PEDIATRIC PROTON RADIOTHERAPY CLINICAL PRACTICE MANUAL

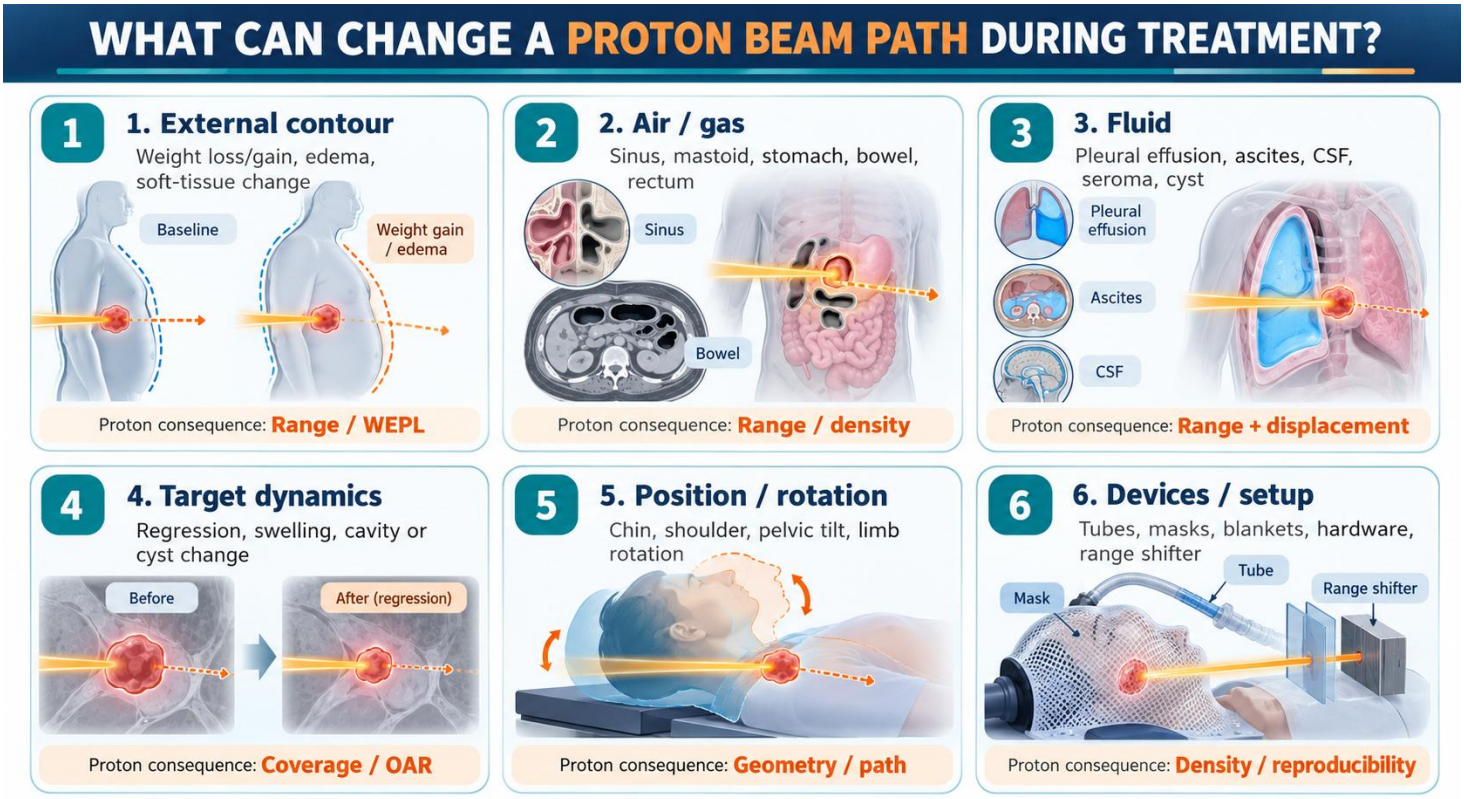
By Ory Haisraely MD, MPH

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PAGE U1 • SIMULATION & REPRODUCIBILITY - PROTON-SPECIFIC RISKS

Core principle

For proton therapy, daily image review is not only a positioning exercise. The clinical question is: “Is today’s proton beam path equivalent to the planning beam path?” Changes in density, external contour, fluid, target geometry, setup or devices can alter water-equivalent path length (WEPL), target coverage and OAR dose.



Simulation & positioning checklist

- Use indexed, reproducible immobilization appropriate to site and age; anesthesia/sedation only when needed for reliable reproducibility. Document the intended neck/chin, shoulder, arm, pelvic and limb position before planning.
- For scanning proton therapy, assess motion when relevant (4DCT, gated imaging or MRI). Interplay is particularly important near the diaphragm and for moving thoraco-abdominal targets.
- Place oxygen/feeding tubes, blankets, bolus and auxiliary devices consistently and, when possible, outside proton beam-entry paths. Determine the need for range shifters before simulation.
- Build the adaptation strategy before fraction 1: what will be reviewed daily, what requires verification CT/MRI, who reviews it, and what constitutes a replan trigger.

Evidence base: COG Pediatric RT Simulation Guideline (Alaei et al., Pediatr Blood Cancer 2026; DOI 10.1002/1545-5017.70460).

PAGE U2 • DAILY CBCT / VOLUMETRIC IMAGE REVIEW

What to inspect every fraction

Domain	Daily question	Why it matters for protons
External contour	Has body surface changed in a beam path? Weight loss/gain, edema, swelling, mask or soft-tissue change?	Changes path length and WEPL; persistent few-mm change can degrade target coverage.
Air / gas	New or changed sinus/mastoid, oral/nasal, stomach, bowel or rectal gas?	Air/tissue interfaces are high-impact range perturbations.
Fluid	Pleural/pericardial effusion, ascites, CSF/ventricular change, pseudomeningocele, seroma or cyst?	Adds/removes WET and can displace target/OARs.
Target dynamics	Regression, swelling, postoperative cavity resolution, cyst expansion/collapse?	Can create undercoverage or OAR overdose even with good setup.
Position / rotation	Chin/neck, shoulders, pelvic tilt, limb/joint rotation, DIBH or diaphragm reproducibility?	Rotations and beam-path changes may not be corrected by translational shifts.
Devices / hardware	Tubes, shunts, reservoirs, catheters, hardware, blankets or immobilization changed?	Density and reproducibility can affect range and dose calculation.
OAR displacement	Has bowel, kidney, heart, optic apparatus, brainstem or other serial OAR moved relative to target?	Target can remain geometrically aligned while OAR dose changes.

CBCT dose-calculation caution

Conventional CBCT is primarily an anatomic monitoring tool. Do not assume it is suitable for proton dose recalculation unless the system and conversion workflow have been validated. Use repeat CT or validated synthetic/virtual CT for dose verification.

Pediatric IGRT principle

COG recommends 3D imaging when bony anatomy is an unreliable target surrogate, margins are small, or rotational correction is important. Do not rely only on weekly imaging at the start of conformal therapy/CSI; daily imaging should first establish setup stability.

Evidence: Hua et al. Pediatr Blood Cancer 2020;67:e28629, PMID 32776500; Alaei et al. 2026 COG Simulation Guideline.

PAGE U3 • ACTION LEVELS & EVIDENCE-INFORMED ADAPTIVE WORKFLOW

DAILY IMAGE REVIEW -> ACTION LEVEL

GREEN **Treat**

Anatomy equivalent to planning; setup correction only.

YELLOW **Physics review**

Persistent/new gas, surface change, sinus filling, bladder/rectal change, or setup drift. Decide whether vCT/qCT is needed.

ORANGE **Verify dose**

Persistent density/geometry change, tumor/cyst/effusion change, or OAR displacement -> repeat CT/MRI or validated sCT/vCT and dose recalculation.

RED **Hold / adapt**

Robust target coverage fails, serial-OAR limit exceeded, or target exits intended treated volume.

Important - these are workflow triggers, not universal biological thresholds

A 2025 pediatric study of 21 non-CNS proton patients found that a 5-mm body-surface change could reduce CTV Dmin by 11.7%; approximately 3.9 mm and 6.3 mm surface change were associated with a 5% decrease in CTV Dmin and D99%, respectively. These data justify a low threshold for physics review of persistent beam-path contour changes, but they should not be treated as rigid replan cutoffs.

Scheduled verification imaging - evidence-informed options

Site / circumstance	Suggested verification strategy	Evidence / rationale
Brain / CSI / head & neck / extremity	Daily CBCT + validated vCT/sCT where available; consider vCT around weeks 1 and 3. MRI during treatment when target morphology cannot be assessed adequately on CBCT.	Sheikh et al. 2024: tumor changes were better detected by MRI; CBCT detected weight/tissue/setup changes.
Abdomen / pelvis / thorax (>15 fx)	Daily CBCT; evidence-informed qCT in week 1 and week 2, or earlier if a persistent beam-path change is seen.	In a pediatric IMPT cohort, abdomen/pelvis had the highest adaptation rate (23%); most adaptations were triggered in first 2 weeks.
Parameningeal RMS treated early during chemotherapy	Planned on-treatment MRI/verification imaging about 3 weeks after simulation (when simulation occurs ~1 week after chemo start).	Median 20% GTV reduction at 3 weeks; without adaptation CTV V95 fell 7-14% in some cases and OAR dose increased 6-21%.

Site / circumstance	Suggested verification strategy	Evidence / rationale
Cystic craniopharyngioma / cystic LGG	Planned serial MRI; frequency individualized to cyst burden and proximity to optic/hypothalamic structures.	Craniopharyngioma cyst growth during RT is common and can require drainage or replanning.

Key sources: Sheikh et al., Adv Radiat Oncol 2024, PMID 39610801; Ates et al., Phys Imaging Radiat Oncol 2025, PMID 40151313; Uh et al., Clin Oncol 2023, PMID 36764878; Bishop et al., IJROBP 2014, PMID 25052561.

PAGE U4 • CNS AND SKULL BASE

Disease	Daily / each-fraction review	Planned verification / adaptation emphasis
Ependymoma	Mask fit; weight; postoperative cavity/CSF collections; shunt/ventricular status; mastoid/sinus aeration in beam path; CTV-brainstem relationship.	Low threshold for CT/MRI after shunt revision, pseudomeningocele/subdural change, cavity evolution or beam-path aeration change.
Medulloblastoma / CSI	Head rotation/flexion, shoulders, vertebral alignment, junction geometry, inferior thecal-sac setup, body contour, abdominal gas, arm position.	Daily image guidance early; verify junction robustness and repeat CT with material weight/posture/anatomy change.
Germinoma / WVI	Ventricular size, hydrocephalus/shunt/ETV status, skull-base sinus change, optic/hypothalamic relationship.	Repeat imaging if ventricular anatomy or shunt status changes; tumor MRI per response pathway.
Craniopharyngioma	Cyst size surrogate if visible, ventricular size, optic/chiasm displacement, hydrocephalus, weight/fluid balance, sinus aeration.	For meaningful cystic component, planned serial MRI (often weekly or q1-2 weeks in high-risk geometry) and replan/drain if coverage or optic dose changes.
Low-grade glioma	Cystic component, mass effect, postoperative cavity, vision-related anatomy, mask fit.	Mid-treatment MRI is supported by ACNS0221; image sooner for cyst expansion or clinical change.
HGG / DMG	Steroid-related edema change, postoperative cavity, mass effect, hydrocephalus, brainstem/optic interface.	MRI rather than CBCT is needed to assess tumor morphology; use vCT/qCT for density/setup change.
Skull-base chordoma	Sinus/mastoid filling, weight, neck flexion, postoperative cavity, hardware, brainstem/optic interface.	Low threshold for verification CT/MRI during long high-dose course when critical interface changes by millimeters.

PAGE U5 • SOLID TUMORS AND LYMPHOMA

Disease / site	Daily / each-fraction review	Planned verification / adaptation emphasis
Ewing - pelvis / sacrum	Bowel/rectal gas, bladder, pelvic tilt, body contour, hardware, edema.	Persistent gas or contour change in beam path -> dose verification; joint/limb setup for extremity disease.
Ewing - chest wall / thorax	Respiratory excursion, diaphragm, lung inflation, pleural fluid, arm/shoulder position, tumor/soft-tissue regression.	4D/motion strategy must remain reproducible; repeat CT for effusion, large regression or body-contour change.
Wilms / flank	Bowel gas specifically along each beam path, stomach filling, diaphragm position, body contour, remaining kidney relation, vertebral symmetry.	Daily CBCT bowel-gas review. Wilms proton data showed up to 8% D100 loss with ΔWEPL 11.3 mm.
RMS - parameningeal	Nasal/oral/sinus air, tumor-related soft tissue, skin surface, mask fit, skull-base/optic relationship.	Scheduled MRI/verification around 3 weeks from simulation for early-RT regimens; adapt for regression or air/tissue change.
RMS - bladder/prostate	Bladder volume, rectal gas, bowel descent, pelvic rotation, catheter status.	Use reproducible bladder/bowel protocol; persistent deviation -> qCT/dose recalculation.
RMS - orbit	Globe position, sinus filling, mask fit, eyelid/soft-tissue swelling, target response.	Consider MRI/CT if tumor response changes globe/optic relationship.
RMS / Ewing - extremity	Limb/joint rotation, edema, seroma, skin contour, hardware, immobilization fit; include joint above/below as applicable.	Repeat CT if limb contour changes materially in the beam path or immobilization becomes nonreproducible.
Neuroblastoma - abdomen	Bowel/stomach gas, diaphragm, kidney/bowel displacement, body contour, vertebral alignment.	Midline tumors are more sensitive to GI gas; general anesthesia has been associated with greater GI-air variability.
Hodgkin - mediastinum	DIBH/lung inflation, heart displacement, shoulders/arms, weight, residual mass regression, pleural effusion/pneumonia.	Verification CT/dose recalculation if 3D anatomy differs; margins do not protect against effusion, pneumonia, weight loss or major regression.

Disease-specific evidence anchors: Ates et al. Cancers 2024 (Wilms, PMID 38339393); Lim et al. Clin Oncol 2021 (neuroblastoma, PMID 32962907); Uh et al. Clin Oncol 2023 (PM-RMS, PMID 36764878); Dabaja et al. Blood 2018 (mediastinal lymphoma, PMID 30108066).

PAGE U6 • KEY REFERENCES

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Ependymoma • Medulloblastoma • CNS Germ Cell Tumors • Craniopharyngioma • Pediatric Low-Grade Glioma • Pediatric High-Grade / Diffuse Midline Glioma

PAGE 1 • DECISION, PATHOLOGY, STAGING, SURGERY

Clinical bottom line

For localized intracranial ependymoma, the modern default is maximal safe resection followed by focal postoperative RT. Extent of resection is a major prognostic factor; second-look surgery should be revisited before RT when meaningful residual disease is safely resectable. Molecular subtype informs prognosis and trial stratification but should not automatically alter first-line RT dose outside a defined protocol.

Pre-RT checklist

☐ Integrated WHO diagnosis; PFA/PFB, ZFTA, YAP1 or spinal subtype documented (MYC)

☐ Pre-op MRI brain available for target reconstruction

☐ Early post-op MRI reviewed with operative note

☐ MRI entire neuraxis; metastatic status documented

☐ CSF cytology when appropriate and safely timed

☐ Extent of resection: GTR/NTR/STR; deliberate residual site recorded

☐ Second-look surgery discussed if residual is approachable

☐ Prior chemotherapy/platinum exposure documented

RT indication

Clinical scenario	Working recommendation	Evidence note
Localized intracranial disease after GTR/NTR	Focal postoperative RT — STANDARD	COG/SIOPE contemporary practice
Gross residual disease	Focal RT; re-discuss second-look surgery first	Residual disease strongly worsens outcome
Selected completely resected supratentorial historic grade 2	Observation only in defined protocol/risk setting	ACNS0831 permitted observation; recurrence risk remains meaningful
Disseminated disease	CSI-based therapy + primary/metastatic boosts	Protocol-dependent
Very young child	Do not omit RT based on age alone; individualize dose/timing	Modern focal RT may be preferable to prolonged RT deferral in selected cases

Do not miss

Do not contour from the postoperative MRI alone. The treatment volume must be reconstructed from preoperative disease extent, postoperative anatomy and the operative report.

PAGE 2 • SIMULATION AND TARGET DELINEATION

Simulation & imaging

- Supine immobilization with thermoplastic mask; anesthesia when required for reproducibility.
- Thin-slice planning CT with MRI fusion. Use pre-op MRI plus high-quality postoperative contrast T1 and T2/FLAIR.
- Review shunt, pseudomeningocele, subdural collections, mastoid/sinus aeration and postoperative cavity evolution before final beam selection.
- Daily image guidance; robust optimization for proton therapy rather than relying on a geometric PTV alone.

Target delineation

Volume	Definition / rule	Practical pitfall
Tumor bed / GTV	Postoperative bed + residual disease, reconstructed using pre-op MRI and operative findings	Do not reduce to visible enhancement only
CTV	ACNS0831: 5 mm anatomically constrained expansion	Edit at true barriers; not blind isotropic expansion
Brainstem interface	CTV expansion may be limited to ~3 mm into uninvolved brainstem	If brainstem was invaded, do not treat displacement as a barrier
Boost/high-risk volume	Residual disease / high-risk bed per protocol	Avoid creating a geographic miss to spare brainstem

Contouring pitfall

Posterior-fossa tumors can extend through the lateral recess/foramina of Luschka, through Magendie, along the cerebellopontine angle, or adhere to cranial nerves and brainstem. These directions should be checked explicitly on preoperative imaging rather than inferred from the postoperative cavity.

Proton-specific geometry

Avoid placing the distal edge of a dominant proton field in the brainstem when a reasonable beam arrangement exists. Inspect robustness specifically at the CTV–brainstem interface and review hotspot location, not only global D95.

PAGE 3 • DOSE, OAR PRIORITIES AND PLAN APPROVAL

Dose / fractionation

Scenario	Dose	Comment
Standard localized intracranial ependymoma	59.4 Gy(RBE) / 33 fx	Common COG/SIOPE backbone
Selected very young child with GTR / favorable anatomy	54 Gy(RBE) / 30 fx	Protocol/consensus-dependent; not automatic
Metastatic disease	CSI commonly ~36 Gy + boosts	Exact regimen protocol-dependent

Disease-specific OAR review

OAR	Must / protocol reference	Preferred proton planning goal
Brainstem	ACNS0831 proton goals included D50% ~52.4 Gy(RBE) and D0.1cc ~56.6 Gy(RBE); max values were higher	Keep high-dose volume and distal-edge uncertainty as low as possible; prioritize serial-organ safety over small coverage gains
Cochlea	No single pediatric hard limit applies	Aim well below 35 Gy mean; often ≤20–25 Gy if feasible, especially after platinum
Optic apparatus	Serial-organ tolerance applies if uninvolved	Keep below prescription/high-dose region; ALARA when not adjacent to target
HPA / pituitary	No validated 'safe' threshold	ALARA; report mean dose and counsel using PENTEC endocrine risk
Normal brain / temporal lobes / hippocampi	No ependymoma-specific hard limits	Report mean/Vx; minimize low/intermediate dose and integral dose

PENTEC interpretation

PENTEC is used as dose–risk evidence, not as a universal hard-constraint table. Examples: cochlear mean dose ≤35 Gy with RT alone is associated with <5% modeled hearing-loss risk, while platinum exposure shifts risk upward; HPA endocrine risk rises continuously with dose; neurocognitive risk depends on age, brain volume and dose.

Plan approval checklist

☐ Pre-op extent incorporated
☐ CTV–brainstem interface reviewed slice-by-slice
☐ No avoidable distal edge in brainstem/optic apparatus
☐ Anatomic-change sensitivity assessed
☐ Residual disease separately identified
☐ Robust CTV coverage acceptable
☐ Cochlea/HPA/normal brain goals reviewed
☐ Verification/adaptation plan documented

PAGE 4 • ON-TREATMENT IMAGING, FOLLOW-UP, RECURRENCE AND REFERENCES

On-treatment / adaptive management

- Daily IGRT/CBCT: review mask fit, weight/body contour, shunt/ventricular status, postoperative cavity/CSF collections, and any mastoid/sinus aeration within a proton beam path.
- Verification CT/MRI is triggered by shunt revision, pseudomeningocele/subdural or cavity evolution, persistent beam-path surface change, altered mastoid/sinus aeration, or any new uncertainty at the CTV-brainstem interface.
- Replan if robust target coverage or critical-OAR dose is no longer acceptable; do not wait for a scheduled scan if anatomy has clearly changed.

