Purpose

To show the feasibility and robustness of actively scanned proton therapy with single and matched fields in order to assure reproducibility and stability of treatment delivery.

Extremity soft tissue sarcomas (ESTS) are treated with combined surgery and radiotherapy. Matched fields should be guaranteed to avoid hot or cold spots.

Larger tumor sizes

- Involvement of large volumes of healthy tissue
- Increased late toxicity
- Negative impact on quality of life

Protons as treatment option:

- Conformal treatment due to their inverted dose profile
- Reduction of healthy tissue exposure and preventing long term toxicity

Results

Treatment volumes shorter than 17 cm (4 patients) (Figure 2)

<table>
<thead>
<tr>
<th></th>
<th>Patient 6</th>
<th>Patient 9</th>
<th>Patient 3</th>
<th>Patient 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose surface area</td>
<td>9.0</td>
<td>16.5</td>
<td>14.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Robust analysis:

- Robust against HU perturbation and shifts in superior-inferior and left-right direction (PTV<sub>95%</sub> > 93%, PTV<sub>107%</sub> < 107%, PTV<sub>RBE</sub> > 90%)
- Isocenter shift in anterior-posterior direction: underdosage PTV<sub>95%</sub> below 68%. Robust optimization in ant-post direction could increase these values up to 91%.

Treatment volumes longer than 17 cm (4 patients):

- Robustness analysis

Isocenter shift by 1 cm to each other and apart: (Figure 1 e-h)

- Overlapping region influences PTV<sub>RBE</sub>
- 7% for overlap region > 6 cm, 15% for overlap region < 6 cm

Material and Methods

- Treatment planning software: RayStation v4.7 (Raystation Laboratories, Sweden)
- Single beam optimization (SBO)
- MedAustron Particle Therapy Accelerator with horizontal beam line and field size of 20x20 cm² (maximal treatable field size 17 cm)
- Matching of two fields with different isocenters: Robust optimization (0.5 cm superior and inferior) to produce flat dose fall-off in the overlapping region (Figure 1a-d)
- With 6 cm overlap maximum field size with one matching boarder: 31 cm

Residual field size: 18.5 cm

1.5 cm for spots outside the target

Overlapping region of 6 cm

1.5 cm for spots outside the target

- 8 postoperative extremity soft tissue sarcoma patients

- Volume: 186-2240 cm³, length: 15-34 cm (4/8 PTVs longer than 17 cm)
- CTV = GTV radially expanded by 1.5 cm and longitudinally by 4 cm
- PTV = CTV + 5 mm (isotropically) [1]

Dose prescription to the PTV: D<sub>95%</sub> = 60 Gy (RBE) (2 Gy (RBE)/fraction)

Robustness assessment:

- Hounsfield unit (HU) perturbations of 3.5%
- Isocenter were shifted 1 cm towards and apart of each other as well as independent from each other in all directions

Evaluation parameter:

- PTV: D<sub>95%</sub> > 107%, D<sub>105%</sub> > 90% and V<sub>RBE</sub> > 95% (ICRU)
- Organs at risk (OARs):
  - Skin dose surface area: A<sub>RBE</sub> (RBE) < 20 cm² [2]
  - Bone maximum dose: D<sub>105%</sub> < 60 Gy (RBE)

Robust treatment plans could be achieved for ESTS patients employing a horizontal beam line only. Before clinical implementation, dosimetric monitoring of skin doses should be performed to verify the calculated values. If field matching is needed a maximal overlap of matching fields should be guaranteed to avoid hot or cold spots.