Robust proton CSI planning in Proteus®ONE

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INTRODUCTION AND OBJECTIVES

This work studies the craniospinal irradiation (CSI) with pencil beam scanning proton therapy in an IBA Proteus®ONE gantry. Robust optimization can be used to create gradient-shaped field-junctions if robustness against setup uncertainties is considered in all dimensions. However, the number of scenarios to compute increases exponentially with the number of beams. In an IBA Proteus®ONE facility, where the maximum field size available is 20x24 cm^2, at least four beams are typically needed to cover the whole craniospinal axis + beams for brain irradiation.

$$\textit{Robust scenarios} = (\textit{setup scenarios})^{\textit{number of fields}} \cdot (\textit{range})$$

For a plan composed of 5 beams → 50421 robust scenarios to be computed!!! (The optimization is not viable)

2 possible solutions are investigated:

❖Robustness against setup uncertainties only in the craniocaudal direction

❖The ancillary beam technique proposed by Farace *et al.*[1].

MATERIALS AND METHODS

- RayStation 6
- CT images of two patients in supine position
- 3 posterior beams to cover the spine + 2 lateral beams for brain irradiation
- 4 cm range shifter

Ancillary Beam Technique :

- PTV: 3-mm isotropic expansion of the CTV
- Implementation of the ABT

Robust Optimization:

- Optimized on the CTV
- Range uncertainties (3%)
- Robustness against 3 mm setup uncertainties only in the craniocaudal direction

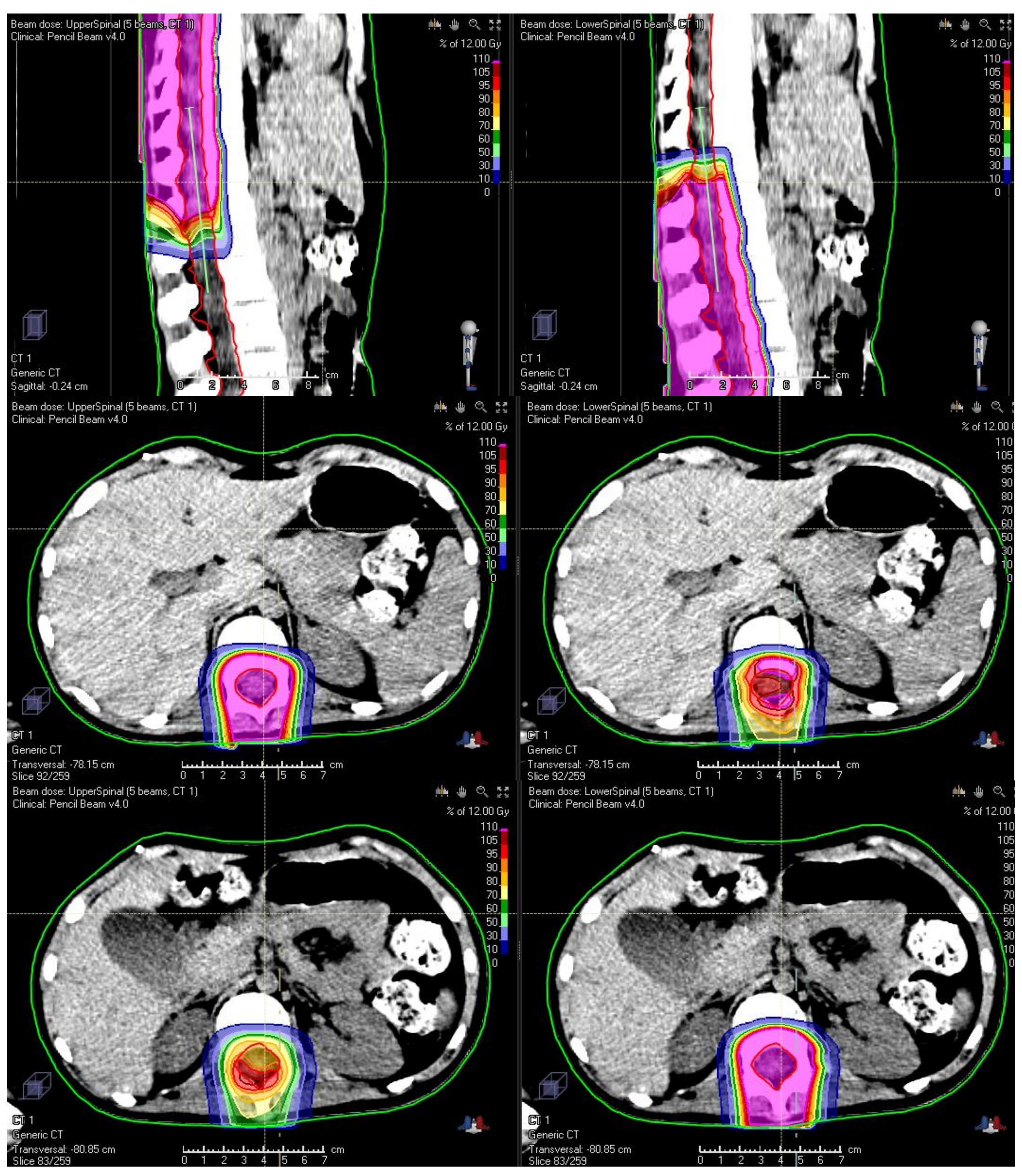
These settings reduced the robust scenarios to be computed:

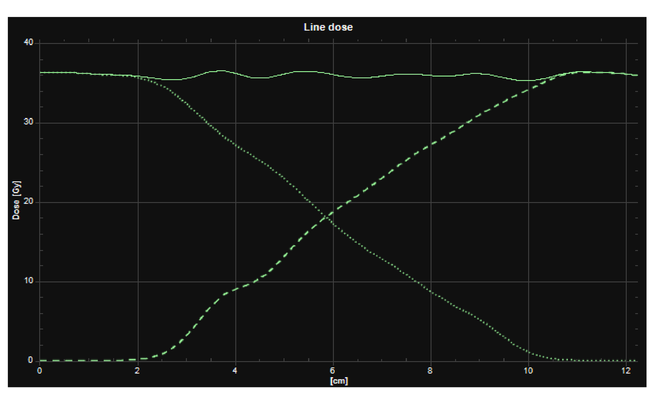
50421 → 729

RESULTS

❖Both approaches yielded an optimal nominal plan. On the other hand, the ancillary beam method, together with the PTV, offered a homogeneous and robust dose distribution throughout the whole craniospinal axis.

Robust optimization:
A dose gradient was obtained through the junction, but the dose distribution for each individual beam was highly inhomogeneous in the anterior-posterior and left-right directions. Therefore, the plan was not robust to setup uncertainties in those directions.



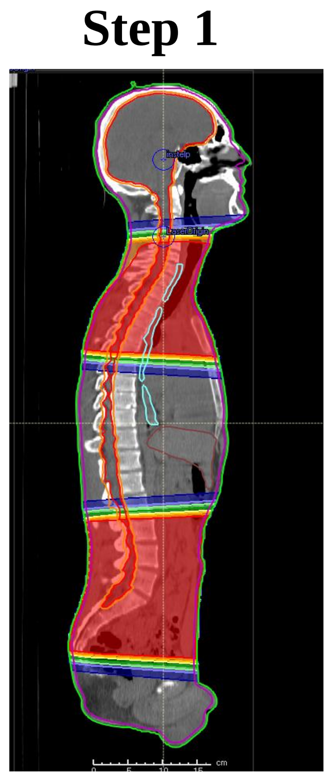


✓ Robustness to setup uncertainties in the craniocaudal direction

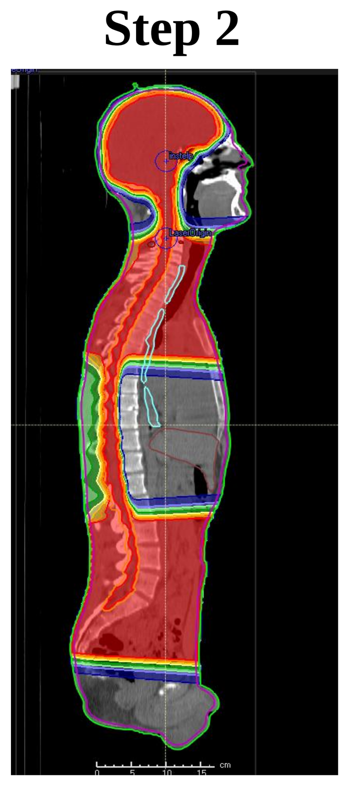
✗ Robustness to setup uncertainties in the anterior-posterior and left-right directions.