Follow-up

Time point	Minimum review
~4–12 weeks after RT	MRI brain with contrast; neurologic exam; document treatment-related imaging change
Years 0–2	MRI brain q3–4 months; spine/CSF surveillance according to disease risk/protocol
Years 3–5	MRI spacing can increase if stable; maintain endocrine, hearing and neurocognitive surveillance
Long term	Monitor endocrine function, hearing, vasculopathy, neurocognition, second neoplasms and school/functional outcomes

Recurrence

For isolated local recurrence, maximal safe re-resection and reirradiation can be considered in selected patients. For reirradiation, perform formal composite dose review; PENTEC reports approximately 5–7% brain/brainstem necrosis around cumulative prescription $EQD2_2$ near 112 Gy in heterogeneous pediatric series.

Key references

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2. COG ACNS0831 public protocol: focal RT dose, target and OAR requirements. Protocol
3. European standard clinical practice recommendations for newly diagnosed childhood ependymoma. EJC Paediatric Oncology. 2025. Open article
4. Patteson BE et al. Proton RT outcomes in 150 pediatric ependymoma patients. Neuro Oncol. 2021;23:156-166. PMID 32514542. PubMed
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PAGE 1 • MOLECULAR/CLINICAL RISK AND RT DECISION

Clinical bottom line

For most children ≥3 years, medulloblastoma therapy includes CSI, primary-site boost and chemotherapy. Modern risk assignment must integrate metastatic status, residual disease, histology and molecular subgroup. Do not adopt experimental CSI de-escalation from a trial arm before outcome data support routine use.

Required review before RT

- ☐ Methylation/integrated molecular group: WNT, SHH (including P53), Group 3, Group 4
- ☐ Histology and TP53 status when relevant (SHH)
- ☐ Pre-op MRI and early post-op MRI; residual area measured
- ☐ MRI entire spine with appropriate timing
- ☐ CSF cytology after postoperative recovery
- ☐ M-stage documented
- ☐ Audiogram and platinum plan documented
- ☐ Surgery-to-RT timing coordinated; avoid unnecessary delay

Working risk framework

Category	Typical RT backbone	Important caveat
Average/standard-risk older child	23.4 Gy CSI + tumor-bed boost to 54 Gy	18 Gy CSI was not noninferior overall in young average-risk patients on ACNS0331
High-risk / metastatic / large residual	~36 Gy CSI + primary boost ~54–55.8 Gy; metastatic boosts as indicated	Exact intensity is protocol- and biology-dependent
Very young child	RT may be deferred or modified within infant-specific strategy	Histology/molecular subgroup matters; avoid reflex CSI outside protocol

Molecular caution

WNT biology is favorable, but routine CSI dose reduction below validated standard therapy should remain protocol-driven. Conversely, high-risk molecular features can intensify systemic therapy without necessarily changing an established RT field/dose outside trial guidance.

PAGE 2 • CSI AND BOOST CONTOURING

CSI target essentials

- Cranial CTV: entire intracranial subarachnoid space with attention to cribriform plate, temporal fossae, skull-base foramina and meningeal recesses.
- Spinal CTV: thecal sac/CSF space to its inferior termination with coverage of exiting nerve-root sleeves according to atlas/protocol.
- Review postoperative collections and shunts; do not exclude meningeal spaces based on convenience of beam arrangement.
- In skeletally immature children, vertebral-body coverage strategy must be explicit to reduce asymmetric growth deformity; follow protocol/institutional pediatric spine policy.

Primary-site boost

Element	Modern principle	Pitfall
GTV/bed	Postoperative tumor bed + residual disease, reconstructed using pre-op MRI	Do not default to whole posterior fossa
CTV	Common contemporary tumor-bed margin ~1–1.5 cm, anatomically constrained	Margin depends on protocol; avoid crossing true barriers blindly
Metastatic lesions	Boost visible metastases / persistent nodules as protocol directs	Document cumulative dose and proximity to cord/brainstem

Contouring pitfall

The highest-impact CSI errors are geographic: inadequate cribriform/skull-base coverage, inferior spinal/thecal-sac miss, or unstable field junctions.

PAGE 3 • DOSE, OAR PRIORITIES AND PROTON PLAN APPROVAL

Dose / fractionation

Scenario	CSI	Primary site
Average-risk (validated conventional backbone)	23.4 Gy / 13 fx	Boost to 54 Gy total
High-risk / metastatic	Usually ~36 Gy / 20 fx	Boost to ~54–55.8 Gy total
Metastatic deposits	CSI backbone	Site-specific boost per protocol/response

OAR priorities in proton CSI

OAR/structure	Planning goal
Cochlea	Mean dose as low as feasible; preferentially <20–25 Gy when compatible with target, especially with cisplatin; ≥35 Gy is a meaningful PENTEC risk threshold
Brainstem	Keep boost hotspot out of brainstem; total dose generally should not exceed primary prescription when brainstem uninvolved
HPA / hypothalamus / pituitary	ALARA; report mean dose; endocrine risk is continuous, not binary
Hippocampi / temporal lobes / supratentorial brain	No validated pediatric hard limits for CSI; minimize low/intermediate dose and report dose-volume metrics
Thyroid / heart / lungs / esophagus / kidneys / bowel	Exploit proton CSI to reduce integral and low/intermediate dose; document organ means/Vx
Vertebral bodies / growth plates	Avoid asymmetric partial-body dosing in growing child; strategy must be documented
Gonads / breasts	ALARA; document scatter/exit-dose advantage when clinically relevant

Proton plan approval

☐ Entire neuraxis reviewed in 3 planes
☐ Inferior thecal sac included
☐ Vertebral-body strategy age-appropriate
☐ Boost bed reconstructed from pre-op imaging
☐ Cribriform/skull-base recesses adequate
☐ Junction robustness reviewed
☐ Cochlea/HPA/thyroid/heart means reviewed
☐ No avoidable distal edge in brainstem

PAGE 4 • IMAGING, FOLLOW-UP AND REFERENCES

On-treatment imaging

- Daily IGRT for proton CSI: explicitly review head flexion/rotation, shoulders, vertebral alignment, junction geometry, inferior thecal-sac setup and body contour. Confirm junction robustness rather than relying on translational alignment alone.
- Repeat CT/dose verification if weight/body contour, posture, immobilization, abdominal gas or other density change alters a beam path; treat persistent setup or junction change as a proton robustness issue, not merely a positioning issue.
- Audiology and chemotherapy coordination are essential because platinum-related ototoxicity can dominate cochlear late effects.

Post-RT surveillance

Domain	Working follow-up
Imaging	Brain + spine MRI per protocol; early post-treatment baseline commonly within ~4–12 weeks, then frequent surveillance during first 2–3 years
Hearing	Serial audiology during/after platinum and RT
Endocrine/growth	Annual or risk-adapted endocrine follow-up; thyroid and HPA are high-priority after CSI
Neurocognition	Baseline when feasible + longitudinal testing; school performance and processing speed are sensitive domains
Late effects	Vasculopathy, second neoplasm, spinal growth/deformity, fertility and cardiopulmonary risk

Evidence note

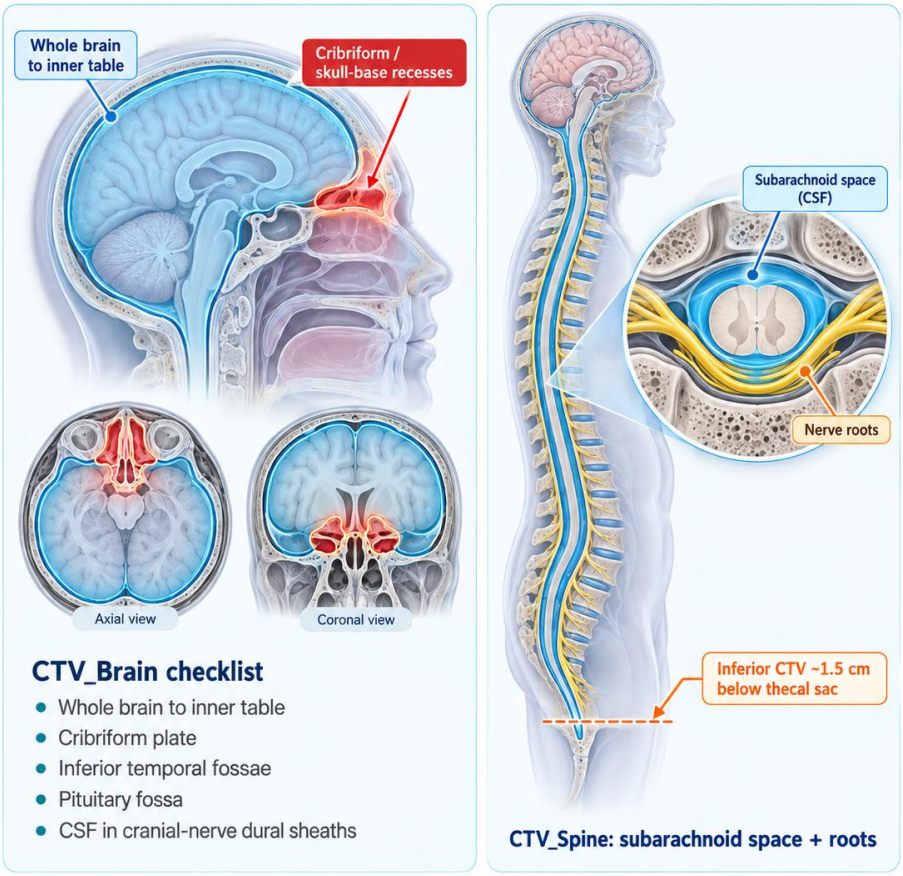
ACNS0331 established that involved/tumor-bed boost can replace whole-posterior-fossa boost for average-risk disease, while 18 Gy CSI in children aged 3–7 did not meet the trial's noninferiority objective overall.

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MEDULLOBLASTOMA • VISUAL CONTOURING SUMMARY

Original schematic based on ACNS2031 text guidance; ACNS2031 images are not reproduced



CTV_Brain checklist

- Whole brain to inner table
- Cribriform plate
- Inferior temporal fossae
- Pituitary fossa
- CSF in cranial-nerve dural sheaths

CTV_Spine: subarachnoid space + roots

Plan-review pearl

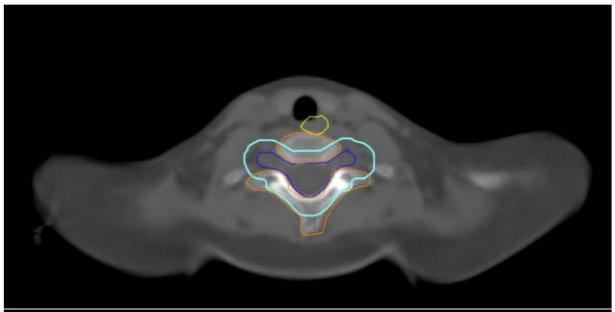
The largest CSI failures are geographic: skull-base/cribriform miss, inadequate nerve-root coverage, incorrect inferior spinal extent, or unstable junctions. Proton conformality never compensates for an incomplete neuraxis CTV.

Source concept: user-supplied ACNS2031 contouring atlas, pp. 3, 24-28, 48-75. Original drawing; atlas images not copied.

Institutional working draft • September 2026 • Verify against active protocol before clinical adoption.

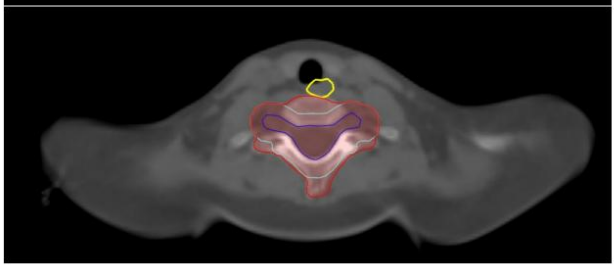
Vertebral coverage

Vertebral Body Sparing



Non- Vertebral Body Sparing

Vertebral body (VB) contours- to be covered by 18 Gy for skeletally immature patients (<13 yo). PTV_CSI-2340 in cyan, VB_1800 in red



CTV_CSI / PTV_CSI

V95% ≥ 95% of CSI prescription

VB_1800 [skeletally immature]
V18Gy ≥ 95%
Preferred: D95% ≥ 18 Gy
Avoid marked asymmetric / focal vertebral underdosage

PAGE 1 • DIAGNOSIS, STAGING AND RT INDICATION

Clinical bottom line

The first decision is not the proton plan — it is correct classification as germinoma versus NGGCT using imaging, serum/CSF markers and tissue when indicated. Localized germinoma is usually treated with chemotherapy plus whole-ventricular RT; disseminated disease requires CSI. For NGGCT, reduced whole-ventricular fields after chemotherapy produced excess spinal failures in ACNS1123, so CSI remains an important reference backbone outside a validated reduced-volume strategy.

Required staging

☐ Serum and CSF AFP + β-hCG before treatment

☐ CSF cytology when safe

☐ Biopsy when markers/imaging do not establish diagnosis

☐ Second-look surgery discussed for residual NGGCT / suspected teratoma

☐ MRI brain and entire spine

☐ Document pineal, suprasellar and/or bifocal disease

☐ Response MRI after induction chemotherapy

☐ M-stage and marker response documented before RT

Working RT framework

Disease / response	RT approach	Key evidence
Localized pure germinoma, CR after chemo	COG: 18 Gy WVI + 12 Gy boost (30 Gy total)	ACNS1123
Localized pure germinoma, PR after chemo	COG: 24 Gy WVI + 12 Gy boost (36 Gy total)	ACNS1123
Localized germinoma, European CR	SIOP-CNS-GCT II: 24 Gy WVRT without boost	Final report 2026
Disseminated germinoma	CSI + primary/metastatic boost	Protocol-dependent
Localized NGGCT	CSI-based therapy remains reference; primary total ~54 Gy	Reduced WVI-only ACNS1123 had spinal failures

Evidence conflict worth preserving

COG and current European germinoma strategies differ. COG uses lower WVI with a boost; SIOP-CNS-GCT II supports 24 Gy whole-ventricular RT without a boost for localized germinoma in complete remission after chemotherapy.

PAGE 2 • WHOLE-VENTRICULAR / CSI CONTOURING

Whole-ventricular target

- Contour the entire ventricular system on planning MRI/CT fusion, including lateral, third and fourth ventricles and ventricular recesses according to protocol atlas.
- Use diagnostic pre-chemotherapy imaging to define the original primary-site/tumor-bed boost volume; response does not erase the initial disease footprint.
- For suprasellar disease, explicitly review optic chiasm, hypothalamus, pituitary stalk and temporal-lobe dose.
- For bifocal disease, confirm that markers and staging truly support germinoma; bifocality does not automatically equal disseminated disease, but management is protocol-specific.

NGGCT

- After induction chemotherapy, residual mass may represent viable malignant GCT or teratoma; second-look surgery can change RT planning.
- If using a CSI-based backbone, contour neuraxis as for other CSI indications and define the primary boost from the pre-chemotherapy extent plus postoperative/residual anatomy.
- Do not extrapolate ACNS1123 reduced WVI-only RT as a default: spinal-only relapses drove early closure.

Proton rationale

Whole-ventricular RT is an ideal geometry for proton normal-brain sparing because large portions of the supratentorial brain, temporal lobes and hippocampal regions lie near—but outside—the ventricular target. For CSI, the same integral-dose, thyroid, cardiopulmonary and gonadal advantages described for medulloblastoma apply.

Contouring pitfall	Correction
Boost drawn only on post-chemo residual	Reconstruct original tumor bed using pre-treatment MRI
Fourth ventricle omitted from WVI	Use a complete ventricular atlas; review sagittal/coronal planes
Hippocampal sparing prioritized over ventricular coverage	Target coverage takes priority; hippocampi are planning/reporting structures, not avoidance structures if overlapping
NGGCT treated with WVI because of good response	Field selection must follow validated protocol, not response alone

PAGE 3 • DOSE, OAR REVIEW AND PROTON PLAN APPROVAL

Dose summary

Scenario	Dose / field
COG localized germinoma CR	18 Gy WVI + 12 Gy boost
COG localized germinoma PR	24 Gy WVI + 12 Gy boost
SIOP localized germinoma CR	24 Gy WVRT, no boost
Historical RT-alone localized germinoma	CSI ~24 Gy + primary boost to ~40 Gy; not the modern COG chemo pathway
Localized NGGCT reference backbone	36 Gy CSI + primary total ~54 Gy (ACNS0122 reference); exact current regimen protocol-dependent

OAR / planning priorities

Structure	Planning approach
Normal brain	Report mean dose and V12/V18/V24/V30; minimize integral dose
Hippocampi / temporal lobes	ALARA outside WVI; no validated pediatric hard constraint
HPA / pituitary	ALARA if not directly involved; endocrine risk rises continuously with dose
Optic nerves / chiasm	Serial-organ constraints; suprasellar target may overlap—document trade-off
Cochlea	Mean dose ALARA; <35 Gy has favorable PENTEC risk, lower preferred with platinum
Thyroid / heart / lungs / kidneys / gonads (CSI)	Exploit proton CSI to reduce mean and low-dose exposure

Plan approval checklist

☐ Diagnosis verified as germinoma vs NGGCT
☐ Entire ventricular system included
☐ WVI dose matches response pathway
☐ Normal brain/hippocampi/HPA metrics reviewed
☐ Pre-chemo target reconstructed
☐ Fourth ventricle/recesses reviewed
☐ CSI used when indicated
☐ Robustness acceptable near optic/hypothalamic structures

PAGE 4 • RESPONSE ASSESSMENT, FOLLOW-UP AND REFERENCES

During / after RT

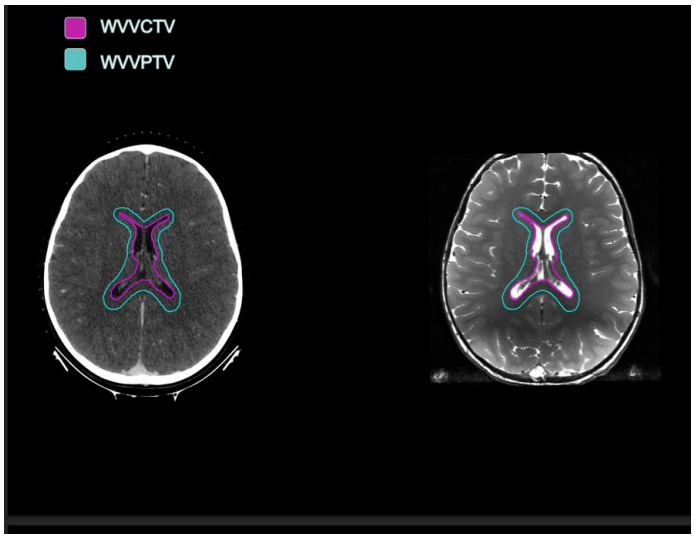
- MRI-based response assessment should distinguish residual scar/teratoma from active disease in the context of marker normalization and operative findings.
- Daily review should include ventricular size surrogate, hydrocephalus/shunt/ETV status, body contour and skull-base sinus anatomy. Verification imaging is indicated when these changes could alter ventricular coverage or proton range.
- Post-treatment surveillance must include markers when appropriate and neuraxis imaging according to disease type/protocol.

