West Midlands Radiotherapy Clinical Protocol

Paediatric Whole CNS Protocol

Revision history

Version	Date	Summary of changes
1.5	5.1.25	UHB reviewed protocol
Review Date:	January 2028	

Paediatric Whole CNS Protocol

Introduction

Medulloblastoma (MB) is a primitive cerebellar tumour of neuroectodermal origin (PNET). It is the most common malignant brain tumour in childhood, accounting for between 15 and 20% of all childhood primary CNS neoplasms and around 80 % of PNETs. The outcome for children with MB is most closely related to the age of the patient and extent of disease at diagnosis. MB is associated with CSF seeding / metastases.

Histologically, MB is a densely cellular neoplasm composed predominantly of undifferentiated small round, blue cells.

WHO Classification 2007:

- Classic variant – 70-80%
- Desmoplastic – 20% (associated with mutations in sonic hedgehog patched pathway (PTCH)).
- Medulloblastoma with extensive nodularity (MBEN)
- Anaplastic
- Large Cell

} Marked by chromosomal loss (17p-), MYC amplification and poor prognosis

MYC and *MYCN* represent the most commonly amplified genetic loci in medulloblastoma, and have been associated with large cell and anaplastic medulloblastomas, although can be observed in other MB phenotypes. Amplification of *MYC* or *MYCN* appears clearly associated with a poor outcome and is accepted as an adverse prognostic factor (high risk disease) by the SIOP Europe PNET group.

Four molecular subtypes of medulloblastoma have been identified and although at present are not used to guide treatment decisions, are prognostically important:

- SHH (Sonic HedgeHog): 25% incidence. Intermediate prognosis. 5 yr OS 60-80%. Most relapses tend to be local.
- WNT (Wingless): 10% incidence, >95% OS rate,?candidates for de-escalation in treatment intensity (currently being investigated in PNET 5).
- Group 3 (Subtype C): 25% incidence. 50% 5 yr OS
- Group 4 (Subtype D):35% incidence. 75% 5 year OS. Almost all recurrences are metastatic.

Staging Investigations:

- MRI Brain (Pre & Post op)
- MRI Whole Spine (ideally pre-op)
- CSF cytology. At least D15 post operatively to avoid false positives.
- If metastatic disease suspected on initial imaging, bone scan and bone marrow aspirate should be performed.

Chang Staging of Medulloblastoma
T stage is no longer used clinically.

M_0 : No evidence of subarachnoid / haematogenous metastases
M_1 : Tumour cells found in CSF
M_2 : Intracranial disease beyond primary site but still in brain
M_3 : Gross nodular seeding in spinal subarachnoid space
M_4 : Metastasis outside the cerebrospinal axis (especially bone marrow & bone).

Risk Stratification:

Risk Factor	Average Risk	High Risk
Age	>3 years	< 3 years
Residual Tumour	< 1.5cm^2	>1.5cm^2
Stage	M_0	M_{1-4}
Other factors		Amplification of MYC or MYC-N Large Cell / Anaplastic subtypes
5 year survival	>80%	30-60%

Principles of Management

Multi-disciplinary management including surgery, chemotherapy and radiotherapy.
The management of supratentorial embryonal tumours follows similar risk-adapted radiotherapy principles to MB.

3 years of age is the cut-off for craniospinal radiotherapy. Children under 3 are treated with chemotherapy alone (HeadStart Protocol) or together with radiotherapy to the posterior fossa only (Infant PNET Study).

All patients are to be treated using TomoTherapy

Dose and Fractionation Average Risk MB and StPNET:

- Craniospinal Axis Irradiation: 23.4Gy in 13 fractions treating once daily. Concurrent vincristine is no longer given during craniospinal radiotherapy.
- Boost to tumour bed: 30.6Gy in 17 fractions, treating once daily (total dose 54Gy in 30 fractions to tumour bed)
    - Preliminary results of COG ACNS0331 have shown equivalent overall survival and event free survival using posterior fossa versus involved field (tumour bed) radiotherapy.
- Adjuvant 'Packer' Chemotherapy (Vincristine, CCNU, Cisplatin).
- See below for details on immobilisation / contouring.

