West Midlands Radiotherapy Clinical Protocol

Paediatric Radiotherapy

Revision history

Version	Date	Summary of changes
1.0	10.06.2020	UHB Created Date
	06.11.2020	Adopted from UHB Protocol
1.0	Dec 2023	As of Dec 2023, it was confirmed via UHB that this protocol is valid and still in use.
Review Date:	December 2024	

Key Words:

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Macmillan Paediatric Liaison Radiographer: **Liam Herbert**

Patients are seen and parents consented at Birmingham Children's Hospital after discussion at the relevant MDT. Consent needs to be obtained on a BCH form (Consent Form 2).

General Anaesthesia is often required. Input from the Play Specialists may be helpful.

General Principles

- A number of indications are now routinely sent for proton beam radiotherapy and details of planning / treatment protocols will not be discussed here.
- Aim for fraction sizes no greater than 1.8Gy/#
- In growing children, late effects, including symmetrical growth is an important consideration when planning treatment.

Contents:

Extracranial Indications for Radiotherapy

Wilms Tumour

- The UMBRELLA protocol [SIOP-RTSG 2016] should be followed

Patient is scanned supine with appropriate immobilisation device for more information please see documents, RAW60-P and RAW122-3. Typically the whole torso, from lung apices to pelvic floor is included.

The following table can be used as a summary for the treatment of non-metastatic Wilms tumours:

17.4 Summary recommendation of radiation therapy treatment of abdominal disease

	Stage II	Stage III (except major rupture)	Stage III (major rupture)
Intermediate Risk	no indication	14.4 Gy in 8 fractions, +/- 10.8 Gy boost	Whole abdomen 15.0 Gy in 10 fractions +/- 10.8 Gy boost
High risk Diffuse anaplasia	25.2 Gy in 14 fractions +/- 10.8 Gy boost	25.2 Gy in 14 fractions +/- 10.8 Gy boost	Whole abdomen 19.5 Gy in 13 fractions +/- 10.8 Gy boost
High Risk Blastemal type	no indication	25.2Gy in 14 fractions +/- 10.8 Gy boost	Whole Abdomen 19.5 Gy in 13 fractions +/- 10.8 Gy boost

The following table can be used as a summary of recommendations for radiotherapy to metastatic sites:

17.8 Summary recommendations of radiation therapy treatment of metastatic sites

	Metastatic Site Lung	Liver (incomplete resection)	Brain	Bone
Intermediate Risk histology	Whole lung 12.0 Gy in 8 fractions	Whole liver/ local 14.4 Gy in 8 fractions (boost 10.8 Gy)	Whole brain 15.0 Gy in 10 fractions +/- 10.5 Gy boost	Local 30.6 Gy in 17 fractions or 30 Gy in 10 fractions
High Risk histology	Whole lung 15.0 Gy in 10 fractions	Whole liver/ local 20-25.2 Gy in 11 fractions (boost 16.2 Gy)	Whole brain 25.2 Gy in 14 fractions +/- 10.5 Gy boost	Local 30.6 Gy in 17 fractions or 30 Gy in 10 fractions

For detailed guidance the UMBRELLA Protocol should be referred to.
Parallel-opposed fields are traditionally used.

IMRT (tomotherapy) is used for whole lung / whole abdominal volumes. See separate protocol for details of contouring / dose constraints.

Neuroblastoma

- Radiotherapy is indicated in high risk disease. The post-induction chemo, pre-operative tumour volume is treated to a dose of 21Gy in 14 fractions.
- If there is significant residual disease, dose escalation to 36Gy in 24 fractions can be considered.
- **Please refer to the IMAT trial protocol for detailed guidance.**

Contouring Guidelines:

Detailed information should be available for all patients pre-planning; including imaging reports, histopathology and operation notes.

Patient is scanned supine with appropriate immobilisation device. For more information please see RAW60-P. Typically the whole torso, from lung apices to pelvic floor is included.

GTV

- Reconstructed tumour volume (from post induction chemotherapy, pre-surgical imaging)
- Or, the gross residual tumour for inoperable cases
- With any immediately adjacent persistently enlarged nodes
- Trim the GTV from uninvolved organs that were displaced pre-operatively.

CTV

- GTV + 5mm (may be trimmed at natural barriers to spread e.g. bone / abdominal wall)

PTV

- As per departmental protocol, typically = CTV+ 5mm.

The following OARs should be contoured:

Right and Left kidney, Liver, Vertebrae (body and posterior arch) at least one vertebra above and below PTV, heart, lungs, GI tract, Spinal canal.