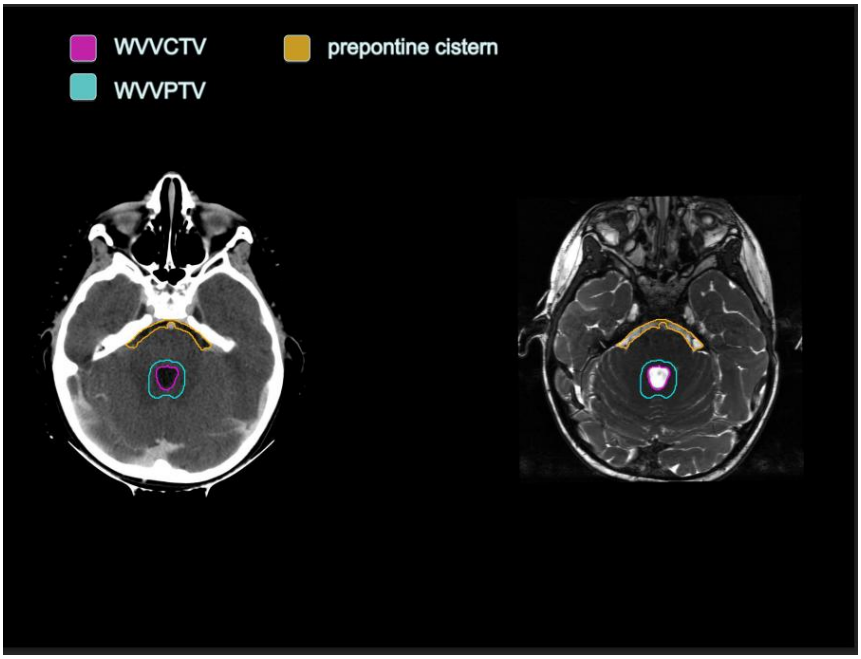
Clinical pearl

For germinoma, a smaller boost or lower WVI dose is only useful if the ventricular field is anatomically complete. For NGGCT, the key lesson from ACNS1123 is the opposite: excellent local response does not eliminate the risk of occult spinal disease.

Key references

1. Bartels U et al. COG ACNS1123 localized germinoma response-based RT. Neuro Oncol. 2022. PMID 34850169. PubMed
2. SIOP-CNS-GCT II final germinoma report: 24 Gy WVRT without boost in CR. 2026. PMID 42234858. PubMed
3. Fangusaro J et al. COG ACNS1123 localized NGGCT reduced-volume RT. J Clin Oncol. 2019. PMID 31545689. PubMed
4. Murphy ES et al. ACNS1123 NGGCT patterns of failure. IJROBP. 2022. PMID 34990779. PubMed
5. Correia D et al. Whole-ventricular proton vs photon planning. Clin Transl Radiat Oncol. 2019;15:53-61. CC BY-NC-ND. Open article




WVVCTV
WVVPTV
prepontine cistern

CHAPTER 4 | CRANIOPHARYNGIOMA

Limited surgery + focal proton radiotherapy, with active cyst monitoring

PAGE 1 • RT INDICATION AND MULTIDISCIPLINARY DECISION

Clinical bottom line

The modern strategy aims to preserve hypothalamic, visual and vascular function: maximal safe/limited surgery rather than radical resection when morbidity would be high, followed by focal RT for residual or recurrent disease. Proton therapy is attractive because survival is excellent and the target is centrally located near critical structures, but cyst dynamics make adaptation a core part of treatment.

Pre-RT checklist

- ☐ Adamantinomatous vs papillary diagnosis documented
- ☐ Pre-op and serial post-op MRI reviewed
- ☐ Solid + cystic components separately identified
- ☐ Operative report: hypothalamic/optic/chiasm/stalk adherence documented
- ☐ Baseline visual acuity and fields
- ☐ Baseline endocrine function / DI status
- ☐ Hydrocephalus, reservoir/catheter/shunt status
- ☐ Decision documented: adjuvant RT vs surveillance until progression

When RT is commonly used

Scenario	Working approach
Residual tumor after limited/STR surgery	Focal RT — common standard when durable control is desired
Progressive residual / recurrent disease	Focal RT after multidisciplinary review; cyst drainage or surgery if needed
Gross-total resection	Observation generally appropriate; RT reserved for recurrence
Very young child	Individualize timing, balancing progression risk vs developmental toxicity

Do not miss

Baseline endocrine deficits are often caused by the tumor/surgery and should not be attributed automatically to RT. The plan should still minimize dose to uninvolved hypothalamus/temporal brain because neurocognitive and vascular outcomes remain relevant.

PAGE 2 • SIMULATION, TARGET AND CYST MANAGEMENT

Target definition

Volume	Working definition
GTV	Residual solid + cystic tumor or postoperative tumor bed, using contrast T1 and T2 imaging
CTV	RT2CR prospective proton study: 5 mm, anatomically constrained
PTV / robustness	Technique-specific; proton plans should use robust optimization and evaluate cyst-related geometry changes

Cyst management

- Cysts can enlarge during a 6-week course and can shift the optic apparatus, hypothalamus and proton range path.
- Establish a prospective imaging plan before fraction 1. For a substantial cystic component, weekly or every-1–2-week MRI/verification imaging is reasonable; image sooner with headache, visual change, hydrocephalus or setup/anatomic concern.
- Replan when cyst change compromises robust target coverage or meaningfully increases optic/brainstem dose. Drainage/reservoir intervention may be preferable to repeated large-volume replanning in selected cases.

Contouring pitfall

Do not simply exclude a previously present cyst wall because the cyst has collapsed. The preoperative and pre-RT disease footprint plus surgical findings should guide whether that surface remains at risk.

Proton-specific beam review

- Avoid distal-edge termination in optic chiasm/brainstem when possible.
- Assess robustness to cyst expansion and changes in sphenoid/sinus aeration.
- Prefer beam arrangements that reduce low-dose exposure to temporal lobes, hippocampi and frontal brain while preserving robust coverage.

PAGE 3 • DOSE AND OAR OBJECTIVES

Dose

Setting	Dose
Standard focal proton RT	54 Gy(RBE) in 30 fractions (1.8 Gy/fx) — RT2CR prospective backbone
Alternative modern series	~50.4–54 Gy(RBE), depending on protocol/institution and proximity to critical structures

OAR review

OAR	Draft planning objective / interpretation
Optic nerves/chiasm	Avoid hotspots; preferred Dmax/D0.03cc at or below ~54–55 Gy if not part of target. If inseparable from tumor, document trade-off rather than underdose blindly.
Brainstem	Keep at/below prescription when uninvolved; avoid distal-edge uncertainty and hotspots.
Hypothalamus	Often adjacent or involved. Minimize uninvolved dose; report mean dose and volume metrics rather than claiming a safe threshold.
Pituitary	Function may be abnormal pre-RT; still ALARA if anatomically separable.
Temporal lobes / hippocampi / normal brain	ALARA; proton value is mainly reduction in low/intermediate dose and integral dose.
Cochlea	Mean dose ALARA; usually readily spared with central suprasellar targets.
Cerebral vasculature	No validated planning constraint; minimize unnecessary high/intermediate dose, especially in young children.

Evidence note

RT2CR treated children/adolescents with limited surgery + proton therapy to 54 Gy(RBE) using a 0.5-cm CTV margin and demonstrated excellent disease control. A separate proton series of 77 patients found cyst growth requiring replanning or decompression in 9 patients, supporting active on-treatment imaging.

Plan approval checklist

☐ Solid and cystic GTV both included
☐ 5-mm CTV anatomically edited
☐ Cyst-change sensitivity tested
☐ Normal brain/temporal/HPA doses reviewed
☐ Pre-op footprint reviewed
☐ Optic/chiasm overlap explicitly documented
☐ Robustness acceptable
☐ Adaptive imaging schedule entered before start

PAGE 4 • FOLLOW-UP AND REFERENCES

During RT

- Frequent visual and neurologic symptom review; urgent imaging for visual decline, severe headache, vomiting or hydrocephalus concern.
- Monitor weight, steroids, DI/fluid balance and endocrine medications because these can alter anatomy or clinical tolerance.
- For a substantial cystic component, planned serial MRI is preferred because CBCT cannot reliably characterize cyst/tumor morphology. Daily setup imaging should still assess ventricular size, body contour and reproducibility.

Post-RT

Domain	Follow-up priority
MRI	Early baseline after RT, then frequent imaging in first years; distinguish cyst fluctuation from true progression
Vision	Formal visual acuity/fields longitudinally
Endocrine	Lifelong endocrine care; hypothalamic obesity and pituitary deficits are major survivorship issues
Neurocognitive	Longitudinal school/neuropsychological assessment, especially in young children
Vascular	Remain alert to late vasculopathy/stroke risk after sellar/suprasellar RT

Key references

1. Merchant TE et al. RT2CR: proton therapy + limited surgery, phase II. Lancet Oncol. 2023. PMID 37084748. PubMed
2. Jimenez RB et al. Proton RT for pediatric craniopharyngioma. IJROBP. 2021. PMID 33662460. PubMed
3. KiProReg prospective proton registry: modern target planning and outcomes in childhood craniopharyngioma. IJROBP. 2024. Article
4. Proton beam therapy for craniopharyngioma: systematic review/meta-analysis. 2024. PMID 39543740. PubMed
5. Wheeler G et al. PENTEC central endocrine complications. IJROBP. 2024. PMID 37269265. PubMed

PAGE 1 • INDICATION, MOLECULAR REVIEW AND TIMING

Clinical bottom line

RT remains highly effective for unresectable/progressive pLGG, but timing is increasingly selective because surgery, chemotherapy and MAPK-pathway targeted therapy can defer or avoid RT in many children. When RT is chosen, proton therapy is particularly attractive for long-term survivors with focal tumors near visual, endocrine or cognitive structures.

Pre-RT checklist

☐ Histology and WHO diagnosis; biopsy status documented

☐ BRAF fusion vs BRAF V600E / other MAPK alteration

☐ NF1 status

☐ Tumor site: optic pathway/hypothalamic, brainstem, hemispheric, cerebellar, spinal

☐ Prior surgery and residual disease

☐ Prior chemotherapy / targeted therapy and response

☐ Baseline vision for optic pathway tumors

☐ Baseline endocrine function for hypothalamic/suprasellar tumors

When RT is commonly considered

Scenario	RT role
Progressive/unresectable disease after systemic therapy	Strong option, especially in older child or when durable control is needed
Vision-threatening optic pathway/hypothalamic tumor	Consider when progression threatens vision and surgery/systemic options are inadequate or unsuitable
Brainstem/spinal LGG	Focal RT can provide durable control when unresectable/progressive
NF1-associated LGG	Prefer non-RT options when effective; RT reserved for selected refractory cases because of vasculopathy/second-tumor concerns
Completely resected focal LGG	No adjuvant RT

Modern decision point

The question is usually not 'does RT work?' — it does. The question is whether immediate durable local control outweighs the late-effect risk compared with another line of systemic/MAPK-directed therapy.

PAGE 2 • SIMULATION AND TARGET DELINEATION

Target definition

Volume	Rule
GTV	MRI-defined tumor; for pilocytic tumors include enhancing and relevant T2/FLAIR components and tumor cysts
CTV	COG ACNS0221: 5 mm anatomically limited; NOPHO 2026: usually 5 mm, consider 10 mm for infiltrative diffuse grade 2 patterns
Partially resected tumor	CTV should include entire credible tumor bed, not only residual nodule
PTV / robustness	Photon PTV typically 3–5 mm; proton: robust optimization and image-guidance strategy documented

Required mid-treatment check

ACNS0221 required mid-treatment imaging to detect possible tumor enlargement. This is particularly relevant for cystic pilocytic tumors and for proton plans in which a small geometric change can alter range or OAR dose.

Site-specific contouring priorities

- Optic pathway/hypothalamic: include true tumor, not edema; carefully define optic nerves/chiasm/tracts and hypothalamus.
- Brainstem: distinguish focal/exophytic LGG from diffuse midline glioma; avoid unnecessary brainstem margin.
- Spinal cord: define longitudinal T2 abnormality and true cord expansion; motion is limited but range/vertebral growth considerations remain.

PAGE 3 • DOSE, OAR OBJECTIVES AND PROTON APPROVAL

Dose

Source / setting	Dose
COG ACNS0221	54 Gy / 30 fx
NOPHO 2026 consensus	45–54 Gy in 1.8-Gy fractions, individualized by age/site/extent
Modern proton series	54 Gy(RBE) common; selected brainstem/spinal tumors may receive 50.4 Gy(RBE)

OAR priorities

Tumor site	Key OARs / plan objective
Optic pathway / hypothalamic	Contralateral optic nerve/retina when uninvolved, chiasm, hypothalamus, pituitary, hippocampi, temporal lobes, normal brain; vision preservation overrides cosmetic DVH goals
Brainstem	Brainstem high-dose volume, cochlea, cerebellum, spinal cord; avoid distal-edge/high-LET concentration in critical uninvolved tissue
Hemispheric	Normal brain, hippocampi, temporal/frontal white matter, optic structures if near field
Spinal	Cord outside target, vertebral bodies/growth plates, thyroid/esophagus depending level

Preferred planning goals

Cochlea: mean dose as low as possible and preferably well below 35 Gy. HPA: report mean dose and use PENTEC endocrine risk rather than a single threshold. Hippocampi/normal brain: no validated pLGG hard limit — minimize dose-volume exposure. For optic pathway tumors, do not underdose tumor simply to meet an arbitrary optic constraint when the optic apparatus is the target.

Plan approval checklist

☐ Histology/molecular/site confirmed
☐ GTV includes cystic disease if relevant
☐ Tumor bed included after partial resection
☐ Robustness acceptable
☐ Systemic alternatives considered
☐ 5-mm CTV used unless justified otherwise
☐ Vision/endocrine priorities reviewed
☐ Mid-treatment imaging scheduled

PAGE 4 • RESPONSE, PSEUDOPROGRESSION AND REFERENCES

Response and follow-up

- Use RAPNO principles for MRI response; for optic pathway tumors, visual function is a clinical endpoint and should be followed alongside imaging.
- Pseudoprogression after RT/protons is common in pLGG; in a large proton series it occurred in roughly one-third of patients. Avoid declaring early treatment failure from imaging alone.
- MRI baseline is commonly obtained within ~6–12 weeks after RT, then at 3–4 month intervals initially, spacing with stability and clinical context.
- Long-term endocrine, vascular, neurocognitive, visual and second-neoplasm surveillance is essential.

NF1 caution

Because NF1 increases baseline vasculopathy and secondary-tumor risk, RT should be reserved for situations in which the expected disease-control benefit clearly outweighs available non-RT alternatives. Proton therapy reduces integral dose but does not remove the biologic predisposition.

Key references

1. Embring A et al. NOPHO RT Working Group consensus for pediatric LGG. Acta Oncol. 2026. PMID 41693214. PubMed
2. Cherlow JM et al. COG ACNS0221 conformal RT: 54 Gy, 5-mm CTV. IJROBP. 2019. PMID 30419305. PubMed
3. Indelicato DJ et al. Outcomes following proton therapy for pediatric LGG. IJROBP. 2019. PMID 30684665. PubMed
4. Fangusaro J et al. RAPNO response assessment in pediatric LGG. Lancet Oncol. 2020. PMID 32502457. PubMed
5. SIOP-E-BTG/GPOH guideline for diagnosis and treatment of pLGG. Klin Padiatr. 2019. PMID 31108561. PubMed

PAGE 1 • DIAGNOSIS AND RT DECISION

Clinical bottom line

Focal RT remains a core component of therapy for pediatric high-grade glioma and the principal proven palliative disease-modifying therapy for diffuse midline glioma (DMG). Molecular classification is essential because pediatric HGG is not a single disease. Proton therapy should be used only when it improves normal-tissue sparing without compromising robustness or creating unfavorable high-LET/distal-edge geometry near critical midline structures.

Pathology / molecular review

☐ Diffuse pediatric-type HGG, H3-wildtype/IDH-wildtype

☐ Diffuse hemispheric glioma, H3 G34-mutant

☐ Diffuse midline glioma, H3 K27-altered

☐ Infant-type hemispheric glioma / targetable fusions

☐ Methylation profiling when diagnosis is uncertain

☐ Extent of resection / postoperative MRI

☐ Baseline steroid requirement and neurologic status

☐ Clinical-trial / systemic therapy plan documented

Working RT approach

Entity / scenario	RT approach
Resected non-midline pHGG	Adjuvant focal RT, commonly 54–59.4/60 Gy; systemic therapy protocol-dependent
Residual non-midline pHGG	Focal RT with boost to residual/high-risk volume up to ~59.4–60 Gy
DMG H3 K27-altered / classic pontine phenotype	Focal RT 54 Gy / 30 fx is a common standard; 54–60 Gy in 1.8–2 Gy/fx used in practice
Poor performance / palliative DMG	Hypofractionation such as 39 Gy/13 or 45 Gy/15 may be reasonable in selected patients
Infant-type fusion-driven HGG	RT timing may differ substantially; prioritize protocol/targeted-therapy strategy

Proton-selection principle

Unlike medulloblastoma or craniopharyngioma, prognosis may limit the absolute late-effect benefit in DMG. Proton therapy is most compelling when it clearly reduces normal-brain/cochlear/endocrine dose without worsening brainstem robustness or LET-sensitive geometry.

PAGE 2 • TARGET DELINEATION

Non-midline pHGG

Volume	Protocol-era / practical rule
GTV1	Pre/postoperative tumor bed plus residual and relevant T2/FLAIR abnormality
CTV1	COG ACNS0423 used preoperative tumor volume + 2 cm; modern practice may use 1–2 cm anatomically constrained
GTV2	Residual enhancing tumor / resection bed
CTV2	Common modern approach ~0.5–1 cm; exact margin protocol-dependent

DMG

- GTV should include the full T2/FLAIR-defined infiltrative abnormality and any enhancement, not enhancement alone.
- CTV of roughly 1–2 cm anatomically constrained remains a common reference for DMG; reduce across true barriers and avoid meaningless expansion outside the CNS.
- For spinal/thalamic/midbrain DMG, adapt margins to anatomy and serial OARs; do not import pontine geometry uncritically.

Limited-margin evidence

Modern pediatric/proton studies have explored substantially smaller margins (for example 5–7 mm) and MR-spectroscopy-guided targets. These are promising but should be labeled protocol/investigational rather than silently replacing a validated protocol backbone.

Contouring pitfall

Steroid-responsive reduction in enhancement does not define microscopic extent. Use preoperative/pre-steroid imaging when available and preserve T2/FLAIR-defined infiltrative disease in the target concept.

PAGE 3 • DOSE, OAR PRIORITIES AND PLAN REVIEW

Dose summary

Scenario	Dose
GTR non-midline pHGG (COG-era reference)	54 Gy / 30 fx
Residual non-midline pHGG	54 Gy + boost to 59.4 Gy / 33 fx; 60 Gy / 30 fx used in some modern protocols
DMG conventional	54 Gy / 30 fx (common standard); selected practice 54–60 Gy
DMG hypofractionated	39 Gy / 13 fx or 45 Gy / 15 fx in selected palliative/low-burden settings
DMG reirradiation at progression	24 Gy / 12 fx is a commonly reported salvage regimen in selected patients

OAR priorities

OAR	Planning principle
Brainstem / cord	Serial-organ safety is dominant. Avoid hotspots and distal-edge/high-LET concentration; do not escalate simply to improve nominal GTV coverage.
Optic apparatus	Respect conventional serial-organ limits when uninvolved; target overlap requires explicit risk-benefit documentation.
Normal brain / hippocampi / temporal lobes	ALARA; late-effect benefit matters most in patients with longer expected survival.
Cochlea	Mean dose ALARA, particularly if systemic therapy is ototoxic.
HPA / pituitary	ALARA when not part of target; endocrine risk is dose-continuous.

Proton approval checklist

☐ Molecular entity confirmed

☐ T2/FLAIR disease included

☐ Brainstem/cord serial limits prioritized

☐ Photon alternative considered if more robust

☐ Pre-op / pre-steroid extent reviewed

☐ Margins match protocol intent

☐ Distal-edge/LET geometry acceptable

☐ Follow-up/reirradiation implications documented

PAGE 4 • IMAGING, PROGRESSION, REIRRADIATION AND REFERENCES

Response assessment

- Use RAPNO principles: MRI assessment must integrate T2/FLAIR, enhancement, diffusion, clinical status and steroid/antiangiogenic use.
- Obtain an early post-RT baseline MRI, commonly at ~4–6 weeks; pseudoprogression can complicate interpretation, particularly in non-midline HGG.
- For DMG, clinical neurologic trajectory is at least as important as small radiographic changes.

