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amplification in the pixel make this feasible, and have thicknesses less than 50 μm . The work presented here shows the progress made towards an upstream beam monitor and dose verification system based on a MAPS camera device.

The Achilles MAPS camera was operated at 10 frames per second and mounted to an Elekta SL22 6MV linac head with either Gafchromic film or the MatriXX 2D ionization chamber array, used for MLC leaf position and dose verification, placed below. The film was positioned at 98.5 cm SSD with 1.5 cm of water equivalent buildup and the MatriXX at 95 cm SSD with 5 cm buildup. A series of exposures were then administered with different sequences of fields to allow both MLC position reconstruction and dose calculations to be performed. The reconstruction of the MLC position was based on a feature extraction technique that employs a Sobel kernel. The final position was then extracted from a linear fit to a contour that represents the mean point of the maximal intensity change in the image. The dose is extracted using a Monte-Carlo (MC) simulation of the linac head with 1 mm material upstream of the detector. The photon energy fluence was obtained by subtracting a Monte Carlo calculated charged particle signal. The fluence is converted to dose in the phantom using a pencil beam method. The results presented are for a small clinical IMRT beam.

The MLC position reconstruction was in excellent agreement with the film measurement, with the film error dominating the comparison. The resolution of the MLC reconstruction was $52 \pm 4 \mu\text{m}$ for a single frame. The dose measurement using the Achilles agreed well with the MatriXX, with a comparison using the gamma index giving a 97% pass rate for 3%/3mm, as shown in the figure.

These results demonstrate a working prototype upstream MAPS based dosimeter, which is able to extract both the dose and the MLC positions. The next stage is to push towards real-time application of these techniques for both IMRT and VMAT treatments.

Keywords: IMRT, MAPS, Real-time Beam Monitoring

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208

The ART of translation

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Translational research refers to the transfer of a new scientific concept from its basic preclinical stage to a successful clinical application. This process is bidirectional as clinical results should also be used to re-evaluate and improve their underlying experimental models. An inherent element of translational research is the use of patient material. This should, however, be interpreted widely and not be restricted to biological material. In fact, all information derived from patients - including digital and epidemiological data - is suitable for translational research. Acknowledging translational research as an essential tool to advance oncology, many research groups and funding organizations focus on this area.

NKI is a comprehensive cancer center combining hospital and research laboratories under one roof in a single independent organization with one board of Directors responsible for both clinic and research. The institute has a long tradition of integrating basic science and cancer care, and has developed several strategies to accommodate translational research since its foundation in 1913 [1]. NKI stimulates part-time research appointments of staff clinicians by "twinning" them to basic scientists on joint translational projects. A translational research fellowship program offers to young clinicians after completion of their specialty training, a 2-3 years fellowship in basic research labs to build-up their oncology careers. In addition, internal start-up funding is provided to generate preliminary data and support project proposals. Furthermore, all clinical trial proposals are screened for potential translational research elements. A Translational Research Board, consisting of staff MDs and PhDs with a track record in translational research, coordinates these activities.

Although many regard translational oncology as an interplay between fundamental biological and clinical research, this is certainly not a complete description. In radiation oncology, translational research includes many other areas of "basic" research, such as molecular biology, bioinformatics, imaging, software development, epidemiology and physics. The department of Radiation Oncology at NKI has structured its translational physics research activities in multidisciplinary groups to ensure an optimal two-way interaction between clinicians and physicists and to provide a discussion forum for linking relevant clinical questions to innovative solutions. The software development for image-guided CT-based position verification integrated with the linear accelerator represents an apposite example [2] and has been essential for Adaptive RadioTherapy, the latest piece in art of modern radiotherapy. Building on the practice-changing studies on the interaction between cisplatin and radiation in tumor and normal cells [3] and new insights in molecular effects of radiation [4], biology-driven translational research is facilitated at the departmental level by resident-PhD programs, combined clinical-research appointments and focused start-up funding.

Together, these elements form the "NKI model" of integrated basic and clinical research and provide a stimulating environment for translational radiotherapy.

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209

Clinical experience with adaptive radiotherapy for muscle invasive bladder cancer

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Purpose: Large changes in bladder shape and size during a course of radiotherapy (RT) make adaptive RT (ART) appealing in treatment of muscle invasive bladder cancer. We are running a two-center clinical trial of ART for bladder cancer where the primary aim of the trial is to reduce gastro-intestinal morbidity due to sparing of the bowel and the rectum. We here report on initial clinical experience and outcome of this trial.