Neuroblastoma Dose Reporting Schedule – 21.4Gy/14#

MARK UP LOCATION: - PROSOMA ☐

TO BE PLANNED ON: - XIO ☐ MONACO ☐ TOMO ☐

SIM PLAN ID:-……

MARK UP APPROVED: - CONSULTANT 1…….…….. **CONSULTANT 2**…….…….…

		PTV21.4		PTV 36	
% Volume	**% Dose**	**Dose Required**	**Dose Achieved**	**Dose Required**	**Dose Achieved**
99%	**>90%**	19.2		32.4	
95%	**>95%**	20.3		34.2	
50%	**=100%**	21.4		36	
5%	**<105%**	22.4		37.8	
2%	**<107%**	22.8		38.5	

ORGAN	CONSTRAINT (Gy)	CONCESSION	Dose Received
Contralateral Kidney (Left / Right)	V14Gy < 10%		
For Midline Tumours : Combined Kidney	V14Gy < 40%		
Liver	V19Gy < 100% V21Gy < 50%		
Heart	Mean < 15Gy		
Combined Lungs	V15Gy < 10% V12Gy < 25%		
GI tract	V36Gy < 10% V30Gy < 50% V21Gy < 100 %		
Vertebrae	D95% < 10Gy	V20 > 95% or V25Gy > 95%	
Spinal Canal	D0.1cc < 30Gy		

PLANNED BY: - …… **CHECKED BY: -** …….

PLAN ID:-……

PLAN ACCEPTED: - CONSULTANT 1 ……..…….. **CONSULTANT 2** ……..……..…..

Hodgkin's Disease

- As per EuroNet PHL-C1 study. Patients stratified into one of three groups. Use of involved field radiotherapy determined on radiological and PET response to induction chemotherapy.
- Radiotherapy occurs after completion of chemotherapy.
- Involved field radiotherapy based on **initial** disease area and volume.
- 19.8Gy/11#. See protocol for CTV/PTV guidance
- Boost 10.8Gy/6# if poor response and or bulky residual disease
- Liver and lung aim for a maximum of 15Gy in 1.2Gy/#

Consider proton referral if appropriate.

Sarcoma – Soft Tissue / Bone Tumours

See Chapter on Adult Sarcoma in Medical Treatment Portfolio. Consider Proton referral for appropriate cases.

Total Body Irradiation

TBI dose: 12Gy in 6 fractions over 3 days – 14.4Gy in 8 fractions over 4 days.

Pre TBI : Consider Testicular Boost: 4Gy in 1 fraction.

Consider Cranial Boost: 5.4Gy in 3 fractions over 2 days

Child should be seen for measurements by Paediatric Radiographer / member of TBI team prior to treatment. For further details on TBI set up please see document RAW08-4.

Whole Lung Radiotherapy

May be indicated in patients with metastatic Wilms tumour and Sarcomas. See individual treatment protocols for more detail regarding dose / fractionation and indications. Note dose / fractionation may change depending on age of the child.

- Immobilisation:
  - Supine with arms above head with wing board +/- vac bag
  - Smaller children – consider: supine on head & neck board with arms abducted. H&N mask +/- vac bag.

Contouring Guidelines:

- CTV: Whole lungs. Not including major airways.
- Vertebral bodies should be contoured (Body and posterior arch, not including the transverse or posterior spinal processes; at the level of the PTV and at least one vertebra above and below PTV)
- PTV: CTV + 10mm all round, 15mm sup / inf. If child has not completed growth, then the PTV should include the vertebral bodies to ensure homogenous dose.

OARs to be contoured: Heart, vertebrae, spinal canal, breasts, thyroid, liver, spleen and kidneys.

Patient should be reviewed weekly with FBC assessment.

Whole Abdominal Radiotherapy

May be indicated with Wilms Tumour / Sarcomas. See individual trial / treatment protocols for more detail. Doses may include 15Gy / 10 # - 30Gy in 20 #.

- Immobilisation:
  - Supine on med tec board with arms abducted. Knee fix and vac bag.

Contouring Guidelines:

- CTV: Whole abdominal-pelvic cavity and contents
- Vertebral bodies should be contoured (body and posterior arch, not including the transverse or posterior spinal processes at the level of the PTV).
- PTV = CTV + 10mm all around. If the child has not completed growth, the vertebral bodies should be included in the PTV to ensure dose homogeneity.

OARs to be contoured: Kidneys, vertebrae, spinal canal, liver, spleen, testicles.

Patient will require daily ondansetron prior to radiotherapy and weekly FBC assessment.

