both the approaches can use a stereotactic localization of the target. A crucial issue remains the dose constraints for critical structures, first of all the inner ear that should be respected in order to limit long term side effects.[34–38] These constraints change by using different fractionation schedules and have to be taken carefully into account, especially when using a single shot radiation as in SRS (Table 3).

The main issue in the treatment of VS remains the choice of management strategy between wait and see, surgery and radiotherapy. The principal endpoint of the treatment is local control, possibly with minimal neurological impairment especially in terms of hearing loss.

A quite large consensus exists on the adoption of the wait and see policy for small slow-growing lesions.[14,39,40] Growth rates for small lesions can be of 1–3 mm per year and hearing reduction can be observed between 40% and 60% with the wait and see over time.[41]

It is interesting that local control rates higher than 80% can be achieved either with surgical resection or stereotactic radiotherapy.[28,40,42] Preservation of serviceable hearing is reported to be higher after radiotherapy (30–98%)[13,24,28] than after surgery (30–50%).[28,40,42]

In particular, the metanalysis from Maniakas et al.[2] confirmed that the results of microsurgery and SRS are comparable in terms of local control but SRS can better preserve hearing function and a systematic review of controlled studies showed that SRS for VS of less than 3 cm in diameter can be the treatment of choice.[5]

A recent long-term study confirmed the usefulness of the initial wait and see policy in the small VS and a better quality of life in the patients treated by SRS rather than microsurgery.[6]

In this regard, it should be pointed out that radiation can affect neurologic function even after many years while surgery determines immediate neurological deficit. The length of follow-up in the various studies can therefore influence the incidence of neurologic impairment also on hearing function after radiation treatment.

As far as fractionation is concerned, SRS and FSRT with modern techniques can achieve similar results in terms of local control and hearing function although FSRT allows treating larger and more irregularly shaped lesions. In this regard, more conservative schedules of irradiation have been considered in many institutions in the light of the remarkable side effects observed in old high dose SRS series. SRS should be delivered to a marginal dose of 13 Gy and its use should be limited to lesions smaller than 3 cm to avoid an increase of side effects to normal tissue.

This way, the optimal tumour control obtained from SRS can be improved by a better toxicity profile of FSRT: hearing loss and facial nerve impairment rates can be reduced with a fractionated schedule.

FSRT has not a radiobiological advantage respective to SRS, because VS are slow growing, benign tumours, not hypoxic and have a low α/β ratio, so they theoretically do not benefit from fractionation. The real advantages of FSRT, despite the long lasting treatment course, lies in the feasibility and organs at risk (OARs) tolerance not being dimension related. SRS usually uses a single isocentre prescription technique and requires targets with spherical shape and maximum diameter less than 3 cm. FSRT, conserving a stereotactic location of the target, allows a more conformal dose distributions even around irregularly shaped targets, and a more homogeneous dose deposition in the planning target volume (PTV), avoiding hot spots. Even if SRS requires no margin for set up uncertainty, thanks to invasive head frame used, modern image-guided radiotherapy devices, such as cone beam, allow not to use PTV margin of about 1–2 mm even in FSRT, allowing a further healthy tissue saving. Dividing total dose in fractions of 1.8–2 Gy, OARs tolerance is highly increased.

5. Conclusions

Radiotherapy plays a relevant role in the treatment of VS. In the growing small-size lesions, SRS is an option that can guarantee similar local control and a potentially better function outcome compared to surgery, although these data should be further confirmed in the long term follow-up studies. In the case of large and irregularly shaped lesions, when surgery is not feasible or at high risk, FSRT can be the best option. Anyway, the management of VS should be performed in centres with a multidisciplinary team with experienced professionals, specifically devoted to surgery and radiotherapy of this particular disease.

Conflict of interest

None declared.

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