Cranio-spinal Irradiation

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ICRO course:
26 Apr 2014, Shimla
Cranio-spinal axis radiation therapy

- Medulloblastoma
- Pinealoblastoma
- Ependymoblastoma
- Intracranial Germ cell tumor (germinoma)
- Central neurocytoma
- Glioneuronal tumor
- Choroid plexus carcinoma
- Leukemia/lymphoma (with CNS axis mets)

Perez and Brady. Radiation oncology 5th Ed. P1822-1836
CSF seeding: Cerebrospinal fluid

- Secreted by choroid plexus
- Circulates in ventricles, central canal of spinal cord, and subarachnoid space
- Completely surrounds brain and spinal cord
- Clear liquid
- Nutritive and protective
- Helps maintain stable ion concentrations in CNS

Meyer JJ et al. Radiation Oncol 2006;1:48
Craniospinal Irradiation (CSI) volume

• To treat the entire CNS axis, because tumor cells from the brain parenchyma, for certain neoplasms, have direct access to the subarachnoid space and hence to the CSF.

A two compartment kinetic model, brain parenchyma & the CSF fluid, which are interconnected.

• PTV_brain
• PTV_spine
Dose needed for tumor control

Two compartments:

• brain (solid tumor)
• spine (fluid)

require different total dose, fractions, schedule

PTV_brain: ≤ 54 Gy
PTV_spine: 24-35 Gy

<table>
<thead>
<tr>
<th>Site</th>
<th>Whole</th>
<th>Boost</th>
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<tbody>
<tr>
<td>Brain</td>
<td>23-35 Gy</td>
<td>Posterior fossa=54 Gy</td>
</tr>
<tr>
<td>Spine</td>
<td>23-35 Gy</td>
<td>Seeding = 36-42 Gy</td>
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</table>
Before we deliver CSI

• We should realize, the cranio-spinal irradiation is going to treat a large and complex volume of body.

Leading to:

- acute morbidities
- long-term late effects
CSI: Acute morbidities

- Multiple acute toxicities take place during therapy course, because of the exposure of a large portion of the normal tissues, including bone marrow, head and neck, thorax, abdomen, and pelvis:
  - nausea, vomiting
  - esophagitis
  - diarrhoea
  - myelosuppression
  - fatigue, weight loss
CSI: long-term effects

- Endocrine dysfunction
- Hypothyroidism
- Impaired fertility
- Neurocognitive decline
- Growth retardation
- Hearing/visual impairment
- Cardiomyopathy
- Nephropathy
- Second malignancies
CSI: Reducing Morbidities

• All our techniques and dose regimens for CSI should aim to reduce:
  1. the acute morbidities for better tolerance and compliance
  2. the late effects which diminish the QOL in the cured children (as they achieve adulthood)

• All efforts should be made to monitor closely during RT course, and subsequently maintain a follow-up strategy to identify the long-term effects.
CSI: the evolving techniques

• 2-D
• 3-D CRT
• IMRT
• Adaptive IGRT
• VMAT
• Tomotherapy
• Proton therapy

• Paterson E, Farr RF. Acta radiol 1953;39:323
• Chojnacka M et al. Paediatr Blood Cancer 2004;42:155
• Taylor RE et al. PNET-3 study. IJROBP 2004;58:1184
• Wang Z et al. Radiation Oncology 2013;8:217
Planning steps

- Positioning
- Immobilization
- Simulation
- Verification
- Treatment
- Junction shift
Difficulties in classic irradiation techniques

- Divergences of bilateral brain fields and the upper spine field are in different directions
  - Matching inf. border of cranial fields & sup. border of spine field
- Spine fields are not geometrically matched
  - How to avoid/reduce high dose region?
- Varying depth of spinal cord along its length
- Patient is in prone position – difficult position to reproduce
Goal: To irradiate the entire neuraxis

Classical setup
- Two lateral brain fields
- Abutted to one or two PA spine fields
In standard care, prone positioning is preferred. Supine positioning is required for anesthesia.
Radiotherapy Planning: 2-D

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 organs are too many

- Eye lens, optic apparatus,
- Lungs, heart, breast tissue, kidneys
- Exit dose is an issue
Spare lenses, but cover cribriform plate region
All symmetric fields

A. **Fully divergent skull fields and a divergent upper spine field**

- Two divergences are involved here at the **junction of cranio-spinal fields**
  - Skull fields diverge in the RT – LT direction
  - Upper spine field diverge in the PA direction
- Collimator rotation required to match the skull fields with the divergence of upper spine field
- Additionally, couch rotation *(couch kick)* required to match the divergence of the skull fields
All symmetric fields

- Is that all?
- No, there are two spine fields – another junction
- This junction cannot be matched
  - There will be a gap
  - There will be a overlap
Immobilization cast and frame
CSI: 2-D Simulator settings
Problem 1: Divergence of cranial field

S

Spinal field
Problem 2 Divergence of spinal field
Solution to Problem 1:
Asymmetric block

Spinal field
Solution to Problem 2:
Use asymmetric spinal block
2-D: What are the other techniques? Electron Field(s)

- 16 MeV PA electron beam spine field
3-D image-based : Contouring

due to different calculation p...
3-D: Contouring all planes
CSI: Beam arrangement- 3D-CRT
3-D planning: What are the other techniques?

- Spine treated by PA, RPO & LPO
- Decreased dose to gut, heart, trachea, esophagus and kidneys for 3-field technique
CS: IMRT techniques?

- IMRT
  - Better dose distribution
  - Less dose to parotid and lenses
  - Easy to setup
  - No need to shift junctions
  - Upper & lower spine fields have a long overlap
    - Intensity modulated region
  - Cranial and spinal fields are optimized as a single plan
CSI-VMAT (no Junction shift: dose tapering)
VMAT: Complete dose distribution
A novel VMAT technique for CSI developed at FMRI, Gurgaon

- **IMRT Techniques:**
  Better dose distribution, Less dose to parotid and lenses, Easy to setup, No need to shift junctions. Cranial and spinal fields are optimized as a single plan.

- **We extended this IMRT protocol to VMAT at FMRI, Gurgaon**

Junction free craniospinal irradiation in linear accelerator using volumetric modulated arc therapy: A novel technique using dose tapering.

*Sarkar B et.al., accepted at AAPM, 2014*
Post fossa boost: dose distribution
Comparison of VMAT and 3DCRT dose distribution

3DCRT dose distribution

VMAT dose distribution
CSI: Tomotherapy

- Helical Tomotherapy
- Tomo eliminates junctions
  - In one long couch movement, the entire volume is treated without any need for junctions
    - Biggest advantage
  - However a large volume receives small dose

Sharma DS et al. BJR 2009:82:1000-09
CSI: Proton Therapy

- Protons!
- Advantages are many!
Proton therapy

- Perfect dose painting
- No exit dose whatsoever
- All critical organs saved

Mailhot Vega RB et al. Cancer 2013;119:4299
CSI: treatment results

Long term disease control and survival have consistently improved in last 20 years.

- Medulloblastoma: 50% to 80% survival at 5 years or more
- Other neoplasms: 35% to 80% survival at 5 years or more

Perez and Brady 5th Ed. 1836-42.
Packer RJ et al. JCO 2006;24:4202
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Thank you