Dose and Fractionation: High Risk / Metastatic (first presentation): CCLG Recommend use of St Judes Protocol for HR MB and StPNET: Risk adapted CSI followed by high dose chemotherapy

- M_0 – M_1 : Craniospinal Axis Irradiation: 36.0 Gy in 20 fractions treating once daily
  Boost to primary tumour bed: 19.8Gy in 11 fractions. (Total dose 55.8Gy to primary tumour bed).
- M_2 – M_3 : Craniospinal Axis Irradiation: 36.0 - 39.6Gy in 20 - 22 fractions treating once daily
  Boost to primary tumour bed: 16.2 – 19.8 Gy in 9 – 11 fractions (Total dose 55.8Gy to primary tumour bed)

- Boost other sites of metastatic disease (if applicable) to total dose of 50.4Gy (spinal), or 54-55.8Gy (intracranial).
- E.g. for spinal metastatic disease:
    - If Whole CNS received 36Gy in 20 fractions, boost metastatic disease to 14.4Gy in 8 fractions
    - If Whole CNS received 39.6Gy in 22 fractions, boost metastatic disease to 10.8Gy in 6 fractions

Radiotherapy Principles

RCR Category 1

Patients will receive craniospinal radiotherapy as outlined above followed by a boost to the primary tumour bed and sites of all macroscopic residual disease >5mm based on post-operative MR imaging. Extensive areas of residual meningeal disease may not be amenable to a boost. No concomitant chemotherapy will be given with radiotherapy for high risk / metastatic disease. Radiotherapy will be delivered in two separate phases.

Radiotherapy should start as soon as practicably possible following definitive surgery (ideally within 28 days and no later than 40 days post operatively).

Consent

Patients for whole CNS Tomotherapy and their families must be made aware of the increased radiation dose required for imaging (See appendix 2 for estimation of MVCT dose exposure with Tomo) and also the potential uncertainties with the 'low dose bath.'

Early	Late
Fatigue	Endocrinopathies
Hair loss	Hearing loss
Headaches	Visual impairment including cataracts
Sickness	Reduced growth of vertebra – reduced sitting height
Myelosuppression	Neurocognitive toxicity (↓concentration, IQ, memory)
Somnolence (4-6 weeks post RT)	Effect on fertility
Skin reaction	Damage to normal tissue
Seizures	Radiation induced second cancers
Diarrhoea	
Sore throat	

Written information should be provided regarding craniospinal radiotherapy and families should have contact details of the Specialist Paediatric Therapeutic Radiographers. Families that have been referred from outside of the West Midlands catchment area should also be referred to Birmingham Children's hospital to provide supportive care alongside their radiotherapy treatment.

Patient Position & Immobilisation

Patient should be positioned supine in a neck neutral position. The immobilisation comprises:

A mold care cushion shaped to the posterior of the patients head & neck and fitted to a silverman head curve (usually an "Q1" curve). Q1 headcurve is preferred for children as the addition of a moldcare causes the patient's head to tilt too much which can lead to discomfort or occluding the airway for the anaesthetic team.

Patients will have a kneefix that is interlock and central with the sagittal laser. Patients who are too small for a kneefix can have a vacuum bag that is also interlocked and used to immobilise the legs. This will improve set-up accuracy of the inferior spinal volume.

A 9 point fibreplast mask is then constructed. An open face mask must not be used for craniospinal patients. Special attention should be made to position the patient's arms as far away from the body as is practical and comfortable for the patient to create greater freedom for treatment planning.

Central axis to be marked on BDS, with mid abdomen (midway between xiphistenum and umbilicus) and pelvic alignment tattoos, plus lateral tattoo at level of the abdominal tattoo. There needs to be measurements of the arm position to torso and measurement from the kneefix or vacuum bag to inferior tattoos to also assist set up.

For further information on patient set up, please refer to document ….

A contrast scan is usually requested for the boost volume.

CT Scanning

3mm slice CT images are obtained from the vertex to 5cm below the S5 vertebra and transferred into ProSoma. The appropriate work instruction (RAW4.0-0) for CT should be followed by the radiographers which gives greater detailed instructions. Appropriate MRI datasets are obtained from the referring hospital and fused to enable delineation of posterior fossa / sites of metastatic disease.