Materials/methods: The present study reports preliminary results on the first nine bladder cancer patients included in the ART trial. All patients received 60 Gy in 30 fractions to the bladder; in four patients the pelvic lymph nodes received 48 Gy simultaneously. Patients were set-up by use of cone-beam CT (CBCT) guidance and treatment was delivered by volumetric modulated arc therapy (VMAT). In our ART strategy, the first five fractions were delivered using large non-adaptive margins - the bladder contours from the CBCTs acquired prior to the first four fractions were used to create a library of three plans corresponding to a small, medium and large size bladder. DVHs for organs at risk were calculated by summation of the selected plans calculated on the planning CT and compared to our previous standard non-adaptive RT plans involving population-based margins.

Results: The frequency of which the small and medium size plans were selected was equal, whereas the large size plan was used on less than 27% of the (total of 225) plan selection fractions. The median rectal volume receiving 50 Gy or more was 5% [0-41%], compared to 17% [0-62%] if the patients had been treated with standard, non-adaptive RT. For the bowel cavity, the median volume receiving more than 45 Gy was 269 cm³ [83-486 cm³], compared to 337 cm³ [126-553 cm³] if not treated with adaptation. No grade 3-4 gastro-intestinal morbidity was observed.

Conclusion: Daily adaptive plan selection in RT of bladder cancer results in a considerable normal tissue sparing, and is expected to reduce the risk of gastro-intestinal morbidity.

210

ENTERVISION WP4. Biological Dosimetric Phantom. Proof of Concept Preliminary results

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Development of clinical treatment protocols for radiation therapy is dependent on the availability of information on the biological efficacy of radiation doses. In order to gain robust data, multiple cell irradiation experiments must be performed at different dose points, using a range of cell lines. Therefore, it is important to be able to verify the biological effects of complex dose distributions in homeomorphic phantoms, alongside measurements of physical dose. One of the ENTERVISION projects focuses on the development of a biological dosimetric phantom. Firstly, the phantom and desired set-ups were evaluated then its suitability for radiobiology studies were assessed during a set of cell irradiations. Status: The phantom was irradiated mimicking the patients' pathway starting with the CT scan, followed by treatment planning and being irradiated. For the irradiation, a uniform dose distribution was delivered with a proton beam and the process was repeated using a carbon ion beam. The dose was measured from pinpoint ionisation chambers readings and the uniformity was assessed with radiochromic films. The experimental results were compared with the TPS and Monte

Carlo calculations. Using MC simulations it was also investigated how the simulation of a more detailed geometry would affect the obtained results. From the radiobiology studies the cell survival by analyzing its proliferation was studied. Results: The calculated mean deviation was below 2% for both beams used. This brings the result within the acceptance threshold as desired by CNAO QA procedures. Conclusion: The experimental results obtained showed good agreement with both TPS and Monte Carlo simulations. The next step will involve a full radiobiology study with different biological inputs.

Keywords: Ion beam therapy, radiobiology, dosimetry

211

Realistic on-the-fly dose calculation for low energy X-rays Intra-Operative Radiation Therapy

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Purpose: The aim of this work was to develop a new algorithm to compute dose from a mobile accelerator of low energy X-rays Intra-Operative Radiation Therapy (XIORT) (ex: INTRABEAM®, Carl Zeiss) in heterogeneous conditions, such as a patient 3D volume, within 2-3 seconds. XIORT needs accurate and fast dose calculation. In this work a hybrid Monte Carlo tool is developed which takes into account all the components of the XIORT X-rays up to 50 keV and predicts in a satisfactory way the dose delivered to the patient. The tool is being included in Radiance® from GMV [1], a powerful Treatment Planning System for IORT.

Materials and methods: A few analytical algorithms exist which only consider the primary x-ray beam [2]. A hybrid Monte Carlo code which takes into account the photoelectric and the Compton effects for X-rays up to 50 keV, was developed to compute dose in 3D-CT volumes. Full Monte Carlo simulations have been generated with penEasy to validate our tool in homogeneous and heterogeneous conditions [3]. For the spherical applicators (from 0.75 cm to 2.5 cm radius) and the needle, a genetic algorithm was employed to determine the energy spectra which reproduce the measured dose distribution in water. Once the energy spectrum is obtained, it is implemented in the hybrid Monte Carlo algorithm. The absorbed dose distributions were then simulated in water and heterogeneous media both with penEasy and the hybrid Monte