[OA026] Design of an optimised bow-tie filter for cone-beam CT image guidance for children
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Purpose. Children can receive excessive imaging dose from cone-beam CT (CBCT) during image-guided radiotherapy due to use of protocols designed for adults. Lower dose CBCT is a high priority for reducing the risk of radiation induced late effects in children. The range of imaging doses can be reduced by lowering exposure using an optimal ‘child-sized’ bow-tie filter with additional attenuation and tailored shape. We present a filter design using measurements from paediatric CBCT data and simulate its impact on image quality and registration accuracy.

Methods. The filter was designed to produce uniform signal across the average paediatric patient and provide additional attenuation compared to a standard (adult) bow-tie filter. To estimate the average patient thickness across the detector plane, we used the signal intensity profiles of projection images acquired from 15 paediatric patients (ages 3–17 years) with various tumour sites. The intensity values were converted to an estimate of patient thickness using the Beer-Lambert law, with all tissues approximated as water. We produced a symmetrical design accounting for attenuation through the average patient across the detector. CBCT scans including the added noise resulting from attenuation of the new filter were simulated by modifying projection images before reconstruction. Simulated scan quality was assessed visually and by testing registration accuracy, comparing the table correction to that for the original higher dose images.

Results. The resulting filter had a central thickness of 15.53 mm of Aluminium, corresponding to a fivefold reduction in signal compared to the use of the standard filter (approximately decreasing dose from 1.5 mGy to 0.33 mGy per scan). The thickness increased to 29.87 mm at the outer edge, following a curvature described by a polynomial function relating filter thickness to patient thickness across the detector. Simulated scans showed increased noise but clear bone-/soft tissue boundaries. Registration remained accurate; most scans had table correction vector discrepancies within 1 mm (max 1.09 mm).

Conclusions. We have designed an optimised bow-tie filter for children. This dedicated filter design should allow considerable dose reduction to the patient, maintaining sufficient image quality and accurate registration. Observer studies on the acceptability of very low dose images in clinical practice are underway.

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[OA027] Helium as a range probe in carbon ion therapy
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Purpose. Range uncertainty is a major uncertainty in particle therapy, especially in extracranial irradiations. As helium has the same magnetic rigidity but more than twice the range at the same velocity as carbon, it is in principle possible to mix beams, using carbon for therapy while simultaneously detecting Helium exiting the patient to assess beam range.

Methods. To investigate feasibility, a single field irradiation was simulated on a lung cancer patient using the GSI in-house TPS TRIp98, using a field consisting of 90% carbon and 10% helium. Target dose was optimized to 2 Gy(RBE), taking into account dose from both ions but keeping the ratio constant. The 10% helium deposited less than 0.5% of the target dose while passing through the patient, notably also less than the Carbon fragment tail within the patient.

Results. The maximum energy in this patient was 255 MeV/u, corresponding to ranges of 12.8 and 39.2 cm H2O for helium and carbon, respectively. In the pencil beam dose algorithm, a dose of approximately 1 cGy was calculated in the Bragg Peak region of helium. In order to detect helium ions beyond the patients, secondary nuclear fragments must be separated from primary helium ions. For the lowest energies, carbon and helium delivered approximately the same dose, but carbon dose fell below 1 mGy 10 cm before the distal range of helium. Individual Bragg Peaks of helium were clearly separable in water due to the relatively larger spacing of carbon energies determining the energy layout of the plan.

Conclusions. MC simulations and experiments are needed to study the best combination of simultaneous Carbon-therapy and Helium-imaging. Fast detection systems could be used to check ranges online, while position-sensitive detectors would permit ion radiography before or during therapy. Here, single particle tracking techniques as developed for proton imaging would benefit from the lesser scattering of helium. In moving tumors, range-based motion detection or gating could be possible, especially in the lung with large density differences of tumor and lung.

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[OA028] On the potential of direct MV calibration of ionization chambers by secondary standards laboratories
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Purpose. The IAEA protocol (TRS-398) for absorbed dose to water measurements in therapeutic MV photon beams, recommends that ionization chambers be calibrated directly in MV accelerator photon beams rather than in cobalt-60 combined with generic beam quality correction factors (kQ) tabulated in the protocol. The purpose of this work was to study the feasibility for secondary standards laboratories to provide direct MV calibrations for hospitals and to evaluate the benefit of such calibrations versus conventional cobalt calibrations.

Methods. A laboratory with the potential to provide direct MV calibrations was established. It includes both a cobalt irradiator and a linear accelerator with the following MV beams: 4, 6, 10, 15, and 18 MV with flattening filter and 6 and 10 MV without flattening filter. Procedures were designed for accurate positioning of ionization chambers, beam output monitoring and relevant ionization chamber correction factors. Over a two-month period, kQ-factors were measured in all beams for seven nominally identical chambers (IBA FC65G) covering a wide range of serial numbers. Traceability to primary standards were established using transfer chambers. The results of this work were compared with published kQ-factors from TRS-398.