Contouring Guidelines

TomoTherapy Contouring Guidelines

Planning of Spinal CTV:

- **Outline the Spinal Volume:**
  The aim is to include the entire subarachnoid space including the extensions along the nerve roots as far laterally as the intervertebral foramina.
  Divide the spinal CTV and label as: C-Spine CTV, T-L2 Spine CTV and L3 – S -Spine CTV.
  An additional margin should be added for PTV§ [4]:
  - **C-Spine = 5mm**
  - **T-L2 Spine = 10mm**
  - **L-Spine = 12mm§, but 10mm inferior to thecal sac.**
- **§** Audit of first 8 cases show shifts at lumbar spine to be <10mm. Therefore safe to reduce PTV margin at L – S Spine to 12mm at clinician discretion. Further audit to be carried out. May reduce margin further to 10mm in future.

  Where these PTVs overlap, trim the overlap back to the same slices as the CTV

§These margins should be audited within department and adjusted if necessary.

- **Inferior border of spinal volume**
  The inferior limit of the spinal CTV must be determined by imaging the lower limit of the thecal sac on a pre-operative MRI. This usually comes down to the bottom of S1 as an obvious CSF space, but there is often elongation extending to the bottom of S2 or further inferiorly. Neuroradiological advice should be obtained to confirm position. A further 10mm margin should be added to the inferior border for PTV, which should lie approximately in the S3-4 interspace.

- **Growing Vertebra***
  To ensure uniform irradiation in those who have not reached adolescence, growth plates must be covered symmetrically.
  Outline:
  - Whole of vertebral body
  - Posterior Arch

- Facet Joints
- Not lateral elements / transverse processes.

This will be treated with no margin to PTV as the targets are the growth plates.

- With high risk disease no requirement to include whole vertebra within spinal PTV with prescription doses of 36-39.6Gy, as fall off of dose from spinal PTV will still ensure adequate coverage of vertebral body with dose (despite gradient) to stop growth uniformly, ie >20Gy. Therefore for high risk patients, clinician discretion as to whether whole vertebra needs to be covered.

  **If adolescent / young adult who has finished growth – the entire vertebra does not need to be covered.

- **Spinal Target**
  Spinal Target = Vertebrae (if required) + Spinal PTV. In practice the anterior body of the vertebra becomes part of the target.

Cranial CTV

Outline the following:

- Whole brain (outline on bony windows). At base of skull, cranial CTV should extend up to inner table of skull and cover exit foramina of cranial nerves for phase 1 (i.e. craniospinal).
  - Ensure internal auditory canal, jugular foramen and hypoglossal canal covered by the cranial CTV.
- Brainstem
- Lenses
- Both globes
- Cochleas
- Optic nerves
- Chiasm
- Pituitary & Hypothalamus
- Cribiform plate – contour colour = light blue
- Corneas
- Lips
- Right & Left Submandibular glands
- Right & Left Parotid glands
- Mandible
- Cord (in upper cervical spine only) + 5mm margin = PRV Cord.

Create the Cranial CTV = Brain + Cribiform plate + full length of optic nerves to the back of the globes.

Cranial PTV = Cranial CTV + 5mm

- **Facial Structure should be outlined.** Includes submandibular and parotid glands, the body & ramus of the mandible, upper & lower teeth and the thyroid. This will serve as an avoidance structure.

Organs at Risk to be outlined

Contour the following normal structures:

- Stomach
- Oesophagus
- Kidneys
- Liver
- Heart (Include entire pericardial sac. The superior extent of the heart is the first slice at which the right and left pulmonary arteries have separated).
- Lungs
- Gonads
- Breasts
- Thyroid
- Pancreas
- Spleen

Primary Site Irradiation: Medulloblastoma / Supratentorial PNETs.

GTV: includes all gross residual tumour and/or the tumour bed at the primary site based on the initial pre-operative MRI that defines the tissues initially involved with disease anatomically and the post-operative and pre-irradiation MRI that identify residual disease and/or the tumour bed. The GTV in most cases will be a contracted or collapsed tumour bed. Tissue defects resulting from surgical approaches will not be included as part of the GTV when not previously involved by tumour.

CTV: = GTV + 1cm (limited to anatomic boundaries eg bony calvarium, falx and tentorium).

PTV: = CTV + 0.3 – 0.5cm.

