A Planning Approach for Lens-Sparing Proton Cranio-Spinal Irradiation in Pediatric Patients

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Italian Proton Centers

**Catania:** Laboratory AIFN equipped with one fixed protons low energy line (60 MV-cyclotron) for eye’s tumors

**Pavia:** two fixed proton and carbon ion lines (250 MeV for protons and 4800 MeV for carbon ions) for every type of tumor
Trento Proton Therapy Center
From conformal-3D to 3D-dose modulation
Delivery with Pencil Beam Scanning

✓ Energy from 70 to 226 MV (from 4 to 33 cm in W)

✓ MU per spot from 0.02 to 12

✓ Scanning grid dimension: 30x40cm
Some important calendar dates

- **October 2014:** first treated patient – adult - parotid tumor
- **June 2015:** first pediatric patient – 9 years old – cranial chordoma tumor
- **September 2015:** first CSI pediatric patient
CSI: a technically-complex treatment

- Extensive cranio-caudal tumor volume →
- Necessity to have two or more isocenters →
- Necessity to have one or more zones of junction

Note: The conventional radiotherapy has resolved these problems with Tomotherapy helical delivery
CSI: a clinically-complex treatment

- Medulloblastoma is the most common malignant tumor in childhood. Being a tumor that primarily strikes in pediatric age, the patient usually needs to be put under anesthesia (cut off around 5\6 years of age)
- Total column irradiation to compensate bone-growth related dysfunction (cut-off 12/14 years of age)
- Cribiform plate under risk of recurrences
Waiting for the first CSI patient
(one year ago)

Work teams

• Definition of the set-up position (prone vs. supine) and the positioning devices

• Study of a Planning strategy

• Definition of the dosimetric patient QA verification
Anthropomorphous Rando phantom, which has the dimensions of an adult patient of around 180 cm in height (3 isocenters, 2 junctions)

FOCUS

• individualize the more suitable zones of junction and accordingly the position of the isocenters
• to find the way to create robust junctions
• To elaborate an effective beam arrangement
Simulation CT and contouring

- Phantom prone positioned (couch not yet characterized)
- Contouring of the CTV (from brain to the second sacral vertebra) then expanded to 4mm and divided into PTV Brain, PTVspineUP, PTVspineDOWN, PTVjunUP, PTVjunDown
- Contouring of the OAR: lens, eye and cochlea
Study Phase

Junctions: the ancillary beam technique


Planning field-junction in proton cranio-spinal irradiation - the ancillary-beam technique.

Farace P1, Vinante L, Ravanelli D, Bizzocchi N, Vennarini S.
Study Phase conclusions

- First patient desired characteristics
  1) pediatric not in anesthesia
  2) pediatric post-puberal
- Beam arrangement:
  Lat-Lat for the brain and direct posterior field for the spine
Case

- 6 year-old boy
- Headache, vomiting and gait instability
- **MRI Brain:** 5 cm posterior fossa mass with obstructive hydrocephalus
- **MRI spine:** leptomeningeal thickening abnormalities from C7 to D3
Case

- EVD placed to relieve hydrocephalus
- Posterior fossa Craniectomy and Gross Tumor Resection
  - Path: Medulloblastoma, WHO grade IV (with anaplastic features)
  - Post-op developed posterior fossa syndrome (Mutism and hemiparesis, truncal ataxia, VII CN L palsy)
Case

- Post-op brain MRI: No residual disease
- Lumbar Puncture ten days after surgery: + for malignant cells
- Bone scan: no metastasis
Management

• High Risk MBL

  – Surgery $\rightarrow$ GTR

  – High dose CHT and Bone Marrow transplant

  – MRI brain and spine evaluation pre_Proton

  – CSI (36 Gy/20 fr) + Tumor bed boost (18.0 Gy/10 fr)
Clinical Phase

Simulation CT and Set-Up

Patient position: supine under anesthesia

CT scanning: 3 mm contiguous slice thickness from the top of the head to the lower sacrum
Clinical Phase

Set-up Devices

Anesthesia: Midazolam intravenous injection then maintenance with Propofol
Contouring: TPS Focal by Elekta
Planning: TPS XiO by Elekta

OAR
Eyes
Lenses
ON
Cochlea
Larynx
Esophagus
Lungs
Heart
Liver
Kidneys
Bowel

1 isocenter
2 isocenter
3 isocenter
Clinical Phase Planning

TPS XIO by Elekta

**SFO technique:** optimization field per field independently for reducing dose calculation uncertainties. The evolution of this technique is the IMPT but the risk related to the dose calculation uncertainties is too high without an algorithm like Monte Carlo that is nuclear and atomic interactions correlated.
Clinical Phase
Planning
Clinical Phase Planning
Clinical Phase Planning
Single Field Optimization

