Contribution ID: **6** Type: **Oral**

An ultra-fast field delivery with PSI's Gantry-2 to achieve hypofractionated PBS proton therapy within a single breath-hold for lung cancer

Friday, 28 October 2022 14:35 (10 minutes)

Purpose:
The use of motion mitigation techniques such as breath-hold can reduce the dosimetric uncertainty of lung cancer proton therapy. We studied the feasibility of hypofractionated pencil beam scanning (PBS) proton therapy field delivery within a single breath-hold at PSI's Gantry 2. Treatment delivery time in PBS proton therapy depends on beam-on time and the dead time between proton spots (time required to change the energy and/or lateral spot position). We studied ways to reduce beam-on and lateral scanning time, without sacrificing dosimetric plan quality, aiming at a single field delivery time of 15 seconds at maximum. We tested this approach on ten lung cancer cases with varying target volumes (PTV volume range 137-379 cm3).

Methods:
To reduce the beam-on time, we increased the beam current at the isocenter by developing new beam optics for PSI's PROSCAN beamline and Gantry 2. Experimentally we obtained up to factor 5 higher transmission for all proton energies.
To reduce the dead time between the spots, we used spot-reduced plan optimization. First, a 3-field SFUD treatment plan was generated for all 10 cases using the in-house clinical planning system 'PSIplan'. Spot-reduced plans were subsequently generated while mimicking relevant dosimetric plan parameters of the clinical plans to ensure comparable plan quality. The spot reduction technique reduced the number of spots by 95% compared with the clinical planning system for the lung cases considered.
For the clinical and spot-reduced plans, 6-Gy(RBE) fractions were delivered with PSI's Gantry 2 using the clinical and transmission-efficient beam optics, respectively. We extracted delivery times, including both beam-on time and dead time, from the log files.
Results:
We found that it is possible to achieve hypofractionated (6 Gy(RBE)/fraction) field delivery times within a single breath-hold (<15 sec) for all (100%) index cases.
Conclusions:
In summary, the combination of spot reduction and improved beamline transmission is a promising approach for treating mobile tumors treated with PBS proton therapy within clinically achievable breath-hold durations.

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Session Classification: Session IV: Radioprotection, Treatment Techniques

Track Classification: Radiation Therapy