Whole Lung Dose Reporting Schedule

MARK UP LOCATION: - PROSOMA ☐

TO BE PLANNED ON: - MONACO ☐ TOMO ☐

SIM PLAN ID:-……

MARK UP APPROVED: - CONSULTANT 1…….…….. **CONSULTANT 2**…….…….…

		PTV	
% Volume	**% Dose**	**Dose Required**	**Dose Achieved**
99%	**>90%**		
95%	**>95%**		
50%	**=100%**		
5%	**<105%**		
2%	**<107%**		

ORGAN	CONSTRAINT (Gy)	CONCESSION	Dose Received
Heart	Mean < 15Gy DMax < 107%		
Spinal Canal	DMax < 107%		
Combined Kidneys	Mean < 12Gy V14Gy < 40%		
Liver	Mean < 19Gy DMax < 107%		
Thyroid	Record mean dose		
Breasts	Record mean dose		

PLANNED BY: - …… **CHECKED BY: -** …….

PLAN ID:-……

PLAN ACCEPTED: - **CONSULTANT 1** ……..…….. **CONSULTANT 2** …..……...…..

Whole Abdominal Dose Reporting Schedule

MARK UP LOCATION: - PROSOMA ☐

TO BE PLANNED ON: - MONACO ☐ TOMO ☐

SIM PLAN ID:-……

MARK UP APPROVED: - CONSULTANT 1…….…….. **CONSULTANT 2**…….……..…

		PTV	
% Volume	**% Dose**	**Dose Required**	**Dose Achieved**
99%	**>90%**		
95%	**>95%**		
50%	**=100%**		
5%	**<105%**		
2%	**<107%**		

ORGAN	CONSTRAINT (Gy)	CONCESSION	Dose Received
Combined Kidneys	Aim mean dose < 12Gy V14Gy < 40%		
Liver	Mean < 19Gy V19Gy < 100% V21Gy < 50%		
Heart	Mean < 15Gy		
Combined Lungs	V15Gy < 10% V12Gy < 25%		
Spinal Canal	DMax < 107%		
Testes	Record		
Spleen	Record mean dose		

PLANNED BY: - …… **CHECKED BY: -** …….

PLAN ID:-……

PLAN ACCEPTED: - **CONSULTANT 1** ……..…….... **CONSULTANT 2** ……..……..…..

Ependymoma

- Referred for proton beam radiotherapy if complete excision achieved. Aim to start radiotherapy within 6 weeks of surgery.
- Dose ranges from 54Gy – 59.4Gy in 30-33 fractions
- See Adult Ependymoma and SIOP EPII trial protocol for detailed contouring guidance.

Low and High Grade Glioma

- Dose / contouring principles are the same as in adult population. See Adult CNS chapter in Medical Treatment Portfolio for details.

Germ Cell Tumours

- Intracranial Germinomas / Non- Germinomatous Germ Cell Tumours require meticulous staging.
- See SIOP GCT II trial for full details. Further guidance in Adult CNS chapter in Medical Treatment Portfolio.
- Consider proton beam radiotherapy referral for craniospinal / whole ventricular / focal radiotherapy.

Diffuse Midline Glioma (Diffuse Intrinsic Pontine Glioma)

- Radiotherapy should be started as soon as possible.
- Dose: 54Gy in 30fractions.
- 39Gy in 13 fractions can be considered for selected patients with poor performance status.
- Re-irradiation is an option if a good symptomatic benefit is achieved with the first course of radiotherapy.
- Dose should be calculated using radiobiological principles, including time elapsed since first course of radiotherapy (See Re-RT chapter in Adult CNS portfolio), but can range from 19.8Gy - 36Gy in 1.8Gy fractions.

Paediatric Whole CNS Protocol

Introduction

Medulloblastoma (MB) is a primitive embryonal cerebellar tumour. It is the most common malignant brain tumour in childhood, accounting for between 15 and 20% of all childhood primary CNS neoplasms. 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:

- Can be referred for proton beam radiotherapy.
- 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 / Cyclophosphamide).
- 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: 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 (unusual)	Neurocognitive toxicity (↓concentration, IQ, memory)
Somnolence (4-6 weeks post RT)	Effect on fertility
Skin reaction	Damage to normal tissue
	Radiation induced second cancers

Written information should be provided regarding craniospinal radiotherapy and families should have contact details of the Paediatric Lead Practitioner Therapeutic Radiographer.

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 "A" curve).
If patient is too small to use a kneefix then a vacuum bag should be used. A vacuum bag positioned into heel stocks set on a loc-bar at an appropriate position to support the patients legs and feet . The vacuum bag should reach as close as possible to the pelvis. Using the sagittal laser the vacuum bag is evacuated to support and align the patients legs, feet and pelvis (if possible) with the spine in the midline.
A fibreplast mask is then constructed as described in document MTP22 (Head & Neck Immobilisation system for IMRT). 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.
All patient specific equipment should be labelled as per protocol and recorded on Set up sheet RAF22-2*
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. A measurement from the vacbag or kneefix to pelvic lateral tattoos will also be required at planning to assist in treatment set up.

