Radiotherapy techniques in brain tumors (2D, 3D CRT, IMRT) including craniospinal irradiation

Dr Anusheel Munshi
Additional Director, Radiation Oncology, Fortis Memorial Research Institute, Gurgaon

anusheel.munshi@fortishealthcare.com
Evolution of RT

- Conventional 2 dimensional approaches
- 3 dimensional conformal radiotherapy (3DCRT)
- Intensity modulated radiotherapy (IMRT)
- Image guided radiotherapy (IGRT)
Planning steps

- Positioning
- Immobilization
- Simulation
- Verification
- Treatment
- Junction shift
<table>
<thead>
<tr>
<th>Step</th>
<th>CT simulator</th>
<th>Time</th>
<th>Conventional Simulator</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning/orfit</td>
<td>10 min</td>
<td></td>
<td>Positioning/orfit</td>
<td>10 min</td>
</tr>
<tr>
<td>CT Cuts</td>
<td>10 min</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Contouring</td>
<td>20 min</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Virtual simulation</td>
<td>40 min</td>
<td></td>
<td>Simulation</td>
<td>25 min</td>
</tr>
<tr>
<td>Extrapolating lasers</td>
<td>5 min</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Verification by EPID/Con sim</td>
<td>10 min</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>95 min</td>
<td></td>
<td>Total</td>
<td>35 min</td>
</tr>
</tbody>
</table>
Conventional Radiotherapy planning

- Based primarily on 2D planar radiographs
- Usually done with the aid of a Simulator
- Planned Treatment Portals by collimating rectangular fields that circumscribed the presumed tumor location on the basis of bony landmarks
- 2 to 3 beams are arranged in a standard geometry
2 D SIMULATION

• Steps
  • Turn gantry to right (270)
  • Set up TSD 95 conventionally
  • Define field on patient with the help of recon images
    Scans, bony landmark
  • Get width & length of field
Head Position

- Neutral Position-
- Flexion- Sellar/Suprasellar tumors
  Temporal lobe tumors
  Pineal region Tumors
  All sites where field borders likely to extend to lower Temporal region

- Head flexion –
  NNR+4+3
  Blue Thermocol – Posterior field
  Air equivalent NNR+4+3
SIMULATION

- Immobilization
- Head POSITION
  - Prone, neutral, flexed
- Imaging modality-
  - CT
  - MRI
### Advantages
- Time
- High grade tumour
- Survival
- General condition
- Simulator
- 2D radiographic portal films
- Presumed tumour location on the basis of bony landmarks
- Blocks- Standard/ Custom

### Disadvantages
- Irradiation of large volumes of brain with normal tissue also
- Higher toxicity and side effects
- Lack of 3D visualization of tumour
- 2D planning of 3D tumour
**Shortcoming of conventional planning**

- Lack of 3D appreciations of tumor volume and its location with respect to sensitive organs
- 2D beam planning of a 3D tumor
- Dose computation perform on a single transverse plane
- Dose computation does not take into account of scatter contribution from adjacent body tissue
3D Conformal radiotherapy individualised conformation
Steps of 3DCRT

1. Immobilization
2. Delineation of Target & critical organs
3. Beam Shaping Block, MLC
4. Plan Evaluation Physical dose
5. Plan Implementation
6. Plan Evaluation Biological dose
7. Dose computation
8. TPS
9. Treatment delivery
10. Pre treatment verification
11. Reporting

Immobilization
Delineation of Target & critical organs
Beam Shaping Block, MLC
Plan Evaluation Physical dose
Plan Implementation
Plan Evaluation Biological dose
Dose computation
TPS
Treatment delivery
Pre treatment verification
Reporting

Fortis
Planning CT cuts in CNS radiotherapy

Aim for taking a planning CT in neurooncology

To obtain a stack of images which can be used

- For 3DCRT, IMRT, SRT, SRS (have to be exported to planning station. Plan implementation in conventional simulator/treatment machine)
- For doing virtual simulation (exported to V sim station. Isocenter exported back to CT simulator by moving lasers)
Taking planning CT slices in neurooncology

The commandments:
- Different from diagnostic imaging
- Know your machine/system well!
- Use appropriate immobilisation device
- Image the patient in treatment position
- No gantry tilt please
Planning MRI