Reirradiation

Selected patients with progressive DMG can experience transient neurologic benefit from reirradiation; 24 Gy in 12 fractions is a commonly cited regimen. Composite dose review is mandatory. PENTEC pediatric reirradiation data suggest brain/brainstem necrosis risk around 5–7% near cumulative prescription $EQD2_2$ ≈112 Gy, but patient-level dose-volume data remain limited.

Key references

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2. Merchant TE et al. Prospective conformal RT for pediatric HGG: 59.4 Gy, 2-cm CTV. Neuro Oncol. 2014. PMCID PMC4232080. Open article
3. Erker C et al. RAPNO response assessment in pediatric HGG. Lancet Oncol. 2020. PMID 32502458. PubMed
4. Cooney T et al. RAPNO response assessment in DIPG/DMG. Lancet Oncol. 2020. PMID 32502459. PubMed
5. Practical Radiation Oncology review of H3K27-altered DMG; definitive 54–60 Gy and salvage 24 Gy/12 fx. 2024. Article
6. Ajithkumar T et al. PENTEC pediatric CNS reirradiation necrosis. IJROBP. 2024. PMID 38300187. PubMed

Endpoint	Evidence summary	How to use
Hearing loss / cochlea	PENTEC: RT-alone mean cochlear dose ≤35 Gy associated with <5% modeled HL risk; risk rises with dose and young age; platinum shifts risk upward.	Treat 35 Gy as risk information, not an optimal goal. Aim lower whenever target geometry allows.
Central endocrine	PENTEC: HPA endocrine deficits show continuous dose-response; GH axis is most radiosensitive.	Report HPA/pituitary mean dose and reduce dose even when far below classic serial-organ limits.
Neurocognition / brain	PENTEC: outcome depends on age, dose and irradiated brain volume; no single whole-brain safe threshold.	Use mean/Vx and integral-dose reduction as quality metrics, especially in long-term survivors.
Reirradiation necrosis	PENTEC: pooled pediatric data suggest ~5–7% brain/brainstem necrosis around cumulative prescription $EQD2_2$ ~112 Gy.	Always perform composite dose review; uncertainty is substantial and dose-volume data are incomplete.

Core PENTEC references

1. Constine LS et al. PENTEC user's guide and summary. IJROBP. 2024. PMID 37999712. PubMed
2. Murphy B et al. PENTEC hearing loss. IJROBP. 2024. PMID 37855793. PubMed
3. Wheeler G et al. PENTEC central endocrine complications. IJROBP. 2024. PMID 37269265. PubMed
4. Merchant TE et al. PENTEC neurocognitive effects and necrosis. IJROBP. 2024. PMID 33810950. PubMed
5. Ajithkumar T et al. PENTEC reirradiation brain/brainstem necrosis. IJROBP. 2024. PMID 38300187. PubMed

Chordoma • Ewing Sarcoma • Wilms Tumor • Rhabdomyosarcoma (site-specific) • Neuroblastoma

How to use this section

Each chapter is designed for rapid pre-simulation, contouring and plan-approval review. Protocol-prescribed dose/fields are separated from preferred proton planning goals and PENTEC dose-risk information. Rhabdomyosarcoma is organized by primary site because local therapy, target anatomy and normal-tissue priorities differ substantially.

Important

This is a working institutional manual, not a substitute for the active COG/SIOPEN/EpSSG/CWS protocol. When the patient is enrolled on, or being treated according to, a specific protocol, that protocol takes precedence.

PAGE 1 • DIAGNOSIS, SURGERY AND RT INDICATION

Clinical bottom line

Pediatric chordoma is a high-dose particle-therapy disease. Maximal safe expert surgery followed by high-dose proton therapy is the reference approach for most skull-base and axial tumors. Poorly differentiated chordoma behaves more aggressively and should trigger expert pathology/molecular review and systemic-therapy discussion, but local RT still requires uncompromised high-dose planning.

Pre-RT checklist

☐ Expert pathology review; conventional vs poorly differentiated/dedifferentiated chordoma

☐ Brachyury/TBXT and SMARCB1/INI1 status when appropriate

☐ Preoperative MRI + thin-slice bone CT available

☐ Early postoperative MRI and operative report reviewed

☐ Skull-base cranial nerve/vascular involvement documented

☐ For mobile spine/sacrum: full spine/site MRI + CT and hardware documented

☐ Confirm no interval progression before RT; repeat MRI if delayed

☐ Baseline vision, hearing, pituitary/endocrine and cranial-nerve function

RT indication / dose

Scenario	Working approach
Skull-base chordoma after resection	Adjuvant high-dose proton therapy is standard reference; pediatric MGH series median 76.7 Gy(RBE).
Gross residual/unresectable disease	Definitive/adjuvant proton therapy; typical total ~74-76.8 Gy(RBE) in 1.8-2 Gy(RBE)/fx, individualized to OAR interface.
Mobile spine/sacral chordoma	High-dose proton-based RT after surgery or for unresectable disease; pediatric series median ~74.5 Gy(RBE).
Progression before planned RT	Re-image and re-discuss surgery; pre-RT progression is adverse and target must reflect current disease.

Do not miss

A “gross total resection” does not remove the need to reconstruct the original tumor bed. Chordoma fails at bone/mucosal and critical-OAR interfaces; the preoperative anatomy and surgical decompression must be explicitly reviewed.

PAGE 2 • PTCOG 2026 CONTOURING FRAMEWORK

Target volumes - skull base

Volume	PTCOG 2026 consensus concept
Pre-op GTV	Reconstruct the full original chordoma extent on preoperative MRI/CT.
Residual GTV	Postoperative residual disease; scrutinize lateral clivus, cavernous sinus, atlanto-occipital joint and prevertebral soft tissues.
CTV-Intermediate	Entire tumor bed + median ~5 mm, remainder of the clivus, anatomically modified for postoperative decompression/pushing anatomy.
CTV-High	Bone and mucosa of the entire primary tumor bed + any residual disease, typically with ~5-mm margin.

Key contouring concept

Do not rigidly "chase" normal tissue that was merely displaced preoperatively. Distinguish invasion from pushing/displacement. After decompression, reshape the CTV to the postoperative anatomy while preserving bone/mucosal surfaces and true pathways at risk.

Proton planning

- Use multi-field robust optimization; avoid a single dominant distal edge terminating in brainstem, optic pathway or cord.
- Review robust coverage separately for high-dose and intermediate-dose CTVs.
- Review LET/RBE-sensitive interfaces qualitatively; high-dose chordoma plans should not be approved from nominal DVH alone.
- For mobile spine, account for hardware, density uncertainty, bowel/lung motion and vertebral growth.

PAGE 3 • HIGH-DOSE OAR GOALS AND PLAN APPROVAL

Skull-base particle-planning reference goals

OAR	Reference goal	Interpretation
Brainstem surface (outer 3 mm)	D0.03cc <63 Gy(RBE)	High-priority serial OAR; center-specific high-dose particle goal.
Brainstem center	D0.03cc <50 Gy(RBE)	Prefer substantial central sparing.
Optic nerve / chiasm	D2% <60 Gy(RBE)	Risk rises at ≥60 Gy; do not exceed casually to improve a small interface cold spot.
Temporal lobe	D2cc <71 Gy(RBE)	High-dose necrosis avoidance; minimize V60-70 when feasible.
Cochlea	Mean <45 Gy(RBE); lower preferred in child	Hearing preservation; ALARA.
Pituitary	Mean <45 Gy(RBE); ALARA	PENTEC endocrine risk begins well below this.
Eye / lens	Eye mean <35, D0.03cc <50; lens D0.03cc <10 Gy(RBE)	Vision/cataract protection.

Caution

These high-dose goals are particle-planning reference constraints, not pediatric prospective tolerance thresholds. If target and serial OAR overlap, document the intended compromise and the expected disease-control consequence.

Plan approval checklist

☐ Pre-op GTV reconstructed

☐ Residual GTV reviewed with surgeon/neuroradiology

☐ CTV-intermediate includes clival compartment at risk

☐ CTV-high includes primary bone/mucosal bed

☐ Brainstem surface/core reviewed

☐ Optic D2% reviewed

☐ Temporal-lobe high-dose volume reviewed

☐ Robustness + LET-sensitive interfaces reviewed

PAGE 4 • IMAGING, FOLLOW-UP AND REFERENCES

Imaging / adaptation

- Daily high-quality image guidance. For long courses, verification CT/MRI should be obtained if weight, sinus aeration, postoperative cavity or hardware-related geometry changes can alter range.
- Repeat MRI during treatment when anatomy is evolving or when a critical OAR interface is within a few millimeters of the high-dose target.
- After RT, skull-base MRI is commonly obtained every ~3-6 months initially, then spaced with stability; chest imaging is reasonable because distant metastases can occur.

Pediatric outcome anchor

The largest pediatric skull-base series (204 patients) used a median total dose of 76.7 Gy(RBE); 10-year OS was 78% and late grade ≥ clinically significant toxicity was relatively uncommon. High-dose proton therapy therefore has both pediatric efficacy and long-term follow-up support.

Key references

1. McDonald MW et al. PTCOG international skull-base chordoma target delineation consensus. IJROBP. 2026. PMID 42799736. Link
2. Surgery and proton RT for pediatric base-of-skull chordoma: 204-patient long-term series. 2023. PMID 37029730. Link
3. Local control after proton therapy for pediatric chordoma. 2020. PMID 33253819. Link
4. Long-term proton-based RT for pediatric mobile-spine/sacral chordoma. 2025. PMID 40204245. Link
5. Modern skull-base chordoma proton planning goals including brainstem surface/core. J Med Radiat Sci. 2024. Link

PAGE 1 • LOCAL-CONTROL DECISION AND DOSE

Clinical bottom line

Ewing sarcoma requires chemotherapy plus definitive local control. Surgery is preferred when it can achieve oncologically adequate margins without unacceptable functional loss; definitive RT is appropriate when surgery is morbid or margins are unlikely to be adequate. Proton therapy is most compelling for pelvis, spine/paraspinal, chest wall and head/neck where normal-tissue dose is substantial.

☐ Confirm EWSR1-ETS or alternative Ewing-defining molecular diagnosis

☐ PET/CT or PET/MRI + chest CT and marrow/bone staging per protocol

☐ Operative report + margins (R0/R1/R2) and histologic response reviewed

☐ Metastatic sites enumerated; pulmonary vs osseous burden

☐ Diagnostic MRI defines full pre-chemotherapy bone/soft-tissue extent

☐ Local-control decision made before week of planned surgery/RT

☐ Hardware/reconstruction documented

☐ Anthracycline exposure documented for heart planning

Dose framework

Setting	Typical dose	Comment
Definitive RT	55.8 Gy / 31 fx	COG/NCI reference: 45 Gy initial volume + 10.8 Gy boost.
R1 / microscopic residual	50.4 Gy / 28 fx	Common North-American reference.
R2 / gross residual	54-55.8 Gy	Treat as gross disease.
Preoperative RT	45-50.4 Gy	International practice varies; useful when marginal resection is anticipated.
Selected large unresectable tumor	Dose escalation has improved local control in a randomized study	Not universal standard; use protocol/expert review.

Do not miss

Do not perform a knowingly incomplete/debulking operation and then assume postoperative RT is equivalent to planned definitive RT. If adequate resection is unlikely, multidisciplinary planning should decide definitive RT or a deliberate preoperative RT strategy.

PAGE 2 • TARGET DELINEATION BY ANATOMY

Target element	Working rule
Initial volume	Use the full pre-chemotherapy MRI-defined bone and soft-tissue disease extent; edema alone is not automatically tumor.
CTV	Modern limited-margin data support ~1-cm anatomically constrained margin in selected conformal RT; historical protocols used larger margins. Use active protocol if specified.
Boost volume	Post-chemotherapy gross disease / residual high-risk volume, while ensuring the original infiltrated compartment remains adequately treated.
Postoperative RT	Reconstruct preoperative disease and surgical bed; include contaminated/positive-margin surfaces as indicated.

Site-specific proton issues

Site	Planning priorities
Pelvis/sacrum	Bowel, bladder/rectum, gonads, uterus/ovaries, femoral heads/physes, sacral plexus; robust to bowel/bladder variation.
Spine/paraspinal	True cord vs canal, vertebral growth/symmetry, kidneys/lung/esophagus by level, hardware range uncertainty.
Chest wall/rib	Heart, breasts, lungs, liver; pleural contamination/effusion may change field concept.
Extremity	Circumferential limb dose, physis, joint, skin strip/lymphatics; motion and setup reproducibility.

Growth principle

In young children, avoid highly asymmetric vertebral-body or long-bone growth-plate irradiation when it is oncologically unnecessary. PENTEC associates vertebral dose and dose gradients with later scoliosis/growth impairment.

PAGE 3 • OAR CONSTRAINTS AND PROTON PLAN APPROVAL

AEWS1031-era protocol reference limits + PENTEC refinement

OAR	Protocol-era reference	Preferred pediatric interpretation
Kidneys	~50% <24 Gy; whole kidney <14.4 Gy (AEWS1031-derived)	PENTEC: bilateral/single functioning kidney mean <10 Gy when feasible; partial kidney V15 <40%.
Heart	Whole heart <30 Gy protocol-era	PENTEC: mean <10 Gy is associated with low absolute late cardiac risk without anthracycline; with anthracycline, ALARA.
Lung	V20 <20%; whole lung <15 Gy protocol-era	PENTEC partial-lung: MLD <14 Gy and V20 <30% = low pneumonitis risk.
Liver	Whole liver <23.4 Gy protocol-era	Prefer mean <10 Gy when feasible; whole-liver ~10 Gy corresponds to ~6% modeled SOS risk.
Cord	Point max ~50.4 Gy protocol-era	Serial OAR; prioritize against target hot spot.
Bladder/rectum/bowel	Protocol limits ~45 Gy for whole structure in older COG tables	Use PENTEC dose-volume goals when high pelvic doses are required; minimize mean/low dose.

Plan approval checklist

☐ Pre-chemo MRI extent incorporated

☐ CTV anatomy appropriate

☐ Growth plates/vertebral symmetry reviewed

☐ Robustness acceptable around bowel/lung/hardware

☐ Surgical margins/histologic response reviewed

☐ Boost volume correct

☐ Heart/kidney/gonad mean doses reviewed

☐ All metastatic-site local therapy decisions documented

PAGE 4 • METASTATIC DISEASE, WLI AND REFERENCES

Metastatic-site RT

- Pulmonary metastases: WLI should be strongly considered even after radiographic response; common pediatric doses are 12-15 Gy, protocol/age dependent.
- Consensus guidance supports treating all metastatic sites when disease burden is limited and treatment is feasible; SBRT can be used for selected bone/soft-tissue metastases.
- For pleural/chest-wall contamination, hemithorax/pleural RT may be indicated; exact dose is protocol-dependent and must be coordinated with primary-site boost.

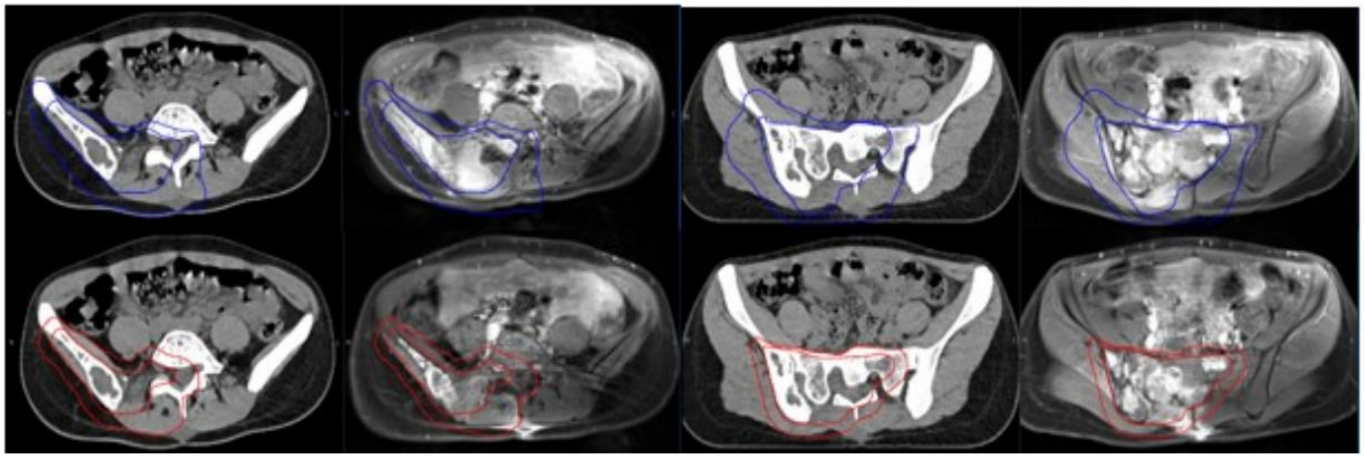
Proton evidence

A prospective proton registry of 42 children with Ewing sarcoma reported 4-year local control of 83%; all local failures were in-field, supporting that conformality itself did not create marginal failure. Pelvic proton series demonstrate high local control with major normal-tissue sparing.

Key references

1. NCI PDQ: Ewing Sarcoma Treatment - current local-control and RT dose framework. Link
2. Comprehensive radiotherapy for pediatric Ewing sarcoma: prospective proton study. 2024. PMID 38583721. Link
3. Pelvic Ewing sarcoma treated with proton therapy. 2020. PMID 32437922. Link
4. Limited-margin RT for Ewing sarcoma. 2016. PMID 27319287. Link
5. Metastatic-site RT consensus for Ewing/RMS. 2024. PMID 39447866. Link
6. PENTEC cardiac disease. 2024. PMID 37061912. Link
7. PENTEC pulmonary effects. 2024. PMID 35525723. Link

Target Volume Example: Pelvic Ewing Sarcoma



Pelvic Ewing sarcoma involving the right ilium and sacrum, with extension into sacral canal and right gluteus and paraspinal muscles. Top row illustrates the simulation CT co-registered to the MRI at presentation. The GTV1 (inner blue line) includes all gross disease prior to induction chemotherapy, and the CTV1 (outer blue line) includes the GTV1 with a 1cm anatomically confined margin, including the entire sacrum, sacral canal, soft tissue edema and biopsy tract to the skin. The bottom row illustrates the same CT slices co-registered to the MRI after induction chemotherapy. The GTV2 (inner red line) includes all remaining gross disease and all originally involved bone. The CTV2 (outer red line) includes the GTV2 plus 1 cm margin in bone and 5 mm in soft tissue, anatomically confined.

Eaton et al, Ped Blood Cancer, 2020

PAGE 1 • PATHOLOGY, STAGE AND RT INDICATION

Clinical bottom line

Wilms RT is protocol-driven and usually low dose, so field correctness matters more than sophisticated dose escalation. The planning review must integrate histology, stage, spill/rupture, margins/nodes, nephrectomy anatomy and lung response. Proton therapy can reduce dose to the remaining kidney, liver, bowel, heart and developing tissues, but must preserve the protocol-required vertebral and abdominal target.

☐ Favorable histology vs focal/diffuse anaplasia

☐ Operative note: rupture/spill, peritoneal implants, margins

☐ Preoperative CT/MRI defines original tumor extent

☐ Lung metastasis response at ~6 weeks if applicable

☐ COG stage I-IV documented

☐ Nodal sampling and positive nodal stations reviewed

☐ Post-nephrectomy anatomy and surgical clips reviewed

☐ LOH/molecular risk relevant to lung-RT omission documented

COG RT dose framework

Scenario	Dose
Stage I-II favorable histology	No RT
Stage III favorable histology - flank	10.8 Gy / 6 fx (1.8 Gy/fx)
Diffuse spill / peritoneal metastasis - whole abdomen	10.5 Gy / 7 fx (1.5 Gy/fx)
Stage III diffuse anaplasia	19.8 Gy to tumor bed; whole-abdomen scenario may receive 10.5 Gy + 9-Gy boost
Pulmonary metastases when WLI indicated	12 Gy / 8 fx if >12 months; 10.5 Gy / 7 fx if <12 months
Liver metastasis	19.8 Gy ± 5.4-10.8-Gy boost to gross disease

Timing

Aim to start indicated postoperative RT promptly. Historical data raised concern for delays beyond ~10-14 days, especially in unfavorable histology; coordinate simulation/pathology review early rather than waiting until chemotherapy is underway.

