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## 5.1 General Principles of Simulation and Target Delineation (Table 5.1 and Fig. 5.1)

**Table 5.1** Suggested target volumes

Target volumes	Definition and description
GTV (EBRT and SRS)	Tumor extent on CT, MRI, or PET scan images
CTV (EBRT and SRS)	CTV = GTV + 0.0–0.7 cm GTV can be expanded further along adjacent vessels (i.e., internal jugular vein)
PTV	EBRT: CTV + 0.3–0.8 cm depending on the comfort of patient positioning, mask fit, and image guidance technique SRS: CTV + 0.1–0.2 cm

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The original version of this chapter was revised. The correction to this chapter can be found at [https://doi.org/10.1007/978-3-030-64508-3\\_28](https://doi.org/10.1007/978-3-030-64508-3_28)

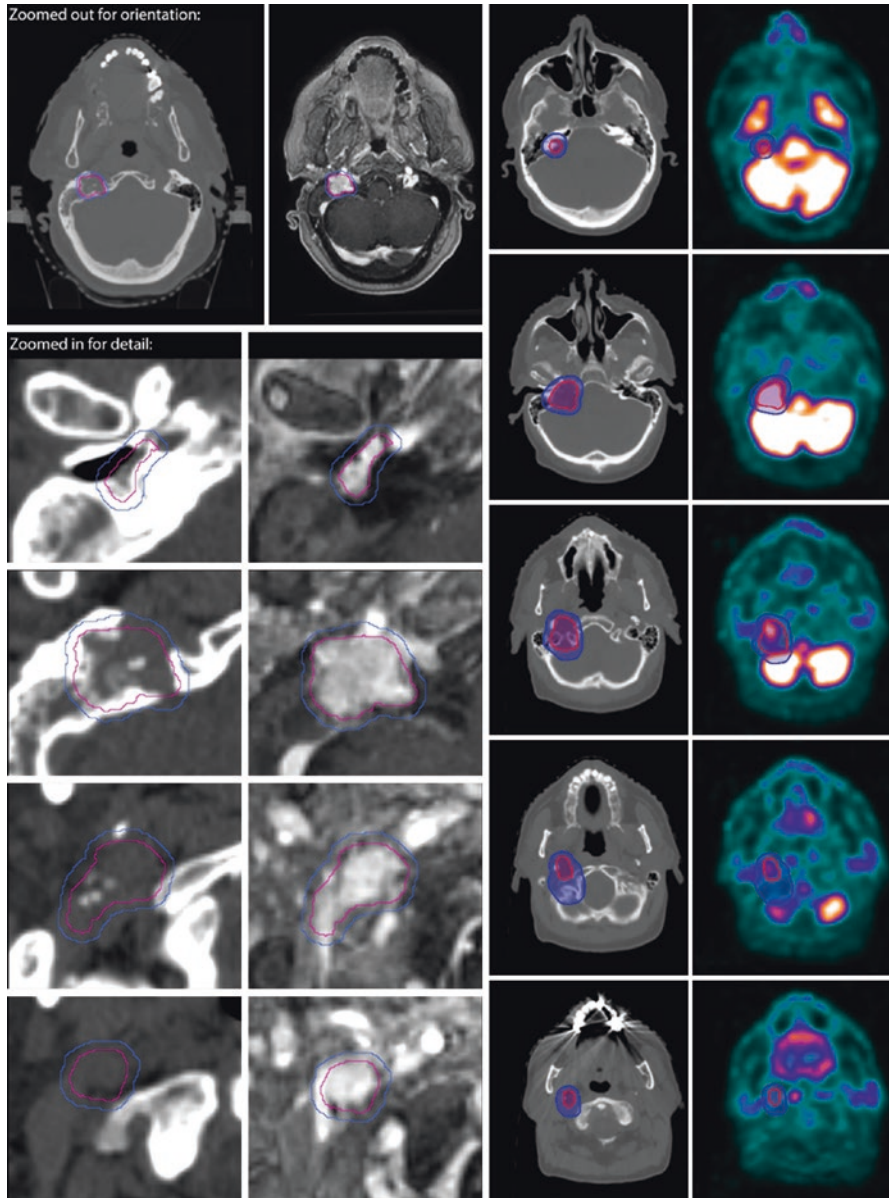
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**Fig. 5.1** Image fusion techniques used for developing right-sided paraganglioma contours for two patients. GTV and CTV, red; PTV, blue. Left: MRI T2W sequence (multi-fraction SRS with a 0.2 cm margin). Right: PET for guidance (IMRT with a 0.7 cm margin)

