Novel Supine Craniospinal Irradiation using a Proton Pencil Beam Scanning Technique without Match Line Changes

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Patient setup and treatment

- Patient is treated supine

- Range shifter device
  - High density sliding table top
  - A U-shaped bolus around pt’s head

- Headrest plastic cup with cushion
  - Comfortable
  - Elevated head position vs bolus edge

- 5 inch custom thermoplastic mask
  - Cut opening on mask over the mouth for GA patients

- Large knee rest
  - Immobilize low part of body
Target volume for planning

- CTV = brain + thecal Sac
  - include cribriform
  - extend anteriorly in the area of orbits to include nerves
  - Include nerve roots
  - Brain + vertebral body for children

- PTV = 3 mm expansion on CTV

- Field specific PBSTV_Compo
  - calculate distal margins on each field (exclude bolus and couch WET)
Planning with PBS

Field Geometry

- Two lateral PBS fields are used to treat the brain
- One or more posterior fields are used to treat the spine
- Fields overlap for 5-8cm
- A shallow dose gradient is created between the fields in order to create a safe, smeared field match
Target volumes for planning

Field specific target volume
- PBSTV_compo
  - Brain
  - Spine

Optimization target volume
- PBSTV
  - Brain
  - Spine
- up gradient volume
  - 80brain_20up
  - 60brain_40up
  - 40brain_60up
  - 20brain_80up
- low gradient volume
  - 80upp_20low
  - 60upp_40low
  - 40upp_60low
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Film measurements on field matching

Sagittal dose profiles comparison for the (a) spinal-spinal and (b) craniospinal junctions. The blue lines indicated the location to draw the dose profiles.
Dose deviations vs longitudinal setup errors

Mathematical model predicted the relationship between dose errors and gradient lengths for different setup errors. “+” and “-” represent superior and inferior errors.

\[
Dose\ deviation(\%) = \frac{100 \times setup\ errors(cm)}{junction\ lengths(cm)}
\]
Dose deviations vs longitudinal setup errors

(a) the percent dose variations for PBS CSI plan with 5 cm junction length when ±0.1, ±0.3, ±0.5, ±1 cm shifts are applied to spine field; dash lines indicate the model-predicted maximal dose deviations for 5 cm junction and 0.3, 0.5 and 1 cm positioning errors (considered 5.5% hot spot); (b) comparison of dose profile when 1 cm superior shift is applied to spine field.
Patient specific QA

A sample patient QA results of a spine field measured with IBA 2D ion chamber array-MatrixX. 3 depths are measured for each patient and compared with planned dose. (a) measured dose; (b) planned dose; (c) isodose distribution for measured dose; (d) Gamma comparison.
Plan evaluation parameters for 10 patients

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<th>N</th>
<th>Mean Junct. length (cm)</th>
<th>Maximal Dose (cGy RBE)</th>
<th>Mean Dose (cGy RBE)</th>
<th>Minimal Dose (cGy RBE)</th>
<th>PTV D95% (%)</th>
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|     | mean | 6.7  | 4216 | 3982 | 977 | 924 | 205 | 219 | 3650 | 3651 | 3542 | 3268 | 3148 | 100.8 | 100.2 | 0.78 | 1.09 |
|     | Std  | 0.5  | 98   | 91   | 363 | 305 | 259 | 128 | 57   | 99  | 99   | 158  | 249  | 0.8   | 0.6   | 0.03 | 0.01 |

“*” indicates patient planned with three spine fields; doses to the middle spinal junction are similar to the other two spinal junctions and thus are not reported; Junct.: junction, which is defined as the PTV between the adjacent OVs along cranio-caudal direction as indicated in figure 1; the column of Cord ±3mm presents the maximal cord dose under worst case scenario when a 3 mm shifts is applied on each treatment field (maximal setup errors of 6mm) along cranio-caudal direction. For consistency of presentation, results for patients with a prescription of 23.4 Gy were all converted to 36 Gy equivalent prescriptions.
Conclusions

- The technique uses a gradient dose optimization approach to create a slow dose gradient in the junction area, reducing the sensitivity to longitudinal setup errors.

- A smooth dose gradient between fields eliminates the need for match line changes while maintaining the safety of treatment delivery relative to potential misalignments.

- Treatment planning and delivery are efficient, and this technique may be widely applicable clinically.
Acknowledgements

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