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A Direct Machine-Specific Parameters Incorporated Spot-Scanning Proton Arc (SPArc) Algorithm

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A direct machine-specific parameters incorporated Spot-scanning Proton Arc (SPArc) algorithm

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Purpose: To address the challenges of generating a deliverable and efficient spot-scanning proton arc (SPArc) plan for a proton therapy system. We developed a novel SPArc optimization algorithm (SPArcDMSP) by directly incorporating machine-specific parameters such as mechanical constraints and delivery sequence.

Method and Material: A SPArc delivery sequence model (DSMarc) was built based on the machine-specific parameters of the prototype arc delivery system IBA ProteusONE®. The SPArcDMSP resamples and adjusts each control point's delivery speed based on the DSMarc calculation through the iterative approach (Fig1). Users could set the expected delivery time and gantry max acceleration as a mechanical constraint during the optimization. Four cases (brain, liver, head neck, liver, and lung cancer) were selected to test SPArcDMSP. Two kinds of SPArc plans were generated using the same planning objective functions:(1) SPArcDMSP plan meeting the maximum allowable gantry acceleration speed(0.6deg/s2);(2) SPArcDMSP-user-speed plan with a user pre-defined delivery time and acceleration speed $<$ 0.1deg/s^2. Arc delivery sequence such as gantry speed, delivery time was simulated based on the DSMarc and was compared.

Results: With a similar objective value, number of energy layers, and spots, both SPArcDMSP and SPArcDMSP-user-speed plans could be delivered continuously within the $\pm$1 degree tolerance window.The SPArcDMSP-user-speed plan could minimize the gantry momentum change based on users' preference (Fig 2).

Conclusions: For the first time, the clinical users could generate a SPArc plan by directly optimize the arc treatment speed and momentum changes of the gantry. This work paved the roadmap for the clinical implementation of proton arc therapy in the treatment planning system.

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A quantitative dose perturbation comparison study between gold and platinum VISICOIL^{TM} fiducial markers in proton beam therapy

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Purpose: To quantitatively investigate the dose perturbations difference between gold and platinum VISICOIL^{TM} fiducial markers in proton beam therapy

Method: Gold and platinum VISICOIL^{TM} fiducial markers with two different dimensions were tested, including 0.35 & 0.5mm in diameter and 5mm in length. Total four kinds of markers. Gafchromic EBT2 was used to measure dose perturbations along the beam path in a "sandwich" setup (Figure 1). Dose perturbation was reported in each depth (0.3mm, 1.65mm, 3.00mm, 5.40mm, 7.80mm, 10.20mm, 12.60mm, 18.15mm). Relative proton stopping power relative to water were calculated through National Institute of Standards and Technology database and SRIM (version -2013) in the therapeutic energy range (70-220MeV).

Result: There is no statistical difference between gold and platinum VISICOIL^{TM} fiducial markers in all the depth with diameter 0.35mm (p=0.125), and 0.5mm (p=0.130). The maximum point dose perturbation between Au and Pt marker with the same dimension are similar (0.35mm diameter at 7.8mm WET: 2.85%$\pm$2.31% Au vs. 2.70%$\pm$2.60% Pt; 0.5mm diameter at 5.4mm WET: 8.81%$\pm$2.60% Au vs. 8.81%$\pm$2.57% Pt.) (Figure 2). Bilateral treatment field arrangement could further reduce the dose perturbation by half. The relative stopping power ratio to water was calculated based on gold and platinum materials. The result showed there are about 3.5% difference between the two materials.

Conclusion: The study indicated that the Au and Pt VISICOIL^{TM} fiducial markers have very similar physics properties and could interchangeable in the proton beam therapy as long as the clinical users correct the RSP during the planning process.