If the GTV is not anterior to the posterior aspect of the brainstem, the anterior border of the CTV may be limited to the centre of the brainstem in axial extent. The primary site PTV will receive a cumulative dose of 55.8 Gy (in high risk disease). In patients with significant measurable residual tumour (>1.5 cm^2or 1.4 cm in greatest diameter), an additional local boost to 59.4 Gy will be considered at the discretion of the consultant (respecting organ at risk tolerance) using a CTV of 0.5 cm and PTV of 0.3-0.5 cm.

Posterior Fossa Boost (when primary site irradiation not applicable).

Posterior fossa contents (CTV) should be outlined on the CT scan (bony windows for lateral margins) fused with the T1 weighted + gadolinium MRI (Pre + post op).

Posterior fossa PTV = Posterior fossa CTV + 5mm

Borders of posterior fossa to aid contouring:

- Anterior: posterior clinoid process
- Inferior: Foramen Magnum
- Superior: Tentorium (use sagittal reconstruction).

The cranial nerve exit foramina should not be covered in the boost/phase 2 volume to reduce cochlea dose.

Metastatic Target Volume (MTV)

Overt metastatic disease >5mm in maximal diameter will define a volume or volumes for potential boost irradiation. Intracranially, the aggregate MTV+PTV will not exceed 25% of the intracranial volume. Intraspinally, the MTV will not exceed 8 consecutive or 10 total spinal segments.

Boost to Spinal Metastases (if applicable):
GTV = gross disease on appropriate MRI sequence
CTV = GTV + 0.5cm
PTV = CTV + 0.5-1.5cm margin depending on location within spinal canal

Summary

Disease Status	CSI	Primary Site	Local Boost	Spinal/Cranial Boost
AR MB / StPNET	23.4	54	NA	
HR Medulloblastoma/StPNET				
M0-1	36	55.8	NA	NA 50.4 (spine)
M2-3	36.0- 39.6	55.8	NA	54-55.8 (cranial)

Plan sign off

- Each phase should be scrutinised along with final summative plan. Every effort should be made to ensure there are no hotspots from phase 1 in critical serial structures.
- All whole craniospinal tomotherapy plans should have dual consultant review and sign off prior to treatment. Summation plan (ie composite of phase 1 and 2) should be reviewed at time of sign off. All doses to serial structures should be reported from summation plan.

Treatment and On-line Imaging

The majority of patients receiving craniospinal radiotherapy (i.e. medulloblastoma / sPNET) patients are Category 1. Therefore they require treatment on service days and Bank Holiday compensation needs to be discussed with Consultant.

TomoTherapy Whole CNS matching protocol

Please refer to document TOW03-0 for image matching protocol.

Assessment during Radiotherapy

- Patients will be reviewed with weekly weights and blood results jointly by Consultant Oncologist and Specialist Paediatric & TYA or Neuro-oncology Therapeutic Radiographers .
- All patients will be registered on a prospective database and subject to regular audit.

Anti-emetics

Ondansetron must be prescribed to all patients.

Modifications due to haematological toxicity

Weekly Full Blood Counts will be performed during radiotherapy. This may be done by the Anaesthetics team if the child has a GA for treatment or for children not requiring anaesthetic, at BCH or by the community nurses.

Consider platelet support / use of growth factors if required. Ideally treatment should not be interrupted. Haemaglobin should be maintained >100.

Supportive care during and following radiotherapy.

- Steroids should not be used routinely during RT. If symptoms of raised intra-cranial pressure develop during treatment the cause, e.g. hydrocephalus, should be actively sought. Dexamethasone may be used as a short-term measure for the treatment of symptoms of raised intracranial pressure or the treatment of nausea and vomiting which cannot be controlled by anti-emetics such as 5HT3 antagonists. The lowest dose of dexamethasone consistent with control of symptoms should be used and steroid treatment should be carefully withdrawn as soon as possible.

Dose Constraints

See Appendix One for dose constraints to be used. Anticipated difficulties should be discussed with dosimetrists prior to planning.

Dose constraints have been modified from Addenbrookes protocol (for 39Gy in 30 fractions) / QUANTEC (assuming $\alpha/\beta = 3$ for late effects).