- 3.5 Gy D1
- 1.0 Gy D1
- 0.5 Gy D1
- 1.0 Gy D1
- 3.5 Gy D1
- 3.5 Gy D1
- 1.0 Gy D1
Evaluation

98% 35.3 Gy
95% 34.2 Gy
90% 32.4 Gy
14% 5.0 Gy
Evaluation

- PTV
- Brain
- Cochlea
- Eyes
- Lenses
Related Papers

Standardized treatment planning methodology for passively scattered proton craniospinal irradiation

Annelise Giebeler¹ ² ⁴, Wayne D Newhauser¹ ² ⁵, Richard A Amos¹ ², Anita Mahajan³, Kenneth Homann¹ ² and Rebecca M Howell¹ ² *

Radiation dose to the lens during craniospinal irradiation—an improvement in proton radiotherapy technique

David M. Cochran, M.D., Ph.D., * Torunn I. Yock, M.D., † Judith A. Adams, C.M.D., † and Nancy J. Tarbell, M.D. †

Supine Craniospinal Irradiation Using a Proton Pencil Beam Scanning Technique Without Match Line Changes for Field Junctions

Haibo Lin, PhD, Xuanfeng Ding, PhD, Maura Kirk, MS, Haoyang Liu, PhD, Huifang Zhai, MS, Christine E. Hill-Kayser, MD, Robert A. Lustig, MD, Zelig Tochner, MD, Stefan Both, PhD, and James McDonough, PhD
# Results

**LENS SPARING PROTON CRANIOSPINAL IRRADIATION IN A PEDIATRIC PATIENT**

Bizzocchi Nicola, Barbara Rombi, Farace Paolo, Algranati Carlo, Righetto Roberto, Marco Schwarz, Maurizio Amichetti

Proton Therapy Center, S. Chiara Hospital, Trento – Italy

<table>
<thead>
<tr>
<th>Dose to the lens (% of prescription dose)</th>
<th>Delivery mode</th>
<th>Beam arrangement</th>
<th>Dmax</th>
<th>Dmean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First pediatric patient</strong></td>
<td>Active</td>
<td>Lens sparing</td>
<td>16.7%</td>
<td>6.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>posterior-oblique</td>
<td>49.4%</td>
<td>34.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>opposed-lateral</td>
<td>56.6%</td>
<td>40.4%</td>
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<tr>
<td><strong>Published studies</strong></td>
<td>Passive</td>
<td>posterior-oblique*</td>
<td>68.5%</td>
<td>48.1%</td>
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<tr>
<td></td>
<td></td>
<td>posterior-oblique**</td>
<td>40.0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Passive</td>
<td>opposed-lateral**</td>
<td>74.0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Active</td>
<td>opposed-lateral***</td>
<td>26.4%</td>
<td></td>
</tr>
</tbody>
</table>

3 months after PT
Complete hair regrowth
During PT

After 6 months PT and one hair-cut
Basal testing (before P-CSI)

- Neurocognitive testing
- Neuro visual testing and ophthalmic exam
- Neuroendocrine testing: N
- ENT and hearing loss testing: mild neurosensorial R hearing loss
- PKT evaluations
Sequelae (6 months after P)

- Neurocognitive decline (negative, good math performance testing and memory tests, QI normal)
- Neuroendocrine deficits (negative)
- Hearing loss testing (negative)
- Neuro visual testing (visual-spatial setting improved, no cataracts)
- PKT evaluations improved globally: speech skills improved, mild ataxia, some steps
After the first patient...

High Risk CSI Protocol

<table>
<thead>
<tr>
<th>Patients</th>
<th>Age</th>
<th>Lens dx D1 cGy</th>
<th>Lens sx D1 cGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pz 1</td>
<td>6</td>
<td>439</td>
<td>533</td>
</tr>
<tr>
<td>Pz 2</td>
<td>14</td>
<td>442</td>
<td>250</td>
</tr>
<tr>
<td>Pz 3</td>
<td>8</td>
<td>460</td>
<td>470</td>
</tr>
<tr>
<td>Pz 4</td>
<td>4</td>
<td>447</td>
<td>468</td>
</tr>
<tr>
<td>Pz 5</td>
<td>7</td>
<td>716</td>
<td>709</td>
</tr>
<tr>
<td>Pz 6</td>
<td>5</td>
<td>794</td>
<td>790</td>
</tr>
</tbody>
</table>
Boost on Posterior Fossa

18 Gy\10 fr
Boost on Posterior Fossa

18 Gy/10 fr
Boost on Posterior Fossa
18 Gy/10 fr
Acknowledgments
Think like a Proton and stay Positive

Grazie

Thank you all