Brainstem Glioma

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Contents

16.1 General Principles of Simulation and Target Delineation (Tables 16.1 and 16.2)

- Information on simulation
  - Recommended imaging

    Preoperative as well as postoperative imaging should be obtained.

    Imaging sequences should include at least T1, T1 with contrast, T2, and FLAIR.

    CT planning scan section thickness should ideally be ≤5 mm, although ≤2–3 mm remains ideal.

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Table 16.1 Target volume guidelines for low-grade intrinsic brainstem gliomas

Target volumes	Definition and description
GTV	Gross tumor on T2/FLAIR and T1 post-gadolinium images. All tumor cysts should be included in the GTV. Any MR imaging before or after surgical or chemotherapeutic intervention are helpful for identifying the extent of initial tumor involvement and evaluating residual disease
CTV	GTV + 0.5–1 cm expansion. This should be modified depending on initial tumor involvement and areas of suspected invasion and manually constrained by neuroanatomical structures where invasion is not likely (bony calvarium, falx, and tentorium)
PTV	CTV + 0.3–0.5 cm depending on institutional standards, patient immobilization and comfort, and image-guided capabilities (portal imaging vs. cone-beam CT)

Table 16.2 Target volume guidelines for diffuse pontine intrinsic gliomas

Target volumes	Definition and description
GTV	Gross tumor as identified on T2/FLAIR and T1 post-gadolinium MRI sequences. Any MR imaging before or after chemotherapeutic intervention are helpful for identifying extent of initial tumor involvement and evaluating residual disease. DIPG rarely undergo neoadjuvant chemotherapy or surgery; however, if biopsy is performed, this must also be taken into account
CTV	GTV + 1 cm. This should be modified depending on initial tumor involvement and areas of suspected invasion and manually constrained by neuroanatomical structures where invasion is not likely (bony calvarium, falx and tentorium
PTV	CTV + 0.3–0.5 cm depending on institutional standards, patient immobilization and comfort, and image-guided capabilities (portal imaging vs. cone-beam CT)

  - Patient positioning

    Supine positioning and immobilization with a short aquaplast mask are recommended. The use of photon vs. proton radiotherapy may dictate head position or the need for other special setup devices like table-associated range shifter, etc.

- Recommendations for target delineation (Figs. 16.1 and 16.2)
  - Imaging sequences and special circumstances

    Low-grade intrinsic gliomas tend to hypointense on T1-weighted and hyperintense on T2-weighted sequences, varying in degree following gadolinium infusion depending on independent tumor characteristics. Diffuse intrinsic pontine gliomas are expansile tumors that are homogeneously hypointense lesion on T1 and hyperintense on T2. MR T2 and T2 FLAIR are most likely to assist with defining the extent of disease and postoperative tumor bed (if applicable).
  - On-treatment imaging

    Daily cone-beam CT or other stereotactic technique is recommended given the small tumor volumes and commonly pediatric patients that may require sedation and airway protection during treatment.

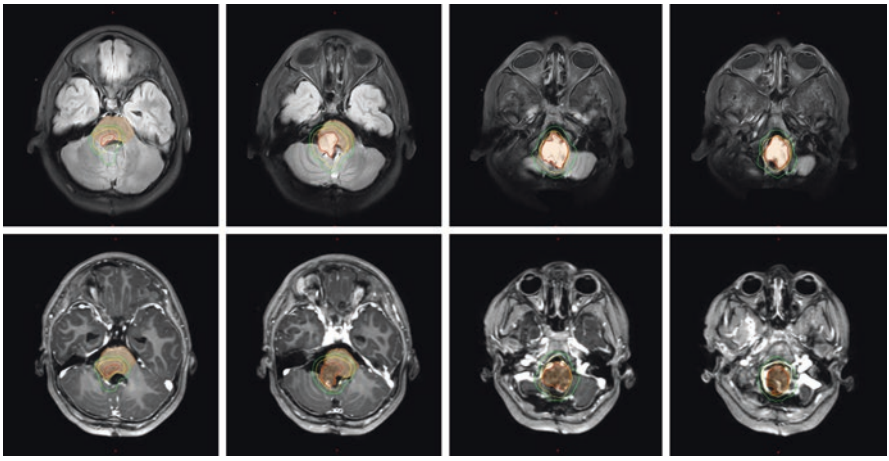

Fig. 16.1 Contours for a patient with low-grade intrinsic ganglioglioma involving the brainstem, WHO grade I. GTV, red; CTV, yellow; PTV, green. Top row, T2 FLAIR axial MRI sequences; bottom row (T1 3D post-contrast axial MRI sequences)