- Position
  Ideally in treatment position with orfit & base plate
  Problems with head / body coil
  Fiducial markers Vit.E cap. Platinum, etc.
- 3D- FSPGR
  T1 contrast axial cuts
  Matrix resolution 256 x 256
  Slice thickness 2mm with no gap
- Transfer images to contouring stations
<table>
<thead>
<tr>
<th>Tumour</th>
<th>GTV</th>
<th>CTV</th>
<th>Dose Gy/#</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBM/AA</td>
<td>T1 post contrast/ CECT</td>
<td>2-3</td>
<td>60/30</td>
</tr>
<tr>
<td>GR II</td>
<td>T2 Flair abn.</td>
<td>1.5-2 cm</td>
<td>54/30</td>
</tr>
<tr>
<td>Pilocytic</td>
<td>enhancing</td>
<td>1.5-2cm</td>
<td>54/30</td>
</tr>
<tr>
<td>Meningioma</td>
<td>enhancing</td>
<td>1-2cm</td>
<td>Benign 54/30 Malig. 60/30</td>
</tr>
<tr>
<td>Pit. adenoma</td>
<td>enhancing</td>
<td>0.5-1cm</td>
<td>45/25</td>
</tr>
<tr>
<td>Medullo initial</td>
<td>Brain +spine</td>
<td>1-2cm</td>
<td>35/21</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>boost</td>
<td>enhancing</td>
<td>1-2cm</td>
<td>19.8/11</td>
</tr>
<tr>
<td>Ependymoma</td>
<td>Hypo CT/ HyperT2</td>
<td>2 cm</td>
<td>54/30</td>
</tr>
<tr>
<td>spinal</td>
<td>T2Flair</td>
<td>2-3</td>
<td>50.4/28</td>
</tr>
<tr>
<td>Craniopharyngioma</td>
<td>enhancing</td>
<td>1-2cm</td>
<td>54/30</td>
</tr>
</tbody>
</table>
Multileaf collimators (MLC)
Conventional 3D Treatment

Radiation Source

Beam Shaper

Intensity Map

Target
3-D PLANNING

**Advantages**
- Ideal for all
- Conformal
- Max. sparing of normal tissue
- Lower toxicity

**Disadvantages**
- Time consuming
- Cost
- Technical support
IMRT Treatment
Neurocognitive decline post Radiotherapy

- Recall
- Delayed Recall
- Recognition
- Controlled Oral Word Association

ASCO 2008
Suggested optimal candidates for IMRT

Clinical
- Patients with better prognosis
- (lower age, favorable histology, better PS)

Dosimetric
- FP or TP lesions considering their close proximity to optic pathways
- Lesions close to brainstem
Editorial

The Subventricular Zone Neural Progenitor Cell Hypothesis in Glioblastoma: Epiphany, Trojan Horse, or Cheshire Fact?

Iris C. Gibbs, MD,* Daphne Haas-Kogan, MD,† Stephanie Terezakis, MD,‡ and Brian D. Kavanagh, MD, MPH§

Departments of Radiation Oncology, *Stanford University, Palo Alto, California; †University of California, San Francisco; ‡Johns Hopkins University, Baltimore, Maryland; and §University of Colorado, Aurora, Colorado
Biological Adaptive RT

Gregoire V, Lancet Oncol 2012
### 3 D CRT vs IMRT

<table>
<thead>
<tr>
<th></th>
<th>3 D CRT</th>
<th>IMRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conformality</td>
<td>Less (may be preferable for a moving target!)</td>
<td>More</td>
</tr>
<tr>
<td>Dose reduction to OAR</td>
<td>Less efficacious</td>
<td>More efficacious</td>
</tr>
<tr>
<td>MU efficacy/Quickness of delivery</td>
<td>Better</td>
<td>Worse</td>
</tr>
<tr>
<td>Dose sculpting</td>
<td>Less efficacious</td>
<td>Highly efficacious</td>
</tr>
</tbody>
</table>
3D-CRT and IMRT techniques provide similar results in terms of target coverage;

- IMRT more efficient in reducing the maximum dose to the OAR (extent varies)

- IMRT better in terms of dose conformity and sparing of the healthy brain at medium to low doses

- IMRT can be worse with respect to very low dose areas.
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.
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 (shoulders in low position if possible)
- 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
- Alignment of the thoracic & lumbar spine parallel to the couch (to confirm under fluoroscopy)
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
(Upper border)

Blue (Brain line)

Red (Spinal Line)

5 mm gap between the two lines
Gap calculation-formula
Gap calculation-formula
Gap calculation-formula

\[ S = \frac{1}{2} L_1 \left( \frac{d}{SSD_1} \right) + \frac{1}{2} L_2 \left( \frac{d}{SSD_2} \right) \]
Problem 1: Divergence of cranial 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
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.
Junction shift in CSI
Junction shift in CSI
Junction shift in CSI
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.
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.
A SIMPLE TECHNIQUE OF SUPINE CRANIOSPINAL IRRADIATION

ANUSHEE MUNSHI
Department of Radiation Oncology, Tata Memorial Hospital, Mumbai, Maharashtra, India

(Received 22 November 2006; accepted 27 March 2007)

Abstract—We describe a simple procedure of craniospinal irradiation in supine position. The procedure was carried out with a 100-cm isocenter linear accelerator and compatible simulator. Treatment was with a 1 or 2 posteroanterior (PA)-directed spinal fields abutting lateral-directed cranial fields. Abutment of the fields was established by placement of markers on the neck of the patient, which provided a measure of the divergence of the spinal field. The precision and reproducibility of this technique, including the placement of junctions, appeared to be as good as for treatment in the prone position. The same could be verified with port films. We conclude that this new technique of supine craniospinal treatment is a simple and convenient alternative to traditional treatment in the prone position. © 2007 American Association of Medical Dosimetrist.

Key Words: •••.
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 anaesthetic maneuvers.
Step a: Gantry taken through table and the upper border of spinal field matched with the markers.

Step b: Two additional markers placed in the line of upper border
Step C: 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