PAGE 2 • FLANK, WHOLE ABDOMEN AND WLI CONTOURING

Flank / abdominal target

- Reconstruct the preoperative tumor bed, involved nodal region and operative findings. Do not contour only the post-nephrectomy cavity.
- COG flank RT historically includes the entire adjacent vertebral bodies to avoid asymmetric vertebral growth; proton plans should not "spare" the ipsilateral half of a vertebra if this violates protocol intent.
- Whole-abdomen RT is used for diffuse spill/peritoneal disease and requires complete peritoneal/abdominal coverage per protocol; avoid unintended cold regions from kidney/liver sparing.
- For gross peritoneal implants/residual metastatic sites, define separate boost volumes when required.

Whole-lung irradiation

- Use 4DCT or an equivalent motion strategy; the target is the bilateral lung volume through the respiratory cycle.
- Preserve full lung coverage at apices, costophrenic recesses and cardiac interfaces. Heart/breast/thyroid sparing should not create lung undercoverage.
- If abdominal/flank RT is also required, explicitly review the thoracoabdominal junction and cumulative liver/heart/kidney dose.

Proton-specific caution

Proton WLI is feasible and can markedly reduce cardiac dose, but the large moving low-density target makes robustness/interplay and range uncertainty central. A photon cardiac-sparing WLI plan may be preferable if proton coverage is less robust.

PAGE 3 • OAR GOALS AND PLAN APPROVAL

OAR	Preferred pediatric planning goal / risk information
Remaining kidney	PENTEC: mean <10 Gy is associated with low chronic moderate/severe renal-toxicity risk; partial kidney V15 <40% where relevant. Keep dose substantially below prescription whenever geometry allows.
Liver	Mean <10 Gy preferred when feasible. PENTEC whole-liver model: ~6% SOS risk after 10 Gy; right-flank fields deliver higher mean liver dose than left.
Heart	ALARA, especially with doxorubicin. PENTEC: mean <10 Gy gives low absolute late cardiac risk in absence of anthracycline; anthracycline multiplies concern.
Pancreas tail	Mean<10Gy
Lungs	For partial thoracic RT: MLD <14 Gy and V20 <30% associated with low pneumonitis risk. WLI has separate low-dose toxicity considerations.
Breasts/thyroid	ALARA; particularly important during WLI in girls and young children.
Spine	Avoid asymmetric dose. PENTEC recommends limiting vertebral dose/gradients where oncologically possible, but Wilms target geometry may intentionally include full adjacent bodies.

Plan approval checklist

☐ Histology/stage verified
☐ Pre-op bed reconstructed
☐ Remaining kidney mean reviewed
☐ Heart/breast/thyroid reviewed for WLI
☐ Spill/rupture/nodes mapped
☐ Protocol-required vertebral coverage maintained
☐ Liver mean reviewed
☐ Thoracoabdominal junction reviewed

PAGE 4 • RESPONSE-ADAPTED LUNG RT, FOLLOW-UP AND REFERENCES

Pulmonary metastases - response matters

Current COG strategy allows omission of WLI in selected favorable-histology patients with lung-only metastases who achieve complete response after initial chemotherapy and lack specified adverse molecular features. Do not decide WLI from diagnostic CT alone; document the protocol response/molecular criteria.

Follow-up / late effects

- Renal function and blood pressure: lifelong surveillance of the solitary/remaining kidney.
- After WLI: pulmonary function, breast development/cancer risk, cardiac risk (especially with anthracycline), thyroid and musculoskeletal growth.
- After abdominal RT: monitor bowel, liver and spinal growth; fertility considerations depend on gonadal dose.

Key references

1. NCI PDQ: Wilms Tumor and Other Childhood Kidney Tumors - current COG RT table. Link
2. Pencil-beam scanning proton RT after nephrectomy for Wilms tumor. 2017. PMID 27565764. Link
3. Proton whole-lung irradiation: initial outcomes. 2022. PMID 36243226. Link
4. Cardiac-sparing whole-lung IMRT and abdominal field matching. 2018. PMID 30096378. Link
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7. PENTEC pulmonary effects. 2024. PMID 35525723. Link

PAGE 1 • UNIVERSAL RMS FRAMEWORK

Clinical bottom line

RT indication and dose depend on FOXO1 fusion status, Clinical Group, nodes, primary site, size and response/surgery. The initial pre-chemotherapy disease extent remains the anchor for target definition, with selective volume reduction only when protocol criteria are met.

- ☐ Histology + FOXO1 fusion status
- ☐ Stage / Clinical Group / nodal status
- ☐ Pre-chemotherapy MRI/CT/PET available
- ☐ Biopsy/resection operative report + margins
- ☐ Response imaging at protocol-defined local-therapy time
- ☐ Delayed primary excision status if applicable
- ☐ All involved nodes mapped at diagnosis
- ☐ Metastatic sites/WLI indication documented

COG dose framework

Clinical Group / setting	Typical RT
Group I fusion-negative	No RT
Group I fusion-positive	36 Gy to involved pre-chemo site
Group II N0	36 Gy
Group II N1	36 Gy primary + 41.4 Gy involved nodes
Group III orbital CR	45 Gy
Group III non-orbital or orbital PR	50.4 Gy
Group III >5 cm on ARST1431-type escalation	Boost residual disease to 59.4 Gy when protocol-defined
After delayed resection	R0: 36 Gy; R1: 41.4 Gy in selected protocol-eligible settings

Target rule

A practical conformal/proton framework is CTV1 = pre-chemotherapy tumor + ~1 cm anatomically constrained; boost/high-dose CTV = post-chemotherapy residual/tumor bed + ~0.5 cm while retaining initial pathways of invasion. Active protocol always supersedes this shorthand.

PAGE 2 • ORBIT AND PARAMENINGEAL RMS

Orbit

Decision	Working rule
Local therapy	Biopsy + chemotherapy + RT; exenteration reserved for exceptional persistent/recurrent disease.
Dose	45 Gy if complete response after induction; 50.4 Gy if less than CR.
Target	Initial orbital disease volume is the anchor; avoid compromising coverage to spare ipsilateral ocular structures that overlap target.
OAR priorities	Lens, cornea/conjunctiva, lacrimal gland, retina, optic nerve/chiasm, contralateral eye, pituitary/HPA, temporal lobe, facial bones/teeth.

Orbit proton goal

Protons can substantially reduce contralateral eye, brain, pituitary/hypothalamus, temporal-lobe and facial-bone dose. Keep lens dose ALARA; preserve orbital/facial growth structures where not part of target.

Parameningeal

- Definitive chemoradiation is standard; surgery is generally biopsy-only except selected salvage situations.
- High-risk anatomy includes intracranial extension, skull-base erosion and cranial-nerve palsy. MRI skull base/brain is mandatory; CSF is considered in high-risk meningeal-impingement settings.
- Dose is usually 50.4 Gy for gross Group III disease; current protocol may escalate large tumors.
- Intracranial extension does not mandate whole-brain/CSI if CSF is negative; include contiguous intracranial/meningeal extension with appropriate margin.
- RT timing is protocol-dependent. Historical data support urgency for true intracranial extension; do not delay a high-risk PM-RMS case without explicit protocol/tumor-board review.

Parameningeal OARs

Brainstem, optic apparatus, cochlea, pituitary/HPA, temporal lobes, parotids, mandible/maxilla, dentition, TMJ, facial bones and developing skull base. In a young child, proton planning should explicitly report skeletal/dental dose, not only neurologic OARs.

PAGE 3 • EXTREMITY RMS

Clinical bottom line

Extremity RMS has a relatively high nodal risk, especially with FOXO1 fusion-positive disease. Local control must integrate primary-site surgery, nodal surgery/imaging and RT; a beautiful primary-site plan is inadequate if the draining nodal basin was not correctly staged.

Planning checklist

☐ Pre-chemo MRI in treatment position if possible

☐ Document compartment, neurovascular bundle, skin/bone invasion

☐ Regional nodes assessed clinically + PET/imaging + biopsy/sampling as indicated

☐ Surgical scar/drain path reviewed

☐ Physis/joint circumference and lymphatic drainage mapped

☐ Avoid full circumferential limb dose when oncologically possible

Dose / targets

- Use group-based COG dose: 36-41.4 Gy for microscopic disease; 50.4 Gy for gross disease; protocol escalation to 59.4 Gy may apply for large residual tumors.
- Involved nodes: commonly 41.4 Gy if resected/controlled microscopic disease; gross residual nodal disease receives gross-disease dose.
- CTV follows initial tumor extent with anatomically constrained margin; high-dose volume follows residual/tumor bed while preserving initial infiltrated pathways.

OAR / quality goals

Structure	Goal
Physis / apophysis	ALARA if not involved; avoid asymmetric partial physeal irradiation where possible.
Joint	Reduce high-dose volume and avoid unnecessary circumferential joint irradiation.
Bone circumference	Avoid irradiating the full circumference of a long bone when target geometry permits.
Skin/subcutaneous tissue	Preserve a longitudinal skin strip outside high dose when oncologically safe to reduce edema/fibrosis risk.
Neurovascular bundle	If uninvolved, reduce high dose; if invaded/encased, target coverage takes priority.

Proton caution

Extremity protons can create very sharp longitudinal/axial dose gradients. Robustly test rotational/setup error and range through variable soft-tissue thickness; do not trade marginal coverage for physis sparing when the initial tumor abutted that physis.

PAGE 4 • BLADDER / PROSTATE RMS

Clinical bottom line

Bladder/prostate RMS is an organ-preservation problem. Modern care is multidisciplinary and may combine chemotherapy, limited/delayed surgery, external-beam RT and/or brachytherapy. The 2026 INSTRuCT consensus emphasizes individualized local therapy based on age, tumor location/size, nodes and available expertise.

- Primary radical surgery is generally avoided when it would sacrifice bladder/sexual function; biopsy followed by chemotherapy is typical.
- At local-therapy reassessment, consider delayed resection only if complete removal is achievable without major functional loss.
- External-beam doses follow group/residual-disease rules (commonly 36, 41.4 or 50.4 Gy; escalation may apply to large residual tumors under protocol).
- Proton therapy can reduce dose to uninvolved bladder, rectum, bowel, pelvic bones, femoral heads/growth plates and gonads compared with IMRT.

Pelvic OAR goals

OAR	Risk-based goal
Testes	ALARA. PENTEC: mean <0.2 Gy generally preserves testosterone; >1 Gy causes very high short-term oligospermia risk.
Least-affected ovary	ALARA; even ~2 Gy is clinically relevant and risk is amplified by alkylators.
Uterus	Keep as low as possible; PENTEC suggests uterine size restriction becomes important around >12 Gy.
Rectum/bowel	Use PENTEC dose-volume goals when feasible; minimize V45-50 and mean dose.
Pelvic bones/physes/femoral heads	Minimize asymmetric high dose and integral dose.

Simulation / adaptation

Use reproducible bladder filling and rectal/bowel preparation appropriate to age. For protons, verify bladder/rectal filling and bowel gas during treatment; replan if robust target coverage or bowel/rectum dose changes materially.

PAGE 5 • PARATESTICULAR RMS, METASTATIC RT AND REFERENCES

Paratesticular RMS

- Primary local therapy is radical inguinal orchiectomy; avoid transscrotal violation.
- Retroperitoneal nodal staging is age/risk dependent; INSTRuCT/COG surgical guidance is essential, particularly in boys ≥10 years where occult nodal disease risk is clinically important.
- Group I fusion-negative primary disease generally does not require RT. Positive margins/fusion-positive disease or involved nodes follow group-based RT doses.
- When nodal RT is required, contour the involved retroperitoneal nodal chain based on diagnostic imaging/surgical findings; minimize contralateral testis, remaining gonad, kidneys, bowel and vertebral asymmetry.

Metastatic disease

- Treat the primary and involved regional nodes when feasible. INSTRuCT 2026 recommends considering definitive local therapy to all metastatic sites when disease burden/prognosis permit.
- Pulmonary metastases: WLI is protocol-recommended in metastatic RMS; contemporary COG data show better EFS in patients who actually received WLI. Common total dose ~12-15 Gy depending age/protocol.
- SBRT or conventional RT can be used for selected osseous/soft-tissue metastases, with modality chosen according to site, age and cumulative toxicity.

Key references

1. NCI PDQ: Childhood Rhabdomyosarcoma Treatment - current COG RT dose table and site guidance. Link
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3. INSTRuCT bladder/prostate RMS local-control consensus. 2026. PMID 41823170. Link
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5. COG/European/CWS paratesticular RMS surgical consensus. 2021. PMID 33522706. Link
6. Patterns of failure after proton RT for pediatric RMS. 2016. PMID 27742542. Link
7. Proton RT for pediatric bladder/prostate RMS. 2011. PMID 20934266. Link
8. Whole-lung irradiation in metastatic RMS: COG report. 2024. PMID 39255438. Link
9. PENTEC testicular dysfunction. 2024. PMID 37791936. Link
10. PENTEC female reproductive tract. 2024. PMID 37804257. Link

PAGE 1 • INDICATION AND TREATMENT SEQUENCE

Clinical bottom line

Consolidative RT is standard for the primary site in high-risk neuroblastoma after induction surgery and myeloablative therapy/stem-cell rescue. The target is based on the preoperative primary-tumor volume after induction chemotherapy, not merely postoperative residual. A routine 36-Gy boost for gross residual disease is no longer recommended after ANBL0532 failed to improve local control.

☐ INRG/COG high-risk status documented

☐ Diagnostic + post-induction MRI/CT reviewed

☐ IDRFs at diagnosis and after induction documented

☐ Transplant/tandem transplant timeline

☐ MYCN and key biology documented

☐ MIBG/PET disease map reviewed

☐ Operative report and extent of resection

☐ Post-induction persistent metastatic sites selected for RT per protocol

Dose / indication

Scenario	Working RT
High-risk primary site	21.6 Gy / 12 fx to preoperative primary-tumor volume after induction chemotherapy (COG reference).
Gross residual primary disease	Do not routinely boost to 36 Gy; ANBL0532 showed no local-control benefit from 14.4-Gy boost. Case to case discussion
Selected prospective dose-reduction after GTR	15-18 Gy has shown ~96% local control in a single-institution prospective program; investigational/not COG standard.
Persistent MIBG-avid metastatic sites	Treat selected sites according to active protocol; typical conventional doses ~21-24 Gy in published proton series.

Sequence

RT is usually delivered after the final autologous stem-cell transplant and before/around maintenance immunotherapy according to protocol. Confirm hematologic recovery and systemic-therapy timing before simulation.

PAGE 2 • TARGET DELINEATION AND PROTON PLANNING

Primary-site target

- Use the preoperative primary-tumor volume after induction chemotherapy as the core local RT volume; reconstruct from the preoperative/pre-surgery CT/MRI rather than the postoperative cavity alone.
- Include involved regional nodal disease according to protocol and response.
- Review diagnostic IDRF interfaces (major vessels, renal pedicle, neural foramina, diaphragm, pancreas/liver/bowel) because surgical decompression can make the postoperative anatomy misleading.
- For paraspinal extension, distinguish pre-treatment intraspinal disease from displaced thecal sac/cord and review vertebral growth.

Proton-specific planning

- For lateralized abdominal primaries, protons often markedly reduce contralateral kidney, liver and bowel dose, but not always ipsilateral kidney dose. Compare plans rather than assuming proton superiority.
- Use 4DCT/motion assessment for adrenal/upper-abdominal or thoracic targets; robustly test diaphragm and bowel-gas changes.
- Avoid highly asymmetric vertebral-body dose in young children when target anatomy allows; growth may dominate long-term morbidity.
- If multiple metastatic sites are irradiated, review composite kidney, liver, lung, heart and marrow/bone dose.

Planning pearl

Because prescription is only 21.6 Gy, proton value is primarily the reduction of low/intermediate integral dose. A small loss of robust target coverage is not justified for a dramatic-looking low-dose DVH improvement.

PAGE 3 • OAR GOALS AND PLAN APPROVAL

OAR	Preferred goal / evidence
Contralateral / remaining kidney	Mean <10 Gy; partial kidney V15 <40% where relevant. With nephrotoxic agents, push lower.
Liver	Mean <10 Gy preferred; whole-liver 10 Gy corresponds to ~6% modeled SOS risk.
Heart	ALARA, particularly after anthracycline; mean <10 Gy associated with low absolute late cardiac risk without anthracycline.
Lungs	For partial lung exposure: MLD <14 Gy and V20 <30% associated with low pneumonitis risk.
Bowel / stomach	Minimize mean and moderate dose; avoid focal hotspots from range uncertainty.
Spine / growth plates	Minimize dose and gradients outside target; PENTEC suggests <20 Gy to spine in children <6 and <10-15 Gy in infants when oncologically feasible.
Gonads	ALARA; quantify actual testis/ovary dose and discuss fertility impact.

Plan approval checklist

☐ Preoperative post-induction volume reconstructed

☐ No routine 36-Gy residual boost

☐ Liver/heart/lung means reviewed

☐ 4D robustness assessed if mobile target

☐ IDRF interfaces reviewed

☐ Kidney mean/V15 reviewed

☐ Vertebral symmetry reviewed

☐ Composite metastatic-site dose reviewed

PAGE 4 • IMAGING, METASTATIC SITES, FOLLOW-UP AND REFERENCES

On-treatment / follow-up

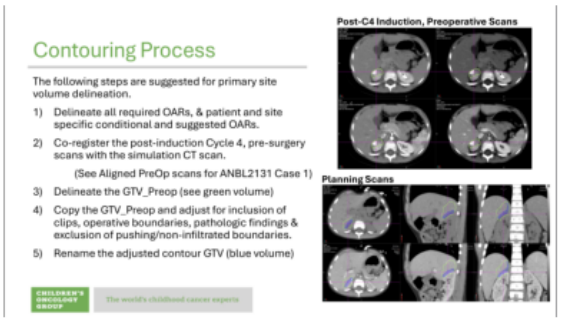
- Daily IGRT. Repeat verification CT if bowel gas, diaphragm position, weight or postoperative anatomy threatens proton robustness.
- Post-therapy surveillance is systemic: MIBG/PET, cross-sectional imaging and marrow assessment follow the neuroblastoma protocol rather than a radiation-only schedule.
- Long-term surveillance should specifically address renal function/HTN, endocrine growth, musculoskeletal development, fertility, bowel function and second malignancy risk.

Key references

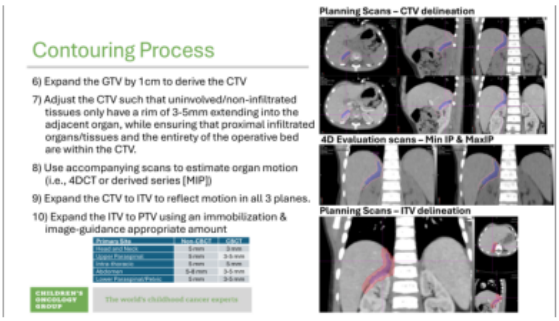
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8. PENTEC spine/growth impairment. 2024. PMID 38069918. Link

NEUROBLASTOMA • PRIMARY-SITE CONTOURING

Selected contouring workflow from user-supplied ANBL2131 radiotherapy material



Step 1: co-register post-induction preoperative imaging, define GTV_Preop and initially involved regional nodes/operative bed.



Step 2: derive CTV with the protocol margin, then anatomically edit into uninvolved organs while preserving infiltrated tissues and the operative bed.

Source: user-supplied COG ANBL2131 Radiotherapy material, pp. 13-14. Internal educational use; verify against active protocol.