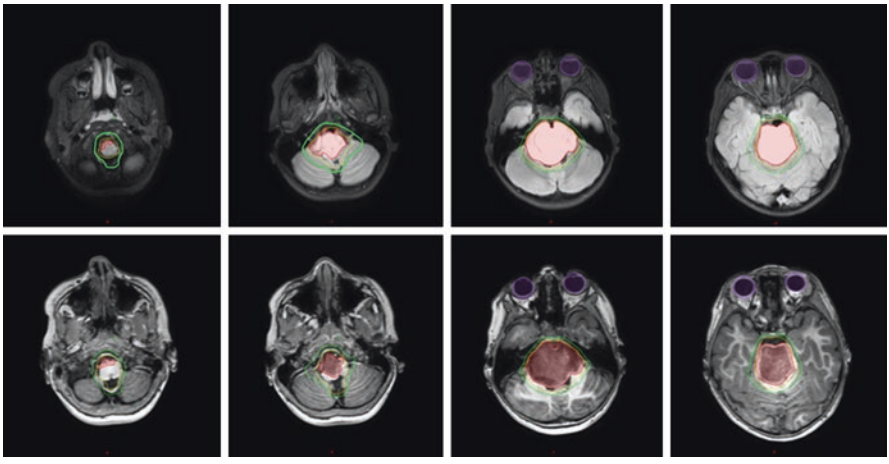

Fig. 16.2 Contours for a patient with a diffuse pontine intrinsic glioma. GTV, red; CTV, yellow; PTV, green. Top row (T2 FLAIR axial MRI sequences); bottom row (T1 3D post-contrast axial MRI sequences)

16.2 Dose Prescriptions

- A dose of 50.4 Gy in 1.8 Gy fractions is generally recommended for low-grade intrinsic brainstem glioma; however, doses ranging from 45 to 50.4 Gy are acceptable depending on the extent of brainstem involvement and ability to meet the dose constraints of the organs at risk.
- A dose of 54.0 Gy in 1.8 Gy fractions is generally recommended for diffuse pontine intrinsic glioma.

16.3 Treatment Planning Techniques (Fig. 16.3 and Table 16.3)

- Modality
  - 4–6 MV photons are typically utilized for treatment. Protons may also be considered.
- Treatment technique
  - Three-dimensional conformal radiotherapy (3D-CRT), intensity-modulated radiotherapy (IMRT), or volumetric modulated arc therapy (VMAT) may be used with the goal of sparing the brain, brainstem, temporal lobes, hippocampi, cochlea, and pituitary/hypothalamic complex if possible.
  - Treatment planning is aimed so that at least 100% of the PTV is covered by 95% of the prescribed dose. Depending on tumor complexity and proximity to organs at risk (brainstem, cochlea, temporal lobes, spinal cord, etc.), achieving 95% coverage of the PTV by 95% of the prescribed dose is acceptable. Furthermore, no more than 10% of the PTV should receive greater than 110% of the prescription dose as determined by the dose volume histogram (DVH).
  - A goal is to achieve uniform dose distributions (utilize wedges, compensators, or any additional techniques).
  - If using proton beam therapy (PBT):

    In patients with focal tumors or low-grade intrinsic brainstem gliomas, consider proton beam therapy, as these children are more likely to achieve a therapeutic benefit by reducing the risk of late toxicities of therapy from reducing radiation dose to normal tissue toxicity while maintaining target volume coverage.

