RT techniques in medulloblastoma

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Rationale for Craniospinal irradiation (CSI) in medulloblastoma

- CSF dissemination is known in 16-46% of cases

- Posterior fossa, spinal cord, ventricular walls & supratentorial region including the cribriform plate form the main sites of relapse.

- Being radiosensitive, RT is curative in up to 70% of standard risk patients.
Target volume for CSI

- Whole brain with its meninges
- Spinal cord down to the caudal end of the thecal sac (usually S2 but should be verified by sagittal MRI)
- Primary tumour site/posterior fossa (for boost)
CSI is challenging and demands precision.....
Challenges in planning CSI

- Immobilization & positioning of a large target area
- Large & irregular shape of the clinical target volume (CTV)
- Multiplicity of fields
- Inhomogeneity at the junctions between the brain and spinal fields
- Large number of critical normal structures having direct bearing on the late effects in these pediatric long term survivors.
Planning steps

- Positioning
- Immobilization
- Simulation
- Verification
- Treatment
- Junction shift
Positioning

PRONE:
- It provides direct visualization of the field junctions on the patient.
- Good alignment of the spine.

SUPINE
- Comfortable.
- Useful in anesthesia (in < 7 yr age gp)
Immobilization

- Prone position of patient
- Arms by the side on a CSI board
- Lucite base plate with a sliding semicircular Lucite structure for head-rest & chin-rest.
- Slots from A to E to allow various degrees of extension of neck
Immobilization

- Thermocol wedge for supporting the chest wall
- Alignment of the thoracic & lumbar spine parallel to the couch (to confirm under fluoroscopy)
- Thermoplastic mold for Immobilization of the head, cervical spine & shoulders.
Radiotherapy Planning

Phase I
- Two lateral cranial fields
- 1 or 2 spinal fields

Phase II: Posterior fossa boost
- Two lateral cranial fields
- Conformal technique in low risk cases.
Critical issues in CSI fields

- Concern 1
  Divergence of the upper border of the spinal field in case of single spinal field (and interdivergence of spinal fields in case of 2 spinal fields)

- Concern 2
  Divergence of both cranial fields
- Spinal field simulated first (get to know the divergence of the spinal field)
- SSD technique
- 2 spinal fields if the length is $> 36$ cm
- Upper border at low neck
- Lower border at termination of thecal sac or S2 whichever is lower
- In case of 2 spinal fields, junction at L2/L3
Blue (Brain line)

Red (Spinal Line)

5 mm gap between the two lines

Spinal field (Upper border)
Craniospinal junction

Possible causes of overdose at the neck

- Narrow neck separation than cranium
- Couch rotation towards gantry decreased treatment distance (and > dose).
- Horns at the lateral aspect of the beam secondary to overflattening of the LA beam.

Halperin IJROBP 1996
Termination of thecal sac

- Traditional recommendation for lower border of spinal field is inferior edge of S2 (myelogram & autopsy studies).

- 8.7% patients have termination below S2-S3 interspace.

- MRI accurately determines the level of termination of the thecal sac & the extent of neuraxial disease if present.

IJROBP, 1998, vol 41
Gap or no gap-spinal fields

- Proponents of no gap
  Concerned over possible lower dose to part of target volume. (Tinkler, 1995).

- Proponents of gap
  Overdose at the junction & cervical spine & may result in disabling late toxicity.
Fixed or calculated gap spinal fields

- Use of fixed gap ranging from < 5 mm to 10 mm between fields OR
- Customised gap for each patient depending on the field length & depth of prescription, may be more appropriate
- Spinal fields are simulated after gap calculation.
- Width - vertebral body + 1 cm to include the intervertebral foramina, usually 5 to 7 cm.
Gap calculation-formula
Gap calculation-formula
Gap calculation formula

\[ S = \frac{1}{2} L_1 \left( \frac{d}{SSD_1} \right) + \frac{1}{2} L_2 \left( \frac{d}{SSD_2} \right) \]
Extended SSD technique

Advantage
Single spinal field and circumventing the issue of junction between two spinal fields

Disadvantage
Higher percentage depth dose and greater penumbra results in higher mean doses to all anterior normal structures, (mandible, esophagus, liver, lungs, heart, gonads and thyroid gland)
Simulation-cranial field

- Whole brain field is simulated & lower border is matched with the superior border of spinal field.
- AP width & superior border include the entire skull with 2 cm clearance.
- Techniques for matching craniospinal fields.
  - Collimator/couch rotation
  - Half beam block
  - Asymmetric jaws
  - Penumbra generators
  - Wedge
  - Tissue compensator
Problem 1: Divergence of cranial field

S

Spinal field
Solution A: Rotate the couch

Spinal field
Solution B: Asymmetric block

Spinal field
Problem 2 Divergence of spinal field
Solution A: Rotate the cranial field collimator
Solution B: Use asymmetric spinal block
Simulation-cranial field

- In practice 5 mm gap left in the cranial and spinal fields.
- Cranial field Collimator angle = $\tan^{-1}\left\{ \frac{1}{2} \frac{L_1}{SSD} \right\}$ $L_1$ is spinal field length.
- Couch angle = $\tan^{-1}\left\{ \frac{1}{2} \frac{L_2}{SAD} \right\}$ $L_2$ is cranial field length.
- Use of asymmetric collimator jaws precludes the need of couch rotation.
Shielding

More important is what not to shield!

