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 < 7yr age gp)
Immobilization

- Prone position of patient
- Arms by the side on a CSI board 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
Spinal field
(Upper border)

Blue (Brain line)

Red (Spinal Line)

5 mm gap between the two lines
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 $< 5 \text{ mm}$ to 10mm 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
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 smoothes 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
Upper border at 2/3 of AB
Dose prescription

<table>
<thead>
<tr>
<th>Dose</th>
<th>Medulloblastoma</th>
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</thead>
<tbody>
<tr>
<td>CSI</td>
<td>35Gy/21#</td>
</tr>
<tr>
<td>PF boost</td>
<td>19.8Gy/11#</td>
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</tbody>
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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