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P2.47: Patient positioning based on a helium-beam radiograph (αRad)

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Introduction: In particle radiotherapy it is even more important to precisely align the patient with the treatment beams than in the conventional photon radiotherapy. Currently two orthogonal X-ray projections are used in clinics for patient positioning. We developed a unique method to perform such alignment of the patient with the beam based on radiography with helium ion beams (αRad). The advantage of such method is a capability of simultaneous verification of stopping power of the tissue, which is crucial in ion beam radiotherapy. Spatial resolutions of approximately 0.5 lp/mm (MTF10%) were demonstrated. With the method presented here, inter- and intrafractional variations, including movements, could be detected and corrected for prior to each treatment. In this contribution, the feasibility of patient positioning using αRad was assessed for an anthropomorphic head phantom.

Materials and Methods: First, we identified a region of interest (ROI) in a head phantom that shows high sensitivity to movements. We performed it on projections of an X-ray CT after small rotations and translations by comparing it to the unaltered CT projection. High sensitivity was typically observed in regions at bone-soft tissue interfaces.
Subsequently, these regions (approx. 3 cm by 3 cm) were imaged by helium ion radiography at the Heidelberg Ion-beam therapy center. The previously developed ion beam imaging system was used. The system consists of six parallel thin silicon pixel detectors using the detector technology Timepix. The sensitive area is 256 pixels by 256 pixels (14 mm x 14 mm) and each detector is capable of detecting single ions with either information on time of arrival or energy deposition. The detectors are placed parallel in pairs. The tracking unit in front and behind the imaged object are used to trace the most-likely path of single ions in the imaged object. The additional unit to measure the energy deposition of the single ions is positioned at the rare of the imager. Helium beams with initial beam energies between 166.8 MeV/u and 186.7 MeV/u were used at fluences and fluence rates far below the clinically used ranges. Calibration curves were developed to translate the energy deposition to water-equivalent thickness of the traversed material of the imaged object.
To investigate the feasibility and accuracy of patient positioning based on αRad, two αRads of the previously identified regions of interest (ROIs) were acquired. The aim was to mimic a possible small rotation of the patient's head at exactly 1° with respect to a reference measurement. The phantom was rotated along its coronal axis by 1° with a high-precision rotation table. An in-house 2D-to-3D image registration algorithm, a tool for aligning a 2D image to a 3D image volume, was used to line up the two radiographs to the original X-ray CT image.

Results: The performance of method was evaluated for three sets of two radiographs by comparing the suggested changes in translation and rotation to the ground truth rotation of 1°. The rotations along the coronal, axial and sagittal axes were accurate to -0.07°, 0.17°, 0.12°, and precise to 0.15°, 0.31°, 0.10°, respectively. For translations, an accuracy of 0.02 mm for x-axis, 0.06 mm for y-axis, and a precision of 0.03 mm for both axes were calculated.

Conclusion: This study of accuracy and precision of patient positioning using αRads demonstrates the feasibility of the usage of helium-beam radiography for patient positioning in future clinical application.

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