CHAPTER A | SHARED SOLID-TUMOR OAR RISK LIBRARY

PENTEC-based planning goals to be used as context, not absolute protocol overrides

PAGE 1 • THORACOABDOMINAL AND SKELETAL ORGANS

OAR	PENTEC / evidence-based risk anchor	Manual use
Kidney	Mean <10 Gy for bilateral/single functioning kidney is a useful pediatric goal; partial kidney V15 <40%.	Use as preferred planning goal; nephrotoxic chemotherapy strengthens ALARA.
Liver	Whole-liver ~10 Gy -> ~6% modeled SOS; mean <10 Gy preferred when feasible.	Particularly relevant to Wilms/neuroblastoma/right-sided tumors.
Lung	Partial-lung MLD <14 Gy and V20 <30% -> low RP risk.	Not a substitute for WLI-specific planning.
Heart	Each +10 Gy mean heart dose roughly doubles relative risk of several late cardiac outcomes; mean <10 Gy gives low absolute risk without anthracycline.	With anthracycline, push mean/substructure doses as low as achievable.
Spine	Risk of scoliosis/growth impairment rises with vertebral dose/gradient; <20 Gy if <6 y and <10-15 Gy in infants when feasible.	Do not violate tumor coverage/protocol-required vertebral inclusion.

PAGE 2 • REPRODUCTIVE / PELVIC ORGANS

OAR	Risk anchor	Planning implication
Testes	Mean <0.2 Gy usually preserves testosterone; >1 Gy produces >90% short-term oligospermia in reported cohorts; Leydig risk rises steeply at high doses.	Contour both testes individually; keep scatter/exit dose ALARA.
Least-affected ovary	Even 2 Gy can produce measurable acute ovarian-failure risk; age and alkylator exposure strongly modify risk.	Report Dmax/mean to each ovary; prioritize the less-affected ovary when oncologically safe.
Uterus	Data suggest uterine size restriction becomes clinically relevant around >12 Gy.	Reduce mean dose and high-dose volume, especially in young girls.
Bladder/rectum/bowel	PENTEC provides dose-volume rather than single-point thresholds; evidence is weaker than for kidney/heart.	Use protocol constraints first; otherwise reduce V45-50 and focal high dose, especially in pelvic RMS.
Bone/physes	Growth injury is age/dose/gradient dependent.	Report physis/joint/vertebral dose in young children; avoid unnecessary asymmetry/circumferential exposure.

Core references

1. PENTEC User Guide and Summary. IJROBP 2024. PMID 37999712. Link
2. PENTEC kidney disease. PMID 37452796. Link
3. PENTEC liver late effects. PMID 37480885. Link
4. PENTEC pulmonary effects. PMID 35525723. Link
5. PENTEC cardiac disease. PMID 37061912. Link
6. PENTEC spinal growth. PMID 38069918. Link
7. PENTEC testicular dysfunction. PMID 37791936. Link
8. PENTEC female reproductive tract. PMID 37804257. Link

Next expansion

Planned next modules can include NRSTS/CIC/BCOR sarcoma, osteosarcoma/axial bone tumors, lymphoma, retinoblastoma and rare pediatric thoracic/abdominopelvic tumors. The contouring-atlas layer can then be added with original schematics and appropriately licensed clinical images.

PEDIATRIC HODGKIN LYMPHOMA

Response-adapted ISRT, PET-directed boost and mediastinal proton planning

PAGE 1 • PATIENT SELECTION, RESPONSE AND RT INDICATION

Clinical bottom line

In pediatric/AYA classical Hodgkin lymphoma, RT is response-adapted and protocol-specific. Modern COG strategies irradiate fewer patients and use involved-site or response-adapted volumes rather than historical IFRT. Proton therapy is most valuable when it materially reduces dose to heart/coronaries, breasts, lungs and thyroid without compromising ISRT coverage.

Pre-RT checklist

- Confirm classical Hodgkin lymphoma, stage and all initially involved nodal/extranodal sites.
- Review baseline PET/CT, interim PET (PET2) and end-of-systemic-therapy PET; record Deauville score and protocol-defined rapid/slow response.
- Fuse baseline PET/CT to simulation CT whenever technically reliable; document arm position and anatomic changes after chemotherapy.
- Record anthracycline, bleomycin/brentuximab and other cardiopulmonary-toxic systemic exposures.
- For mediastinal disease, assess DIBH feasibility and whether proton therapy offers a clinically meaningful OAR reduction.

Current COG examples

Setting	RT trigger / dose	Important nuance
AHOD2131, stage I-II cHL	RT for slow early responders (SER). SER→CMR: 30 Gy/15 fx; selected <16 y or OAR-limited patients may receive 21 Gy/14 fx + 9 Gy/6 fx to SER site. SER→PMR: 30 Gy + 6–10 Gy boost.	Active response-adapted strategy; do not extrapolate to every pediatric HL patient.
AHOD1331, high-risk cHL	21 Gy/14 fx to protocol-defined sites, with 9 Gy boost to end-of-therapy partial response.	3D, IMRT and proton therapy were allowed; modality does not change target definition.

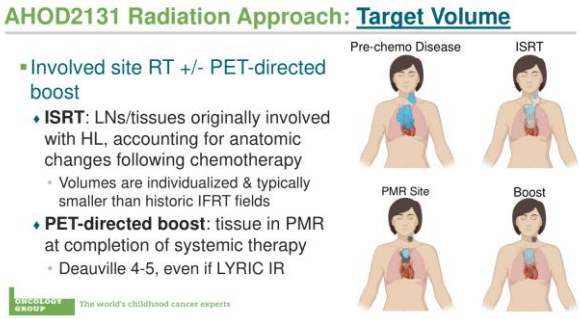
Do not miss

Omission of RT in a rapid responder is a protocol decision, not a general rule. Conversely, if RT is indicated, reducing normal-tissue dose should not be achieved by omitting initially involved tissue that belongs in the ISRT volume.

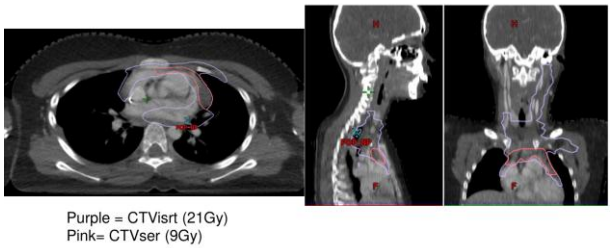
PAGE 2 • SIMULATION, ISRT AND PET-DIRECTED BOOST

Target delineation

- ISRT includes lymph nodes/tissues initially involved by lymphoma, adjusted for anatomic changes after chemotherapy.
- Include tissues that were infiltrated at diagnosis; exclude tissue merely displaced or contacted but not invaded when anatomy has normalized.
- PET-directed boost volume is limited to protocol-defined residual metabolically active tissue at end of systemic therapy (AHOD2131: PMR, Deauville 4–5).
- Use baseline PET/CT and diagnostic CT to prevent site omission; do not rely on the post-chemotherapy simulation CT alone.



AHOD2131 target concept: pre-chemotherapy disease → individualized ISRT; boost reserved for residual metabolic disease.



Nested CTV example: ISRT volume plus smaller slow-response boost volume.

Simulation / proton technique

- Supine immobilization; arms-up when appropriate for mediastinal/axillary disease, while preserving reproducibility with diagnostic PET fusion.
- Motion assessment/reduction is encouraged. Use DIBH when reproducible and when it improves heart/lung/breast dose.
- For pencil-beam scanning, evaluate robustness across respiratory/anatomic variation; repeat CT if body contour, lung inflation or mediastinal anatomy changes materially.
- Contour heart substructures (at minimum whole heart, left ventricle and coronary/LAD region when relevant) rather than relying only on mean heart dose.

Source of figures: user-supplied AHOD2131 RT guidelines/cases, pp. 3 and 23; internal educational use.

PAGE 3 • DOSE, OAR GOALS AND PROTON PLAN APPROVAL

Dose summary

Clinical scenario	Dose / field
AHOD2131 SER→CMR	30 Gy ISRT in 15 fractions
AHOD2131 SER→CMR, selected <16 y or OAR-limited	21 Gy ISRT in 14 fractions + 9 Gy boost in 6 fractions to SER site
AHOD2131 SER→PMR	30 Gy ISRT + 6–10 Gy sequential boost to PMR
AHOD1331 high-risk reference	21 Gy in 14 fractions to protocol-defined sites + 9 Gy boost for end-of-therapy PR

Mediastinal OAR plan-review goals

OAR	Preferred planning goal / interpretation
Heart + substructures	ILROG proton guideline ideal mean heart dose <5 Gy; minimize coronary, LV and valve dose as much as reasonably possible. Adult-derived planning goal, not a pediatric hard limit.
Breasts	ILROG ideal mean <4 Gy in young patients; reduce high dose and low-dose bath, especially in girls/young women.
Lungs	ILROG ideal: mean <10 Gy, V20 <30%, V5 <55%; aim lower when feasible, especially after pulmonary-toxic therapy.
Thyroid	ILROG reference: V25 <62.5%; pediatric practice should pursue ALARA because hypothyroidism/second-cancer risk is dose dependent.
Esophagus / cord	ALARA / serial-organ safety; avoid unnecessary high-dose exit or distal-edge placement.
Integral dose	Compare proton vs best photon plan when benefit is uncertain; advantage is often greatest for lower mediastinal, bilateral mediastinal or axillary targets.

Important

The ILROG dose goals above were developed for mediastinal lymphoma broadly and are adult-derived. In this pediatric manual they are used as aspirational proton planning goals, not as substitutes for the active pediatric protocol OAR table.

Plan approval checklist

- All initially involved sites included in ISRT.
- SER/PMR boost volume matches protocol and PET response.
- Heart/LV/coronary, breast, lung and thyroid metrics reviewed.
- DIBH benefit assessed if feasible.
- Proton robust coverage acceptable across motion/setup scenarios.
- No avoidable distal edge through coronary arteries or other critical serial structures.

PAGE 4 • FOLLOW-UP, SURVIVORSHIP AND KEY REFERENCES

During RT

- Daily IGRT; verify arm/neck position and mediastinal alignment.
- Re-simulate if DIBH reproducibility deteriorates or thoracic anatomy changes enough to affect proton range.
- Monitor cough/dyspnea, esophagitis and fatigue; pneumonitis risk is influenced by both RT and systemic therapy.

Survivorship

Domain	Long-term priority
Cardiac	Risk-based surveillance based on anthracycline + cardiac radiation exposure; preserve substructure dose data in treatment summary.
Breast	Age- and exposure-based breast surveillance; minimizing mean dose is a major planning priority.
Thyroid	TSH/free T4 surveillance; examine thyroid annually.
Pulmonary	Assess symptoms and pulmonary function when clinically indicated, especially after lung-toxic therapy.
Second malignancy	Document irradiated organs/mean doses and minimize integral dose/low-dose bath whenever target coverage permits.

Non-Hodgkin lymphoma

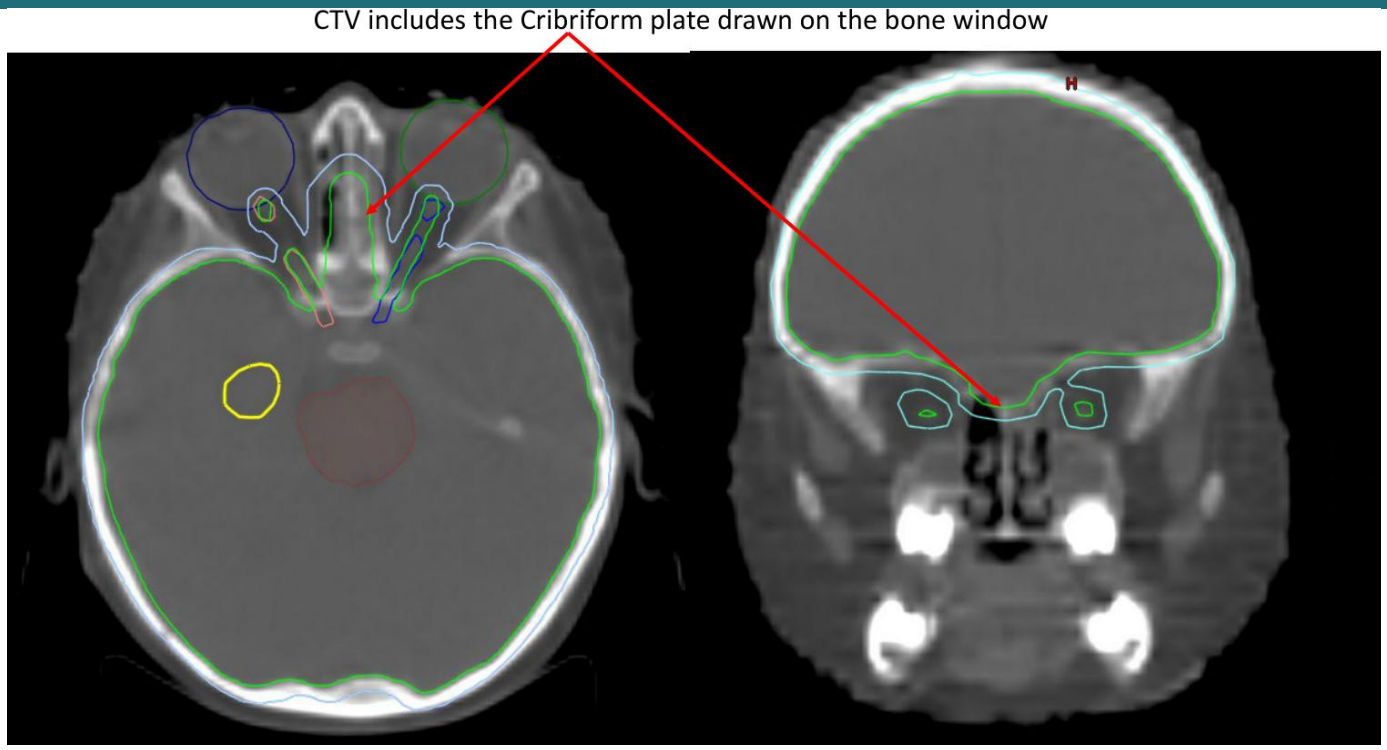
This chapter is intentionally focused on classical Hodgkin lymphoma because the supplied AHOD2131 atlas is cHL-specific. Pediatric NHL RT indications, doses and response criteria are distinct and should be built as a separate protocol-based chapter rather than appended by analogy.

Key references

1. AHOD2131 RT Guidelines including sample cases (user-supplied COG educational deck, 2025).
2. Hoppe BS et al. Comparison of contemporary RT approaches on COG AHOD1331. IJROBP. 2025;123:972-979. PMID 40588069. Link
3. Dabaja BS et al. ILROG guidelines for proton therapy in mediastinal lymphomas. Blood. 2018;132:1635-1646. PMID 30108066. Link
4. Parsons SK et al. SEARCH report: RT across pediatric Hodgkin lymphoma research group protocols. IJROBP. 2022;112:985-996. Link
5. Hoppe BS et al. Vital organ sparing with proton therapy for pediatric Hodgkin lymphoma. Radiother Oncol. 2022;167:11-17. PMID 35101461. Link

INTERNAL VISUAL ATLAS APPENDIX

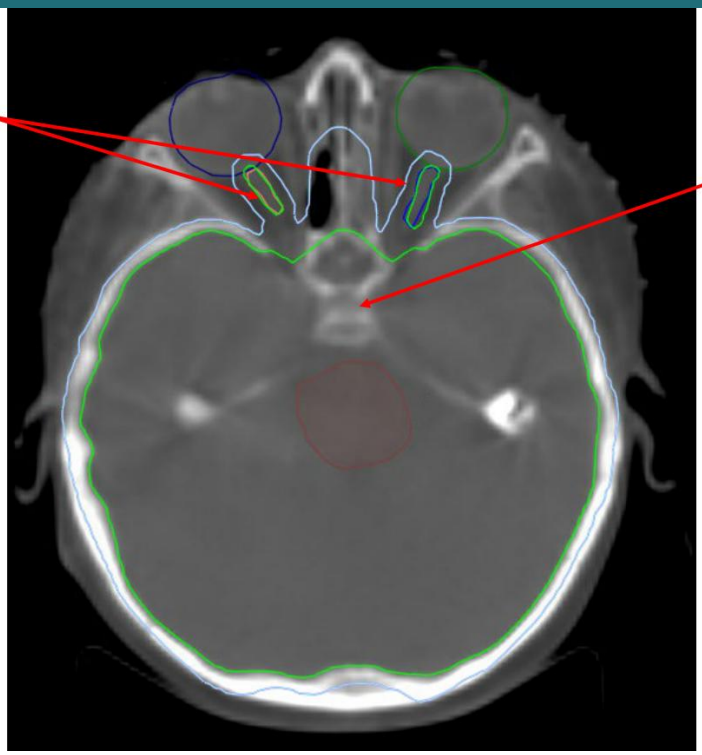
Selected imaging examples from user-supplied cooperative-group atlases



ACNS2031 atlas: cribriform plate coverage on bone window.

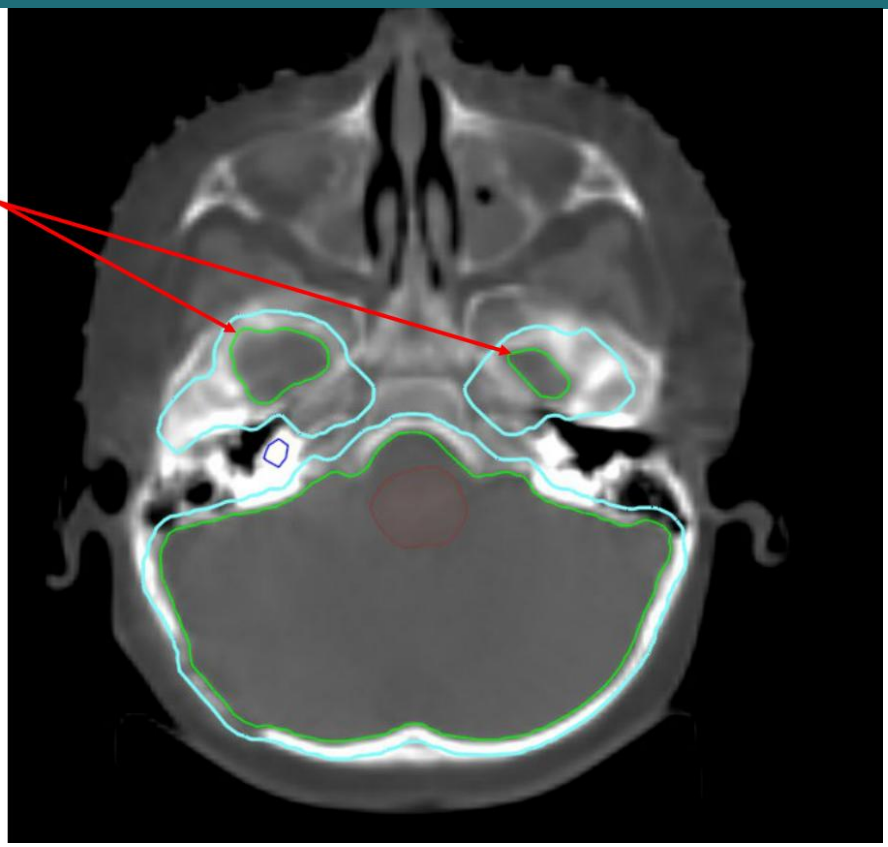
VISUAL ATLAS

Medulloblastoma - skull base / optic-pituitary anatomy



ACNS2031 atlas: optic nerves and pituitary fossa within the cranial CTV framework.