Ancillary Beam Technique:
A dose gradient was obtained through the junctiond and a homogeneous and robust dose distribution was obtained throughout the whole craniospinal axis.

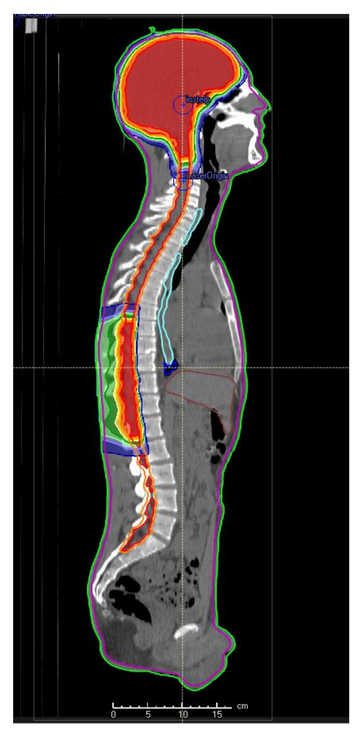
Step 1



Step 2

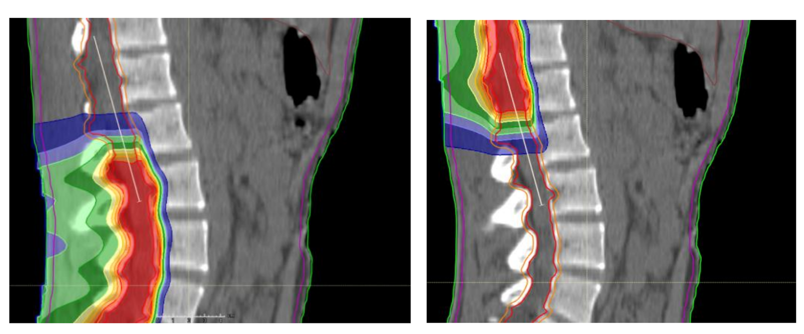


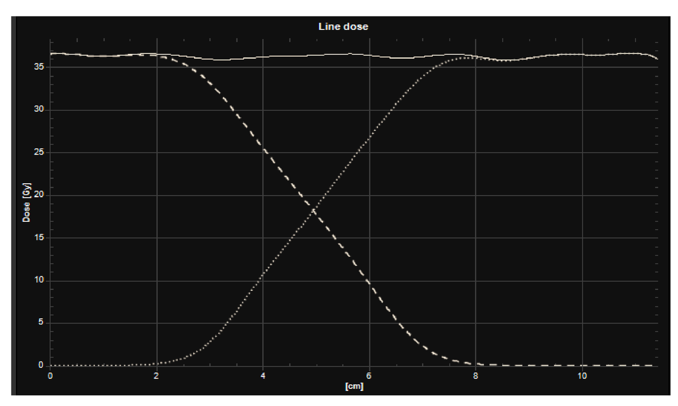
Step 3



Final dose distribution

In **step 1** the ancillary beams are placed and then used to inversely plan the brain and central spinal beams in **step 2**. In **step 3** the ancillary beams are removed. The brain and central spinal beams are switched on during the optimization of the upper and lower spinal beams to obtain the **final dose distribution** [2].





✓ Robustness to setup uncertainties in the craniocaudal direction

✓ Robustness to setup uncertainties in the anterior-posterior and left-right directions.

CONCLUSION

❖The ancillary beam technique offered a superior plan quality and it is therefore the recommended solution to plan CSI irradiations in a Proteus®ONE proton therapy gantry.

References:

[1] Farace P, Vinante L, Ravanelli D, Bizzocchi N, Vennarini S. Planning field-junction in proton cranio-spinal irradiation – the ancillary-beam technique. Acta Oncol 2015;54(7):1075-8.

[2] Farace P, Bizzocchi N, Righetto R, Fellin F, Fracchiolla F, Lorentini S, Widesotta L, Algranati C, Rombi B, Vennarini S, Amichetti M, Schwarz M. Supine craniospinal irradiation in pediatric patients by proton pencil beam scanning. Radiother Oncol 2017;123:112-118.