    Because lateral and range expansions may vary for each beam, a single PTV is no longer adequate and should not be used to determine the distal range for the individual proton beams. Instead of prescribing a uniform dose to a PTV, the treatment plan should be created to encompass the CTV in the setting of expected uncertainties. Thus, the distal target margin is based on the distal aspect of the CTV, range uncertainty, setup margin

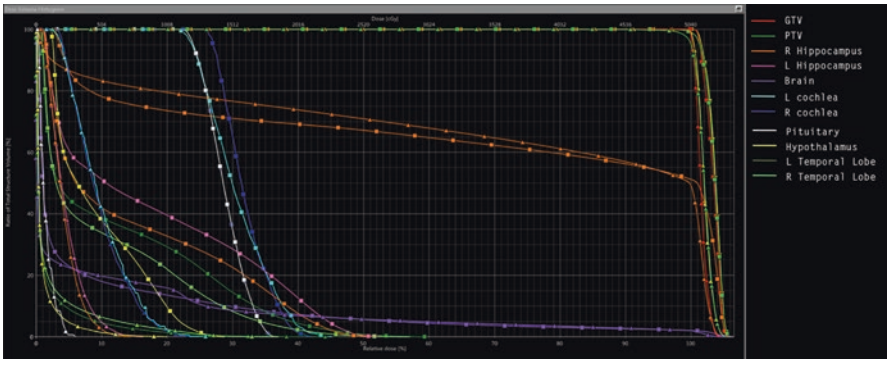

Fig. 16.3 Dose volume histogram diagnosed with low-grade glioma of the brainstem. Proton beam therapy plan, triangle line; VMAT, square line

Table 16.3 Recommended coverage guidelines and dose constraints

Organs at risk	Dose constraints (preferred)
PTV (planning target volume) [1]	Volume receiving 100% dose ≥99%
	Volume receiving 110% dose <10%
Cochlea [1]	Dose received by 50% cochlea ≤20 Gy
Optic globes [1]	Dose received by 90% optic globes ≤5 Gy
	Dose received by 50% ≤10 Gy
	Dose received by 10% ≤35 Gy
Optic nerves [1]	Dose received by 90% (single) optic nerve ≤10 Gy
	Dose received by 50% ≤54 Gy
	Dose received by 10% ≤56 Gy
Optic chiasm [1]	Dose received by 90% optic chiasm ≤10 Gy
	Dose received by 50% ≤54 Gy
	Dose received by 10% ≤56 Gy
Pituitary [2]	Mean <16 Gy
	Volume receiving 30 Gy <50%
Hypothalamus [2]	Mean <16 Gy
	Volume receiving 30 Gy <50%
Brainstem [3]	Mean <44.2 Gy
	Dose received by 0.1 cc brainstem (minus GTV) <56.6 Gy
	Dose received by 90% <44 Gy
	Dose received by 50% <52.2 Gy
	Dose received by 10% <55.4 Gy
Brainstem core [3]	Dose received by 0.1 cc <54.6 Gy
Spinal cord [1]	Volume receiving 50.4 Gy <5 cc
	Dose received by 50% spinal cord <26 Gy

(SM), and internal margin (IM). The IM compensates for all tissue size and shape variation within the CTV. The SM accounts for daily dosimetric and setup uncertainties related to patient positioning, software, and equipment.

16.4 Side Effects

- Acute side effects to evaluate during weekly on-treatment visits
  - Hair loss, fatigue, radiation dermatitis, headaches, nausea, aural fullness, risk of transient edema causing neurological symptoms or resulting in obstructive hydrocephalus.
- Late side effects and complications
  - Temporary or permanent hair loss, injury to the cochlea, causing partial or full hearing loss in one or both ears; hypopituitarism leading to endocrine abnormalities and infertility; neurocognitive decline impacting memory, IQ, and behavior; risk of injury to cranial nerves in the region, which could result in swallowing dysfunction, requiring feeding tube or tracheotomy; injury to the circle of Willis and surrounding vessels, increasing the risk of vasculopa-

thy and stroke; damage to the brainstem and normal brain tissue, which could result in permanent sensory deficit, paralysis, or death; risk of developing secondary malignancies.

- Clinical pearls for addressing those side effects
  - If patients are on steroids at the time of radiotherapy, utilization of gastric prophylaxis (e.g., ranitidine) and evaluation for oral thrush are recommended.
  - Premedicate patients with ondansetron 1 h prior to radiotherapy for prevention of nausea. May need to add a combination of dexamethasone, prochlorperazine, and lorazepam if nausea breaks through prophylaxis.

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Further Reading

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