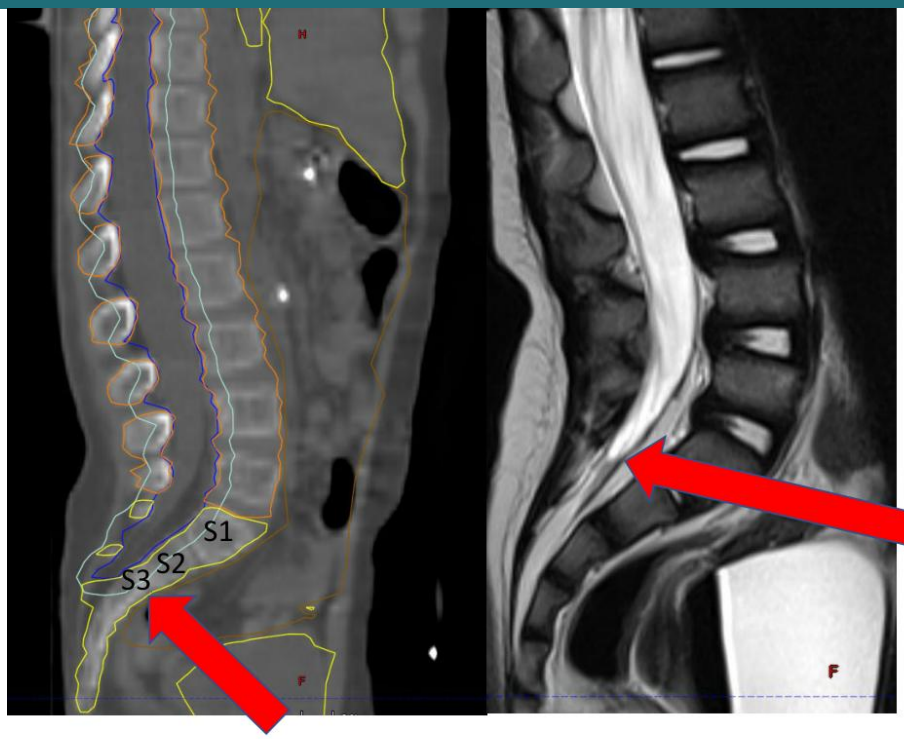
Inferior slices of the middle cranial fossae drawn on the bone window must be included in the CTV_brain



ACNS2031 atlas: inferior temporal/middle cranial fossa coverage.

VISUAL ATLAS

Medulloblastoma - inferior spinal CTV



Inferior termination of the thecal sac (red arrow)

Best seen on Sagittal Lumbar spine T2 MRI (Right panel)

Inferior extent of CTV-spine (Red arrow) approximately 1.5 cm below the termination of the subdural space (thecal sac) usually S2/3 level

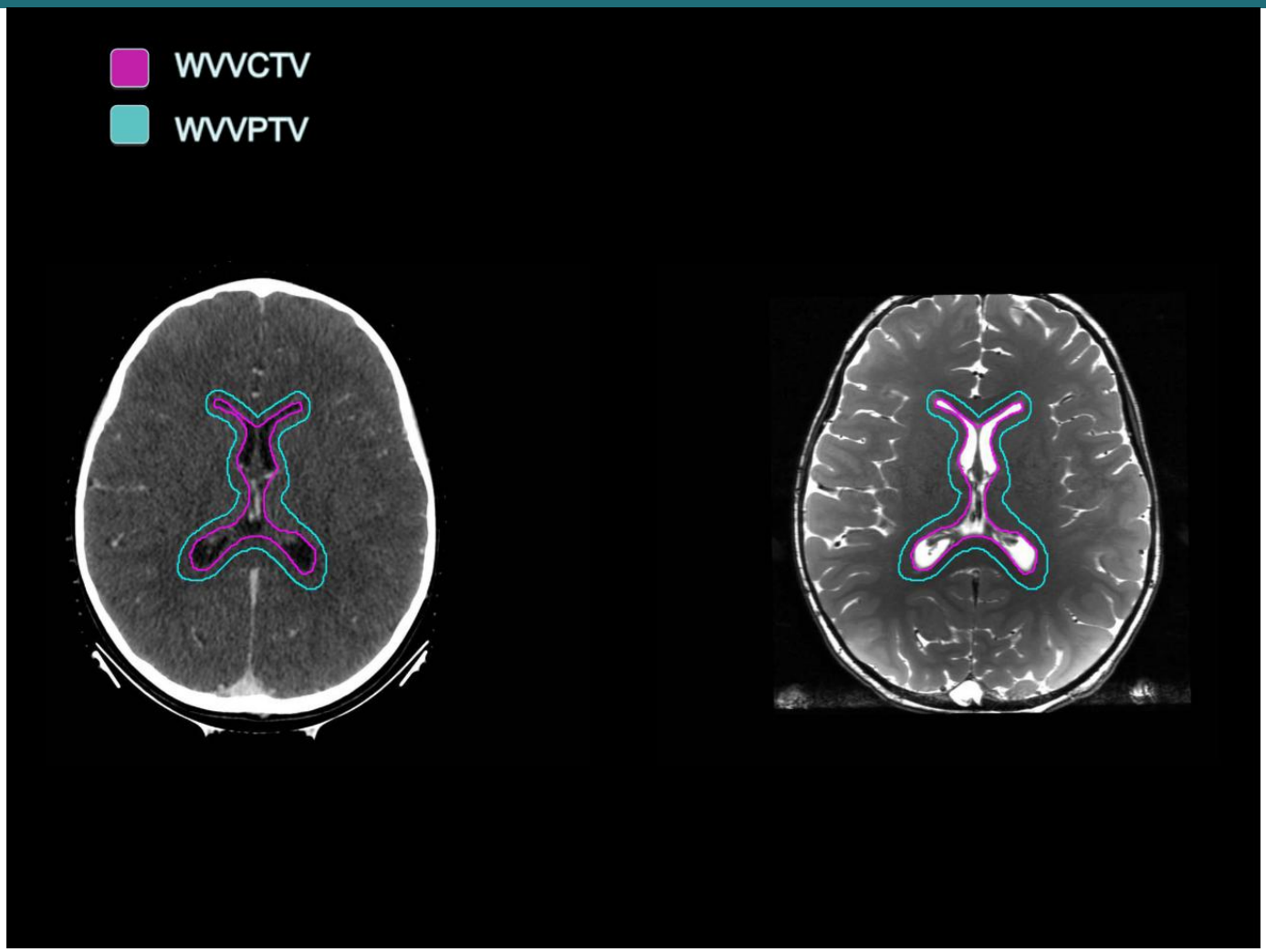
ACNS2031 atlas: thecal-sac termination and inferior CTV-spine extension.

Source / permissions note

Source: user-supplied cooperative-group/teaching atlas. Included in this institutional working draft for contouring education. Confirm redistribution rights before broad circulation; replace with an original or openly licensed figure if required.

VISUAL ATLAS

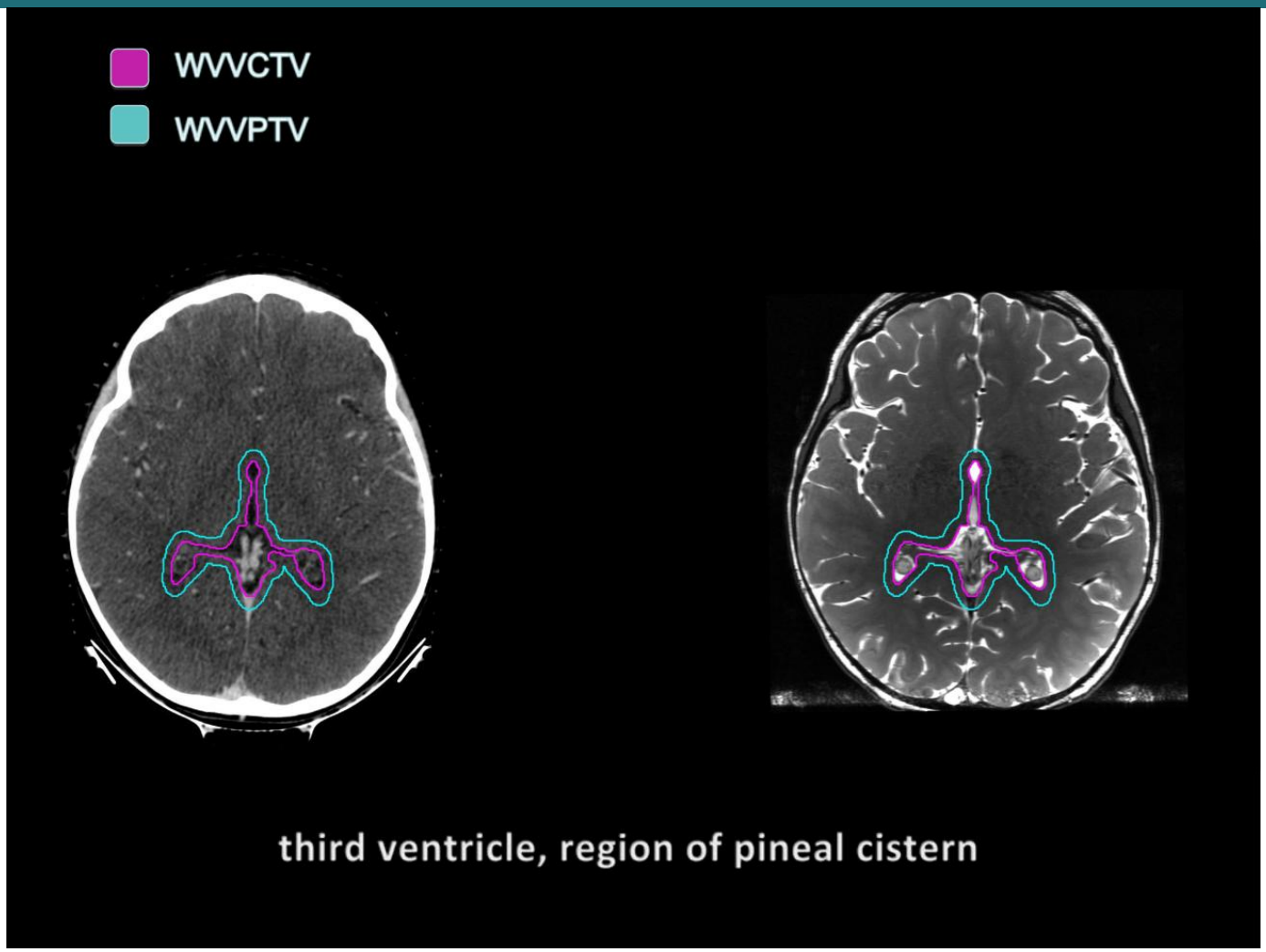
CNS germinoma - whole-ventricle axial anatomy



ACNS1123 atlas: whole-ventricle CTV/PTV at the lateral/third ventricular level.

VISUAL ATLAS

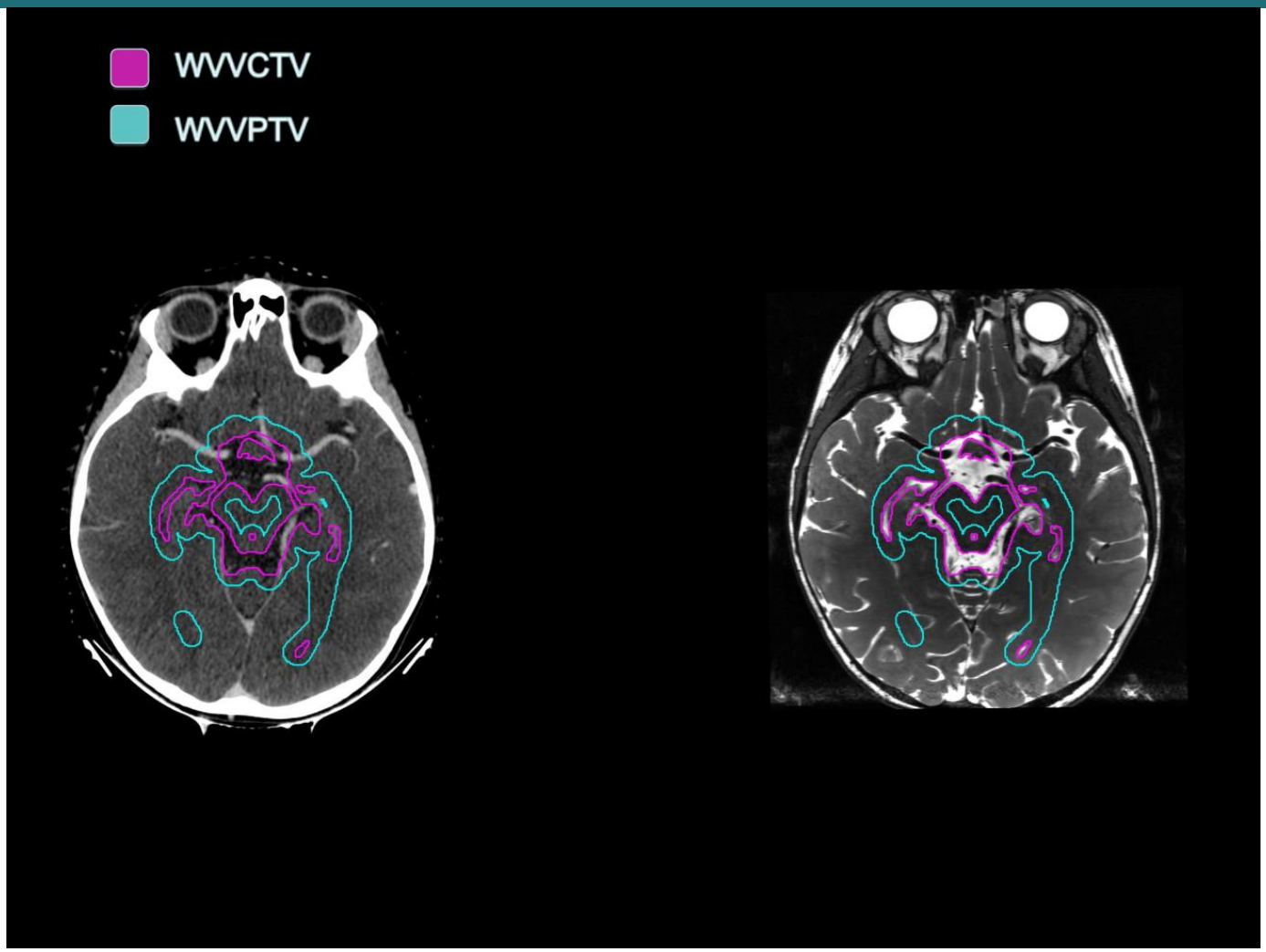
CNS germinoma - pineal recess / third ventricle



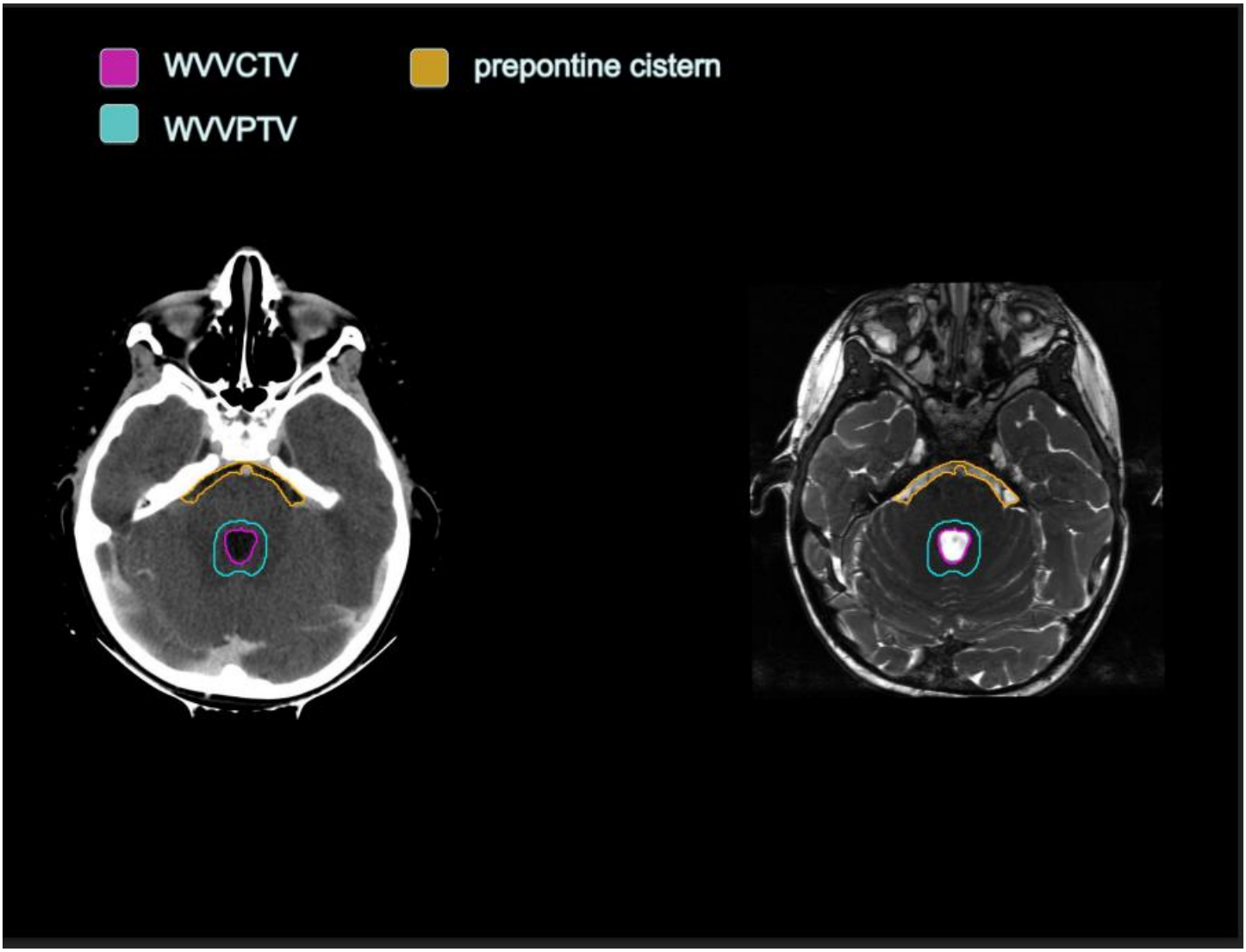
ACNS1123 atlas: third ventricle and pineal cistern region.

VISUAL ATLAS

CNS germinoma - basal / suprasellar recess anatomy

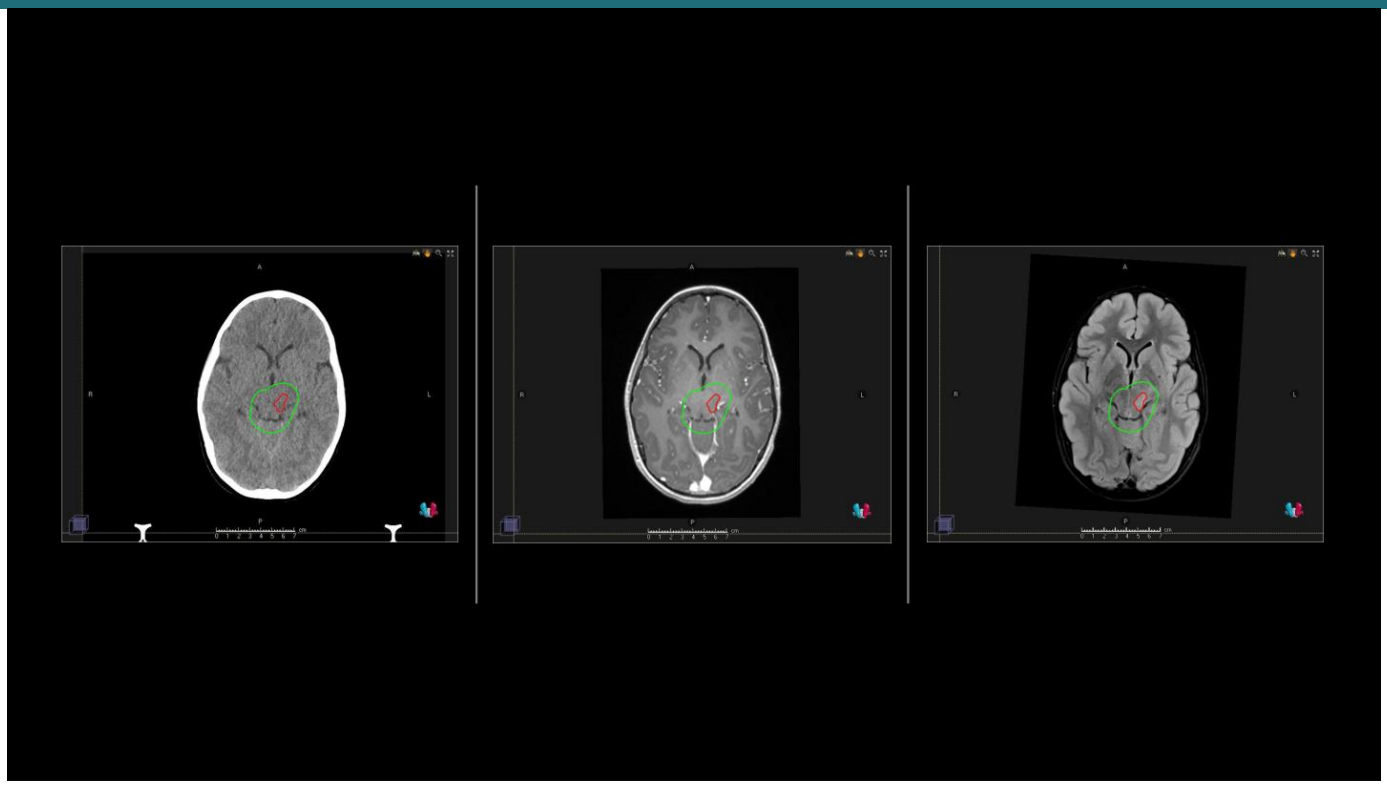


ACNS1123 atlas: inferior ventricular/cisternal anatomy.