- Multifield complex, 3D conformal radiation therapy (3DCRT), intensity-modulated radiation therapy (IMRT), volumetric modulated arc therapy (VMAT), and stereotactic radiosurgery (SRS) are the standard techniques for definitive radiation therapy for paragangliomas.
- Considerations for type of radiotherapy may best include tumor size and location in relation to critical structures.
- Electrons should only be considered for tumors close to the skin surface that are modest in size.
- If external beam radiation therapy (EBRT) or frameless SRS is to be utilized, CT simulation should be performed with a thermoplast mask for immobilization; otherwise, SRS with a frame is suitable.
- There is long-term follow-up data for photon radiotherapy techniques, but this data is still relatively lacking for SRS. Only a few case reports of proton therapy have been published as yet.
- High-resolution CT with contrast, MRI, or PET with an appropriate tracer (those that bind somatostatin receptor subtypes 2 and 5) such as Gallium-68 DOTATOC or Gluc-Lys-TOCA are useful for fusion to properly identify gross tumor volume [1, 2].

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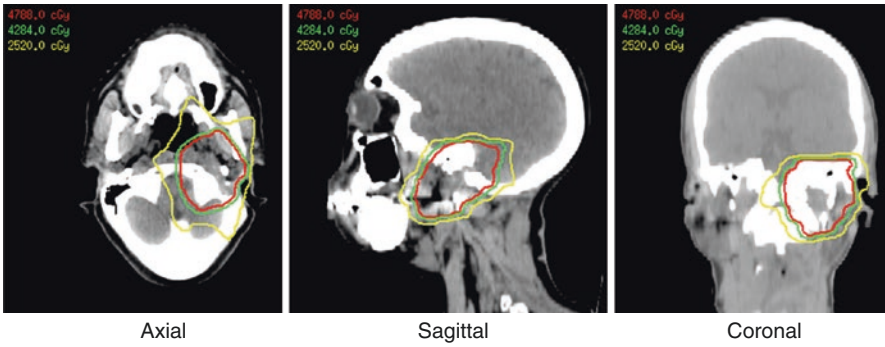
## 5.2 Dose Prescriptions

- IMRT: 45–55 Gy in 1.8–2.0 Gy fractions, using 6–10 MV photons
- Fractionated SRS: 21 Gy in 3 fractions or 25 Gy in 5 fractions, using 6–10 MV photons
- Single-fraction SRS: 13–20 Gy, using MV photons

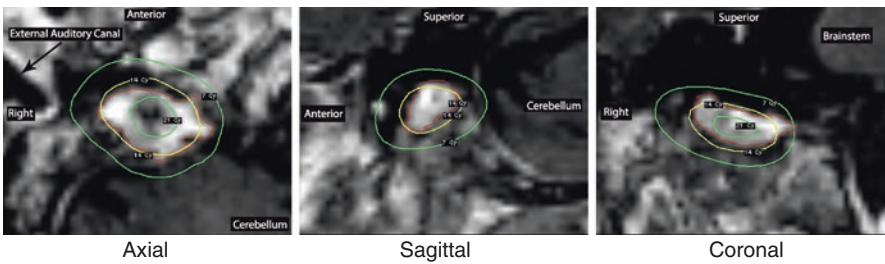
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## 5.3 Treatment Planning Techniques (Figs. 5.2, 5.3, and 5.4, Tables 5.2, 5.3, and 5.4)

- Given the generally nonmalignant nature of the tumor, emphasis is placed on avoiding excess dose to adjacent critical structures such as the brain stem, cranial nerves, cochlea, lens, parotid, retina, and temporal lobe, but the tolerance of many of these structures can be respected while delivering adequate dose to achieve a high probability of tumor control. The presence of cranial nerves within the target volumes merits consideration of dose inhomogeneity possibly contributing to permanent loss of function when selecting treatment approaches.
- While 3DCRT is well-documented to be able to achieve tumor control, IMRT, SRS, or proton therapy may be used with the goal of sparing normal tissue morbidity if dose constraints cannot be met with simpler techniques.