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6. Reiken S, Mohr A, Habermehl D et al. Outcome and prognostic factors of radiation therapy for medulloblastoma. Int J Radiat Oncol Biol Phys. 2011 81 (3), 7-13.
7. SCOPE 1 – Radiotherapy Guidance and Procedures 2008
8. CCLG Interim Guidance: High Risk Medulloblastoma and Supratentorial PNET.
9. COG ACNS0331 – Abstract – Neuro-oncology 2016.

Appendix Two: Estimation of MVCT Imaging doses for Paediatric CNS treatments on Tomotherapy.

Dose Information

For coarse MVCT scans, calculations based on MVCT dose measurements gave an estimated CTDIw of 27mGy.

Dose Length Product (DLP) = $CTDI_{vol}$ x irradiated length on phantom (mGycm)

Convert DLP to effective dose (mSv) using site specific factors given by Shrimpton (1)

TABLE 4 Normalised values of effective dose per dose-length product (DLP) over various body regions and (standard) patient age

Region of body	Effective dose per DLP (mSv (mGy cm)$^{-1}$) by age				
	0[a]	1y[a]	5y[a]	10y[a]	Adult[b]
Head & neck	0.013	0.0085	0.0057	0.0042	0.0031
Head	0.011	0.0067	0.0040	0.0032	0.0021
Neck	0.017	0.012	0.011	0.0079	0.0059
Chest	0.039	0.026	0.018	0.013	0.014
Abdomen & pelvis	0.049	0.030	0.020	0.015	0.015
Trunk	0.044	0.028	0.019	0.014	0.015

[a]All data normalised to $CTDI_w$ in the standard head CT dosimetry phantom.

[b]Data for the head & neck regions normalised to $CTDI_w$ in the standard head CT dosimetry phantom; data for other regions normalised to $CTDI_w$ in the standard body CT dosimetry phantom.

Tomotherapy whole CNS Matching protocol

All patients are to have the whole CNS volume scanned for the first three fractions and then weekly thereafter. If the match is not consistent then continue with whole CNS volume scans for the rest of the treatment. Any queries please discuss with IGRT or tech leads.

After the first week, superior and inferior scanning sections are selected.
Scanning sections are selected after review of the patient's first week of imaging.
The Skull base and C Spine are to be covered in the first scan and the second scan includes lower T/L/S spine.
Estimated scan lengths (based on previous patients):

	Scan length (cm)		
Age (years)	Whole CNS	Section 1 (Skull base + C-spine)	Section 2(T/L/S spine)
5	50	15	15
10	70	18	20
15	90	20	25

Dose Calculations

MVCT Imaging doses were calculated for the whole CNS scan volume and the 2 sectional imaging volumes. The Abdomen and Pelvis effective dose factor was used for the whole

CNS scan and the T/L/S spine. The Head and Neck value was used for the skull base and C-spine. Adult dose factor are used for the 15 year old estimates.

Whole CNS scan

Age	Scan length (cm)	Effective dose factor (abdo&pelvis)	Effective dose (mSv)
5	50	0.02	27.0
10	70	0.015	28.4
15	90	0.015	36.5

Section 1 Skull base/C-spine

Age	Scan length (cm)	Effective dose factor (head&neck)	Effective dose (mSv)
5	15	0.0057	2.3
10	18	0.0042	2.0
15	20	0.0031	1.7

Section 2: T/L/S Spine

Age	Scan length (cm)	Effective dose factor (abdo&pelvis)	Effective dose (mSv)
5	15	0.02	8.1
10	20	0.015	8.1
15	25	0.015	10.1

Fractions		Age 5	Age 10	Age 15
9	Whole CNS scans	243.0	255.2	328.1
13	Sectional scans	135.3	131.8	153.4
22	**Total Effective dose(mSv)**	**378**	**387**	**481**

Boost Treatments

The treatment may include a Phase 2 boost to the primary tumour bed and/or sites of metastatic disease. As the site and fractionation may vary, MVCT doses for boost treatments are calculated per fraction. All calculations assume a 10cm scan length for each site.