WVVCTV
prepontine cistern
WVVPTV

VISUAL ATLAS

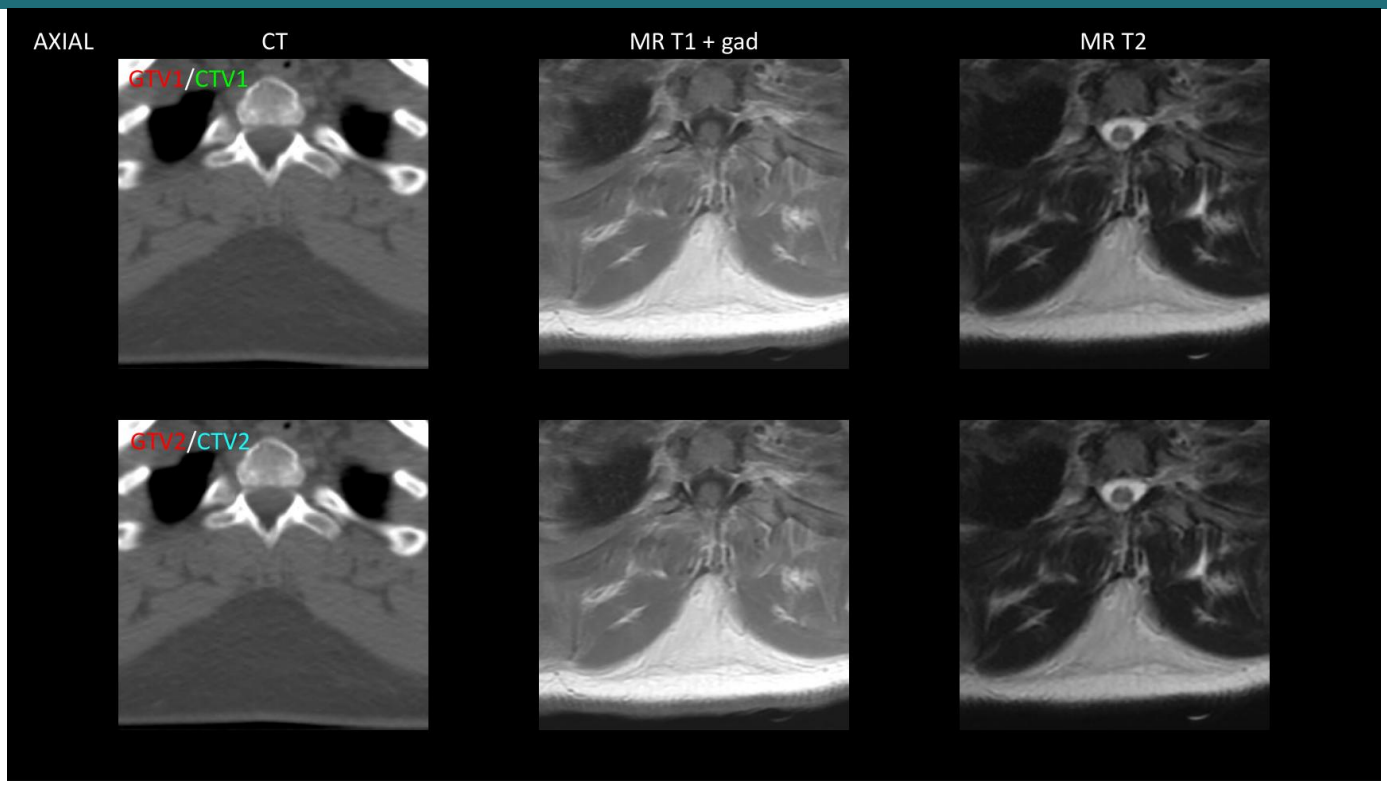
HGG/DMG - hemispheric target example



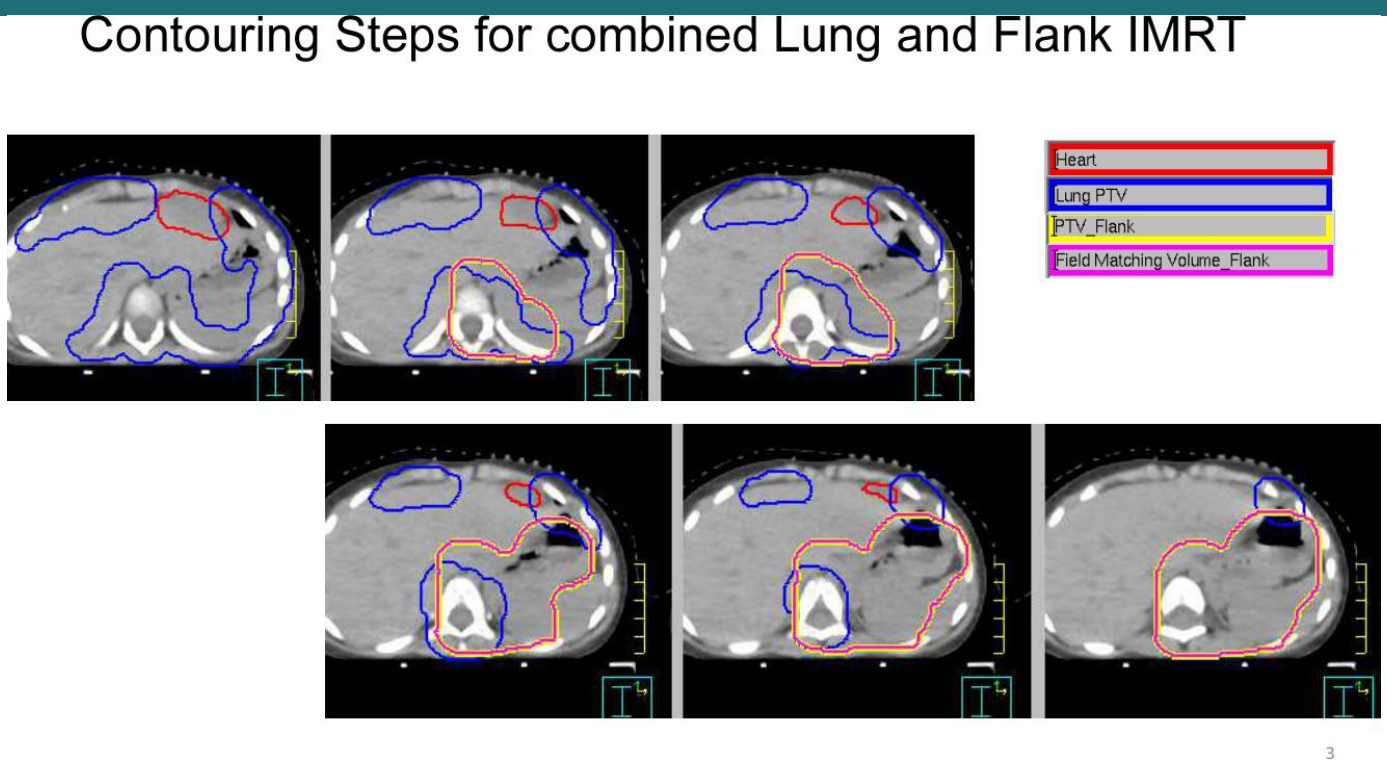
ACNS1821 atlas: GTV/CTV over CT, post-contrast T1 and FLAIR.

VISUAL ATLAS

HGG/DMG - spinal target example



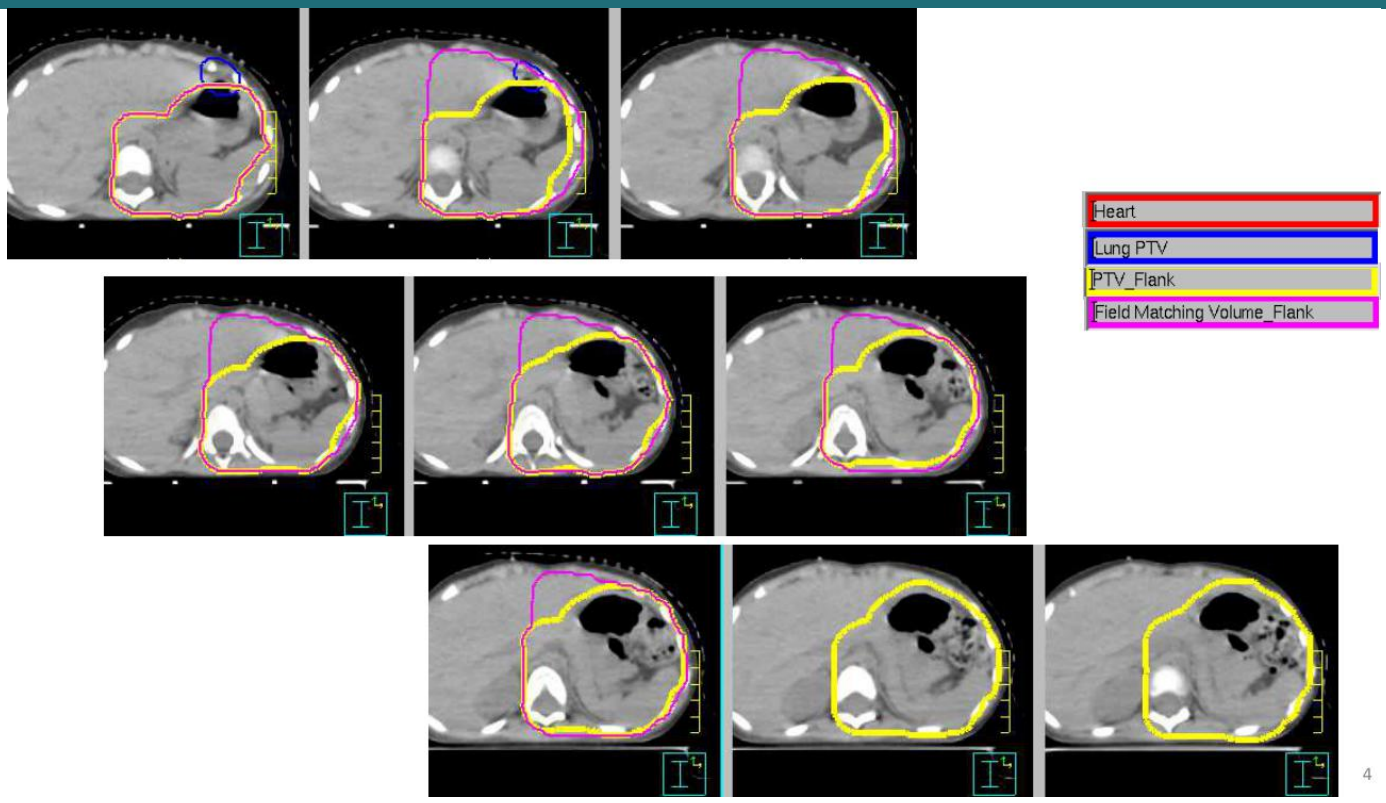
ACNS1821 atlas: primary spinal tumor GTV/CTV across CT and MRI.



User-supplied flank/WLI contouring guide: overlap/matching anatomy.

VISUAL ATLAS

Wilms - combined lung/flank continuation



User-supplied flank/WLI contouring guide: inferior flank/lung matching.

Contouring Process

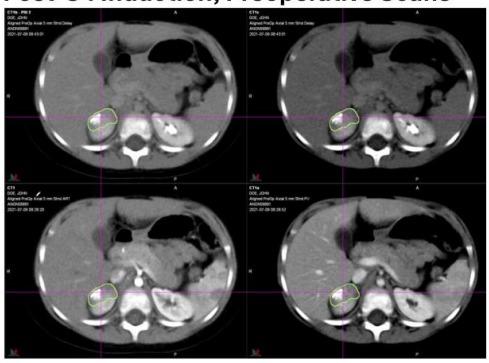
The following steps are suggested for primary site volume delineation.

1) Delineate all required OARs, & patient and site specific conditional and suggested OARs.
2) Co-register the post-induction Cycle 4, pre-surgery scans with the simulation CT scan.

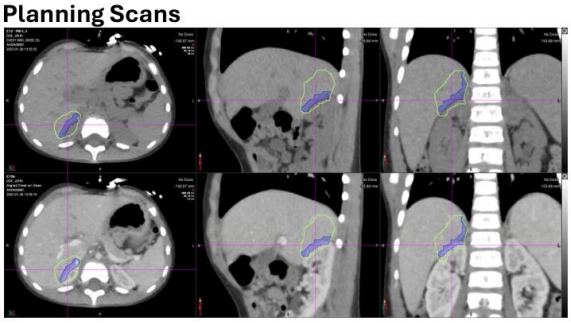
   (See Aligned PreOp scans for ANBL2131 Case 1)
3) Delineate the GTV_Preop (see green volume)
4) Copy the GTV_Preop and adjust for inclusion of clips, operative boundaries, pathologic findings & exclusion of pushing/non-infiltrated boundaries.
5) Rename the adjusted contour GTV (blue volume)

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Post-C4 Induction, Preoperative Scans



Planning Scans



ANBL2131 teaching material: preoperative GTV reconstruction and postoperative adjustment.

Contouring Process

6) Expand the GTV by 1cm to derive the CTV

7) Adjust the CTV such that uninvolved/non-infiltrated tissues only have a rim of 3-5mm extending into the adjacent organ, while ensuring that proximal infiltrated organs/tissues and the entirety of the operative bed are within the CTV.

8) Use accompanying scans to estimate organ motion (i.e., 4DCT or derived series [MIP])

9) Expand the CTV to ITV to reflect motion in all 3 planes.

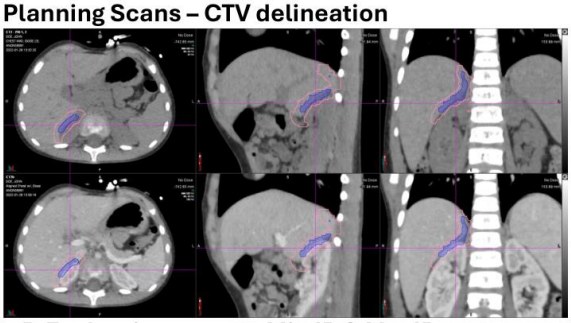
10) Expand the ITV to PTV using an immobilization & image-guidance appropriate amount

Primary Site	Non-CBCT	CBCT
Head and Neck	5 mm	3 mm
Upper Paraspinal	5 mm	3-5 mm
Intra-thoracic	5 mm	5 mm
Abdomen	5-8 mm	3-5 mm
Lower Paraspinal/Pelvic	5 mm	3-5 mm

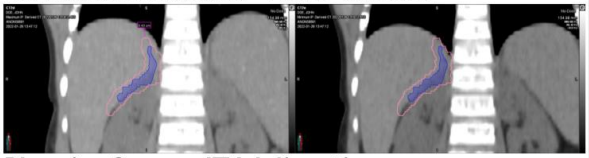
CHILDREN'S ONCOLOGY GROUP

The world's childhood cancer experts

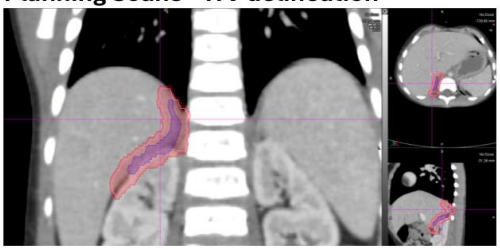
Planning Scans – CTV delineation



4D Evaluation scans – Min IP & MaxIP



Planning Scans – ITV delineation

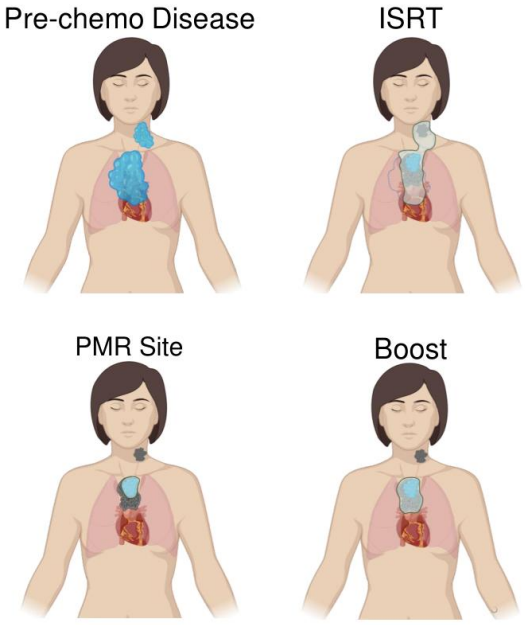


ANBL2131 teaching material: 1-cm CTV framework, anatomic editing and motion/ITV concept.

AHOD2131 Radiation Approach: Target Volume

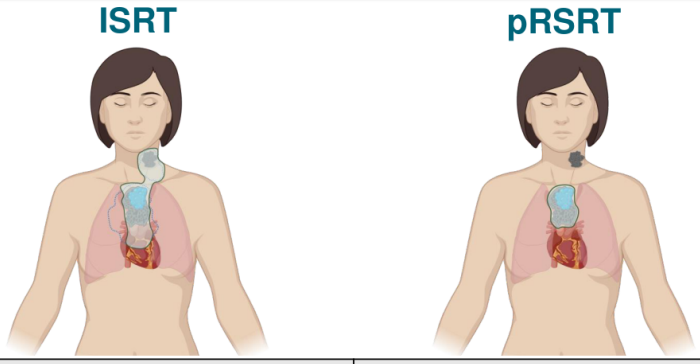
- Involved site RT +/- PET-directed boost
  - **ISRT**: LNs/tissues originally involved with HL, accounting for anatomic changes following chemotherapy
    - Volumes are individualized & typically smaller than historic IFRT fields
  - **PET-directed boost**: tissue in PMR at completion of systemic therapy
    - Deauville 4-5, even if LYRIC IR

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AHOD2131 teaching material: pre-chemotherapy disease, ISRT and PET-directed boost concept.

AHOD2131 Radiation Approach: Dose



SER → CMR	**30 Gy**	
SER → CMR • <16 y/o • Any age, OAR constraints would be exceeded with 30 Gy ISRT	**21 Gy**	**9 Gy (SER)**
SER → PMR	**30 Gy**	**6-10 Gy (PMR)**

AHOD2131 teaching material: 30 Gy vs 21 Gy + response-directed boost pathways.

VISUAL ATLAS - OPEN-LICENSE REPLACEMENT CANDIDATES

Disease / topic	Open-access source
Ewing chest wall	Su Z et al. J Appl Clin Med Phys. 2020;21:100-107. PMID 32268008.
Neuroblastoma proton therapy	Jazmati D et al. Front Oncol. 2021;10:617506.
Craniopharyngioma outcomes/cyst dynamics	Bishop AJ et al. IJROBP. 2014;90:354-361. PMID 25052561.
Pediatric adaptive proton workflow	Sheikh K et al. Adv Radiat Oncol. 2024;9:101634. PMID 39610801.
Pediatric CBCT body-surface monitoring	Ates O et al. Phys Imaging Radiat Oncol. 2025;34:100746. PMID 40151313.
Wilms bowel gas / WEPL	Ates O et al. Cancers. 2024;16:642. PMID 38339393.

More OAR constrains