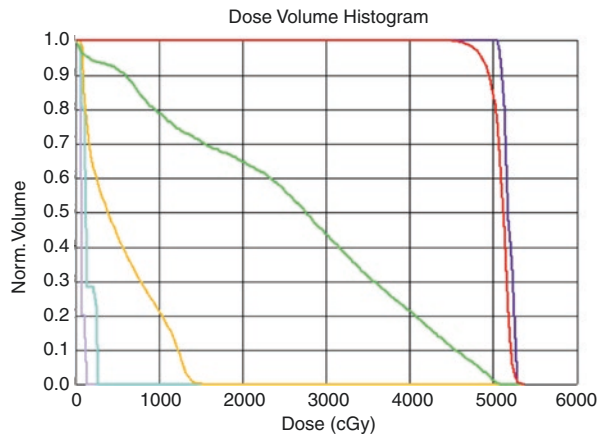


**Fig. 5.2** Sample plan for IMRT using a coplanar four-field approach and 6 MV photons (prescription dose of 5040 cGy) for a left-sided paraganglioma. Red line is 95% isodose line, green is 85% isodose line, and yellow is 50% isodose line



**Fig. 5.3** Sample plan for Gamma Knife SRS (prescription dose of 14 Gy to the 50% isodose line) for a right-sided paraganglioma. Yellow line is 50% isodose line. 21 Gy isodose line is shown most central, and 7 Gy isodose line is shown peripherally

**Fig. 5.4** Sample dose-volume histogram for an IMRT plan for a left-sided jugulotympanic paraganglioma (same patient as in Fig. 5.2 with prescription dose of 5040 cGy). PTV, red; ipsilateral cochlea, purple; brain stem, green; contralateral parotid, yellow; contralateral lens, blue; ipsilateral lens, lavender



**Table 5.2** Recommended normal tissue constraints for IMRT 1.8–2 Gy fractionation schemes

Organs at risk	Suggested dose constraints
Brain stem	Dmax <54 Gy <sup>a</sup> , D1–10cc ≤59 Gy <sup>a</sup> , Dmax 55 Gy <sup>b</sup>
Cochlea, ipsilateral	Mean ≤45 <sup>a</sup> , D5% ≤55 Gy <sup>c</sup>
Lens	Dmax <5 Gy <sup>b</sup>
Optic nerve/chiasm	Dmax <55 Gy <sup>a</sup>
Parotid [sparing contralateral]	Mean dose <20 Gy <sup>a</sup>
Retina/eyes	Dmax <45 Gy <sup>b</sup>
Spinal cord	Dmax <50 Gy <sup>a</sup>
Temporal lobe/brain	Dmax <60 Gy <sup>a</sup>

<sup>a</sup>QUANTEC [3]<sup>b</sup>RTOG 0539<sup>c</sup>RTOG 0615**Table 5.3** Recommended normal tissue constraints for single-fraction SRS

Object at risk	Suggested dose constraints
Brain stem	Max <12.5 Gy <sup>a</sup>
Cochlea, ipsilateral	Max ≤14 Gy <sup>a</sup>
Cranial nerves (including optic nerve)	Max <12 Gy <sup>b</sup>
Optic nerve/chiasm	Dmax <12 Gy <sup>a</sup>
Spinal cord	Dmax <13 Gy <sup>a</sup>
Temporal lobe/brain	V12cc <5–10 cc <sup>a</sup>

<sup>a</sup>QUANTEC [3]<sup>b</sup>[4]**Table 5.4** Side effects for OTV and follow-up with suggested management

Acute	Focal alopecia, dermatitis, dizziness, fatigue, mucositis, xerostomia
Long-term	Eustachian tube dysfunction, facial numbness, hearing loss, skin fibrosis, xerostomia
Mitigating treatments	Skin moisturizers (i.e., Aquaphor <sup>®</sup> , aloe vera, Eucerin <sup>®</sup> ) for dermatitis, lidocaine-based mouthwash (i.e., “magic mouthwash”) for mucositis, calcium phosphate rinse for xerostomia (i.e., NeutraSal <sup>®</sup> )

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