Brain (using Head effective dose factor)

Age	Scan length (cm)	Effective dose factor (abdo&pelvis)	Effective dose per fraction (mSv)
5	10	0.004	1.1
10	10	0.0032	0.9
15	10	0.0021	0.6

Abdo/Pelvis

Age	Scan length (cm)	Effective dose factor (abdo&pelvis)	Effective dose per fraction (mSv)
5	10	0.02	5.4
10	10	0.015	4.1
15	10	0.015	4.1

(1) Shrimpton PC (2004). Assessment of patient dose in CT. Chilton, NRPB-PE/1/2004, 2004. Also published as Appendix C of the 2004 CT Quality Criteria at http://www.msct.info/CT_Quality_Criteria.htm [Accessed 5 May2006]

Appendix One: Dose Constraints Paediatric Whole CNS Tomotherapy: 23.4 Gy in 13 fractions followed by 30.6 Gy in 17 fraction boost to Primary Site.

OAR	Dose objective for CSI (Phase 1) (Gy)		Dose objective for boost (Phase 2)		Dose objective for entire treatment	
	Ideal	Achieved	Ideal	Achieved	Ideal	Achieved
Lens (Lt/Rt)	< 6		<1		<7	
PRV Cochlea (Lt/Rt) **Cochlea (lt/Rt – not PRV)**	Likely to be within PTV for phase 1.				Mean ≤ 40	
Globe (Lt/Rt)	Max < 23.4		<2		<38	
Optic Nerves (Lt/Rt)	Max < 23.4				<54	
Chiasm	Max < 23.4				<54	
Brainstem	Max <23.4				<54	
Cornea (Lt/Rt)	Max < 23.4				<38	
Cord PRV	DMax < 100%				<54	
Spinal PTV	DMax < 107%					
Pituitary	Within PTV Brain. Record.				< 41Gy	
Thyroid	Mean < 17.7					
Heart	V21 <10% Whole heart Mean < 13					
Bilateral Breast	Mean <4.8					
Combined Lungs [5]*	Mean lung dose <10Gy V16.5 < 25%					
Liver	V16 <100% Mean dose					
Combined Kidneys	Mean < 9.4 V10 < 55% V16<32% Mean (Lt/Rt)					
Spleen	Mean					
Pancreas	Mean					
Testis	<0.5					
Oesophagus	Mean dose < 30					
Stomach	V20 < 100% (easily achievable)					
Parotid (Lt/Rt)	Mean < 11		Mean < 11		Mean <21.5	
Submandibular (Lt/Rt)	Mean < 11		Mean < 11		Mean < 21.5	

Facial Avoid	V10 <42 V15<28 V20<20 V25<13		V5 < 30.4 V10 <13 V15<10		Mean < 10	

		PTV 23.4 (Cranial)		PTV 23.4 (Spinal)		PTV 30.6	
% Volume	% Dose	Dose Required	Dose Achieved	Dose Required	Dose Achieved	Dose Required	Dose Achieved
99%	>90%	21.06		21.06		27.5	
95%	>95%	22.23		22.23		29.07	
50%	=100%	23.4		23.4		30.6	
5%	<105%	24.57		24.57		32.13	
2%	<107%	25.0		25.0		32.7	

Appendix Two: Dose Constraints Paediatric Whole CNS Tomotherapy: 36 Gy in 20 fractions followed by 19.8Gy in 11 fraction / 18Gy in 10 fraction boost to Primary site.

OAR	Dose objective for CSI (Phase 1) (Gy)		Dose objective for boost (Phase 2)		Dose objective for entire treatment	
	Ideal	**Achieved**	**Ideal**	**Achieved**	**Ideal**	**Achieved**
Lens (Lt/Rt)	< 6		<1		<8	
PRV Cochlea (Lt/Rt) **Cochlea (lt/Rt – not PRV)**	Likely to be within PTV for phase 1.				Mean ≤ 40	
Globe (Lt/Rt)	Max < 36		<2		<38	
Optic Nerves (Lt/Rt)	Max < 36				<55	
Chiasm	Max < 36				<55	
Brainstem	Max <36				<55	
Cornea (Lt/Rt)	Max < 36				<38	
Cord PRV	DMax < 100%				<55	
Spinal PTV	DMax < 107%					
Pituitary	Within PTV Brain. Record.				Mean < 41Gy	
Thyroid	Mean < 19.5§					
Bilateral Breast	Mean <5					
Heart	V23 <10% Whole heart Mean < 14					
Combined Lungs [5]*	Mean lung dose <12Gy (acceptable < 15Gy) V27 < 22% V18 < 25% V5 < 95%					
Liver	V17.7 <100% Mean					
Combined Kidneys	Mean < 10 V11 <55% V18 <32% Mean (Lt/Rt)					
Spleen	Mean					
Pancreas	Mean					
Testis	<0.5					