Results. The monitoring of beam output using an external monitor chamber was found to be essential for calibration purposes: The raw accelerator output changed systematically by 0.4% over the mea-
measurement period. However, with an external monitor chamber, the output variability was reduced to less than 0.05% (1 sd). For each beam quality, the relative standard deviation for the measured k_o factors for the seven ionization chambers was about 0.07%.

Conclusions. The study demonstrates the feasibility of highly reproducible MV calibrations at the level of a secondary standards laboratory, and the closeness of agreement (sd < 0.1%) among the seven ionization chambers suggests that generic k_o-factors may be adequate for determining ionization chamber model. Ongoing work focuses on characterization of additional ionization chambers models (PTW30013, PTW31021, and NE2571) and on improved estimation of the uncertainty related to establishing traceability to primary standards. The latter work includes direct use of water calorimetry in the specific accelerator beams of the laboratory.

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[OA029] Optimization of phase space files from clinical linear accelerators
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Purpose. This project proposes a methodology inspired by the gradient descent algorithm [1] to manipulate existing IAEA phase space files (PSF) of an Elekta Precise linear accelerator (linac) head, in order to produce a new fine-tuned PSF for an Elekta Synergy linac head.

Methods. An Elekta Synergy coupled with an Elekta Agility multi leaf collimator was modeled in Geant4. Due to unavailability of detailed geometric information of the Synergy head, the IAEA PSF for the Elekta Precise [2] linac was used as initial benchmark. As the geometry of the aforementioned linac heads differs, discrepancies between measured and simulated PDD and lateral profiles in water were quantified in terms of cost value. The Elekta Precise PSF was divided into a grid of squared elements in the x-y plane, each of them holding information on respective particles' initial parameters, such as energy and momentum directions. For each element, small perturbations to the parameters were introduced independently and interim PSFs were generated. Profiles were simulated using the perturbed PSFs and the cost values were updated, yielding a correlation between the cost function and the perturbation. The parameters that produce the minimum cost value were then found iteratively.

Results. The influence of particles' energies and momentum on the cost function has been evaluated. By finding a minimum value of cost, optimal parameters can be determined. The final PSF containing optimal values is being validated and an overview of the results will be presented.

Conclusions. A methodology for optimization of existing PSF was developed, enabling the generation of fine-tuned, machine-specific PSF without requiring knowledge of linac's head geometry.

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References

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[OA030] Improved dose sensitivity of N-(isobutoxymethyl) acrylamide polymer gel dosimeters for radiation therapy
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Purpose. A new and very low dose sensitivity of polymer gel dosimeter containing N-(isobutoxymethyl) acrylamide was introduced (Salah et al., 2017). A significant increase in dose response as well as dose sensitivity of N-(isobutoxymethyl) acrylamide polymer gel dosimeter has been reported in this study.

Methods. The N-(isobutoxymethyl) acrylamide (NIBMA) gels were fabricated under a fume hood in normal atmospheric conditions. Gels were irradiated by X-ray beams of a medical linear accelerator. The irradiated gel dosimeters were evaluated using nuclear magnetic imaging (NMR) techniques in terms of relaxation time (T2) of hydrogen protons within the water molecule.

Results. The dose response as well as dose sensitivity were significantly increased by increasing NIBMA concentration. Slight effects of dose rate, beam energy and post-irradiation stability were noticed on the performance of NIBMA polymer gel dosimeters.

Conclusions. High dose sensitivity with low toxicity polymer gel dosimeters containing N-(isobutoxymethyl) acrylamide (NIBMA) were developed for radiotherapy treatment planning system.

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[OA031] Imaging dose assessment for image guided radiotherapy using a state of the art large-bore CT
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Introduction. Medical imaging has become an essential element of radiotherapy. Imaging techniques improve and are used extensively. This development also leads to an increase in dose exposure of ‘extra-target’ volume. It is recommended [1] to assess the imaging dose and to optimize the procedures.

Materials and methods. The imaging dose of radiotherapy procedures using a state of the art large bore CT (computed tomography) for virtual simulation and 6 MV (mega voltage) on-board planar imaging for position verification was measured. In the presented work the peripheral dose from imaging of the pelvic region and the head and neck region were assessed. The absorbed dose to water was measured using an anthropomorphic phantom and individually calibrated thermoluminescence detectors (TLDs). The positions for TLD placement were selected to cover clinically relevant organ positions at two anatomically interesting locations (pelvis and head and neck area).

Results. The imaging dose of two different devices was assessed: a large bore CT and MV planar imaging detector at