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.

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

- **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
- Cribriform plate
- 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

Primary Site Irradiation: Medulloblastoma
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	23.4	54	NA	
HR Medulloblastoma				
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) 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

All patients are to have the whole CNS volume scanned for the first 3 fractions and then weekly there after (providing reproducibility good).
Match using the bony algorithm and translational corrections only, skull base to take priority – check variation of the spine positions:-
The C spine to vary by no more that 3mm from planned position.
T spine to vary by no more than 7mm from planned position.
L/S spine to vary by no more than 10mm from planned position.

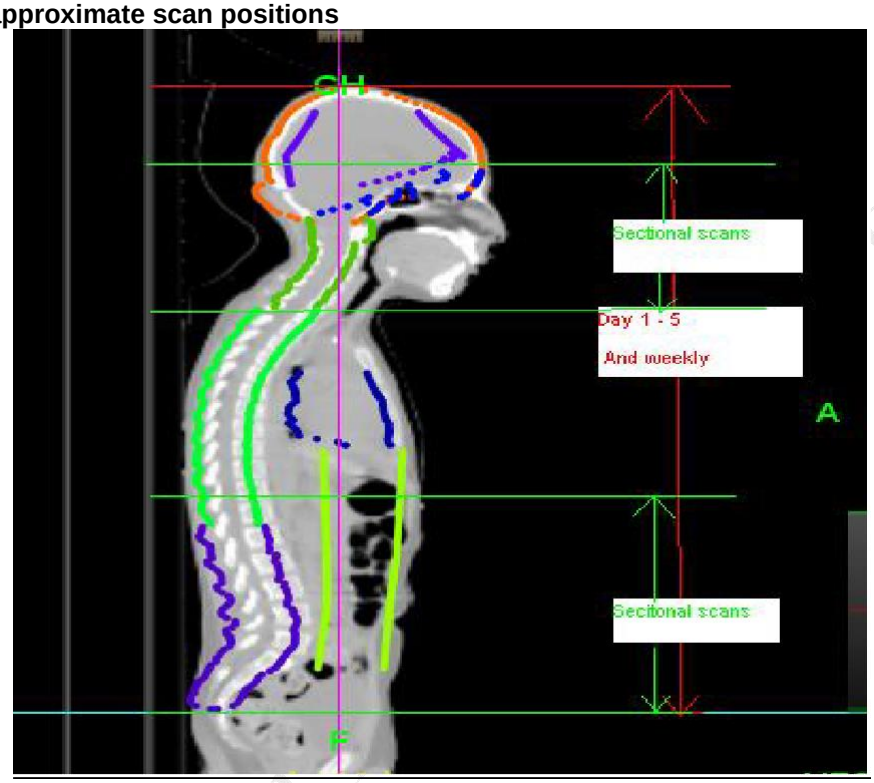
After the first week sectional imaging can commence.

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. Using the translations only with the bony algorithm – match to the skull base / cribiform plate check C Spine deviates by no more than 3mm from planned position.

Record the match results on the CNS imaging sheet. Do not accept the results.

Perform the second scan lower T/L/S spine – perform translational bony match – record the results on the imaging sheet and check results are within 1.0cm of the upper volume results.
Manually type in the results from the first scan – accept and treat on these shifts.
If there are any concerns repeat whole CNS scan on the next fraction.

Diagram of approximate scan positions



Assessment during Radiotherapy

- Patients will be reviewed with weekly weights and blood results jointly by Consultant Oncologist and Paediatric Radiographer.

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. Haemoglobin should be maintained >110.

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 α/β = 3 for late effects).

References

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2. Gajjar A, Chintagumpala M, Ashley D. Risk-adapted craniospinal radiotherapy followed by high-dose chemotherapy and stem-cell rescue in children with newly diagnosed medulloblastoma (St Jude Medulloblastoma-96):long-term results from a prospective, multicentre trial. Lancet Oncol 2006; 7: 813-20.
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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

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)	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%				<55	
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	Mean < 16 Gy					
Combined Kidneys	Mean < 9.4 V10 < 55% V16<32%					
Ovary	<1.5					
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 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)	< 8		<1		<10	
PRV Cochlea (Lt/Rt)	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	Mean < 17Gy					
Combined Kidneys	Mean < 10 V11 <55% V18 <32%					
Ovary	<1.5					
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)	< 8		<1		<10	
PRV Cochlea (Lt/Rt)	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	Mean < 18					
Combined Kidneys	Mean < 10 V11 <55% V19 <32%					
Ovary	<1.5					
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	