Oesophagus	Mean dose <33					
Stomach	V36 < 100% (easily achievable)					
Parotid (Lt/Rt)	Mean < 12		Mean < 12		Mean <23.5	
Submandibular (Lt/Rt)	Mean < 12		Mean < 12		Mean < 23.5	

OAR	Dose objective for CSI (Phase 1) (Gy)		Dose objective for boost (Phase 2)		Dose objective for entire treatment	
Facial Avoid	V10 < 48.8 V15 < 31 V20 < 33 V25 < 14		V5< 26.8 V10<12.6 V15<8.8		Mean < 10	

§As low as reasonably achievable
*This should be easily achieved, and efforts to minimise lung doses should be made.

		PTV 36 (Cranial)		PTV 36 (Spinal)		PTV 19.8	
% Volume	% Dose	Dose Required	Dose Achieved	Dose Required	Dose Achieved	Dose Required	Dose Achieved
99%	>90%	32.4		32.4		17.82	
95%	>95%	34.2		34.2		18.81	
50%	=100%	36		36		19.8	
5%	<105%	37.8		37.8		20.79	
2%	<107%	38.5		38.5		21.2	

NB Dose constraints from the literature are generous and represent maximal safe doses from the literature.

Dose Constraints: Paediatric Whole CNS Tomotherapy: 39.6 Gy in 22 fractions followed by 16.2Gy in 9 fraction boost to Primary site.

OAR	Dose objective for CSI (Phase 1) (Gy)		Dose objective for boost (Phase 2)		Dose objective for entire treatment	
	Ideal	Achieved	Ideal	Achieved	Ideal	Achieved
Lens (Lt/Rt)	< 6		<1		<8	
PRV Cochlea (Lt/Rt) **Cochlea (lt/Rt – not PRV)**	Likely to be within PTV for phase 1.				Mean ≤ 45	
Globe (Lt/Rt)	Max < 39.6		<2		<40	
Optic Nerves (Lt/Rt)	Max < 39.6				<55	
Chiasm	Max < 39.6				<55	
Brainstem	Max <39.6				<55	
Cornea (Lt/Rt)	Max < 39.6				<40	
Cord PRV					<55	
Spinal PTV	DMax < 107%					
Pituitary	Within PTV Brain. Record.				Mean < 41Gy	
Thyroid	Mean < 19.8§					
Bilateral Breast	Mean <5					
Heart	V23.5 <10% Whole heart Mean < 14Gy					
Combined Lungs [5]*	Mean lung dose <12Gy (acceptable <15Gy) V28 < 22% V18.9 < 25% V5 < 95%					
Liver	V18 <100% Mean					
Combined Kidneys	Mean < 10 V11 <55% V19 <32% Mean (Lt/Rt)					
Spleen	Mean					
Pancreas	Mean					

Testis	<0.5					
Oesophagus	Mean dose <34					
Stomach	V39.6 < 100% (easily achievable)					
Parotid (Lt/Rt)	Mean < 12		Mean < 12		Mean <24	
Submandibular (Lt/Rt)	Mean < 12		Mean < 12		Mean < 24	

OAR	Dose objective for CSI (Phase 1) (Gy)		Dose objective for boost (Phase 2)		Dose objective for entire treatment	
Facial Avoid	V10 < 50 V15 < 32 V20 < 23 V20 < 14		V5<25 V10<12 V<8.4		Mean < 10	

§As low as reasonably achievable
*This should be easily achieved, and efforts to minimise lung doses should be made.

		PTV 39.6 (Cranial)		PTV 39.6 (Spinal)		PTV 16.2	
% Volume	% Dose	Dose Required	Dose Achieved	Dose Required	Dose Achieved	Dose Required	Dose Achieved
99%	>90%	35.64		35.64		14.58	
95%	>95%	37.62		37.62		15.39	
50%	=100%	39.6		39.6		16.2	
5%	<105%	41.58		41.58		17.01	
2%	<107%	42.4		42.4		17.3	