DO NOT SHIELD

- Frontal (cribriform plate)
- Temporal region
SFOP (French society Paediatric Oncology) guidelines
Treatment & verification

- Port films after placing radio-opaque markers on the inferior border of cranial field can be used to verify craniospinal field matching.

- Electronic portal imaging has also played important role in verification & correction of set up errors.
Moving Junction in CSI

- 5mm overlap at 4mv photons 30 to 40% overdose (14Gy for 36Gy prescribed dose) which may exceed cord tolerance

  (Hopulka, 1993, IJROBP).

- Systematic error during radiotherapy delivery could further lead to an overlap or gap.

- Feathering after every 5 to 7 fraction smoothes out any overdose or underdose over a longer segment of cord
Moving junction/feathering

Advantage:

Feathering after every 5 to 7 fraction smooths out any overdose or underdose over a longer segment of cord.
Junction shift in CSI
Junction shift in CSI
Junction shift in CSI
Junction shift

- Usually shifted by 1 to 2 cm at each shift
- Done every few fractions (every 7# at our center).
- Either in cranially or caudal direction.
- Cranial inferior collimator is closed & spinal superior collimator is advanced by the same distance superiorly (if junction to be shifted cranially).
- Similarly, lower border of superior spinal field & superior border of inferior spinal field are also shifted superiorly, maintaining the calculated gap between them.
Posterior fossa boost

Borders

- Anterior: Posterior clinoid process.
- Posterior: Internal occipital protuberance.
- Inferior: C2-C3 interspace.
- Superior: Midpoint of foramen magnum & vertex or 1 cm above the tentorium (as seen on MRI).

Field arrangement

- Two lateral opposing fields.
- 3DCRT boost to the preop tumor bed with appropriate margins is being studied.
SFOP guidelines
# Dose prescription

<table>
<thead>
<tr>
<th>Dose</th>
<th>Medulloblastoma</th>
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<tbody>
<tr>
<td>CSI</td>
<td>35Gy/21#</td>
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<tr>
<td>PF boost</td>
<td>19.8Gy/11#</td>
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Dose prescribed at mid separation for the cranial fields
Determined by the MRI for the spinal fields

Junction shift every 7 fractions
Technical beam parameters

- Photons: 4 to 6mv produce good dose homogeneity
- Cranial field - prescribed at midplane SSD
- Spinal field - 5 to 6cm along central axis depending on depth of spinal cord at SSD (posterior vertebral body seen on Lateral X rays / CT scan / MRI).
CT simulation
CT simulation

- Ability to virtually simulate, thereby minimizing the time a patient must remain immobilized.
- Better definition of critical organs (spinal cord) and target volume (cribriform plate)
- Graphical overlays of anatomic CT data onto digitally reconstructed radiographs (DRRs) - improves field placement, shielding accuracy & direct calculation of gap between the fields.
Steps in CT simulation

- Patient positioned using all ancillary devices and the spinal columns aligned with the sagittal external laser.
- Three-point reference marks drawn on the mask in a transverse plane at the center of the head with the aid of the external lasers.
- Two or three reference marks were placed on the posterior skin surface along the spinal column.
- Spiral CT images of 3-5 mm thickness are acquired.
- Following image acquisition, all spinal reference marks are tattooed and the patient permitted to leave.
- A total of 130–170 images are reconstructed depending on the patient’s height.
Supine CSI planning
CT based
Individualized CT planning

- Method analogous to conventional simulation but with use of asymmetric collimator jaws for matching beam divergence.
- Field junctions can be visually verified.
- The distance between the two isocenters (three if two spine fields are required) can be calculated once the beams have been set.
- This distance can then be used as the digital longitudinal table distance shift.
CT simulation – fixed field geometry

Fig. 1. Schematic diagram of the CSI technique as applied to a supine patient.
Sagittal MPR of patient in supine CSI
Supine CSI by conventional simulation-

The TMH technique
Supine CSI planning - conventional

Positioning:
- Supine on NNR with arms by the side of body.
- Check spinal column alignment on fluoroscopy.
- Neck in near neutral position but slightly extended.

Immobilisation:
- Thermoplastic mold for immobilization of face & neck.
- Close fit at the nasion.
- Any constraint for the jaw is removed to facilitate anesthetic maneuvers.
Step 1: Two lead markers by the side of the neck at the same laser level
Step 2: Gantry taken through table and the upper border of spinal field matched with the markers.

Step 3: Two additional markers placed in the line of upper border
Anterior view of the placement of the markers
Markers placed at spinal simulation

Initial Markers
Step 4: Collimation of the cranial field adjusted according to the line joining the two markers on one side of the neck (which is the divergence of the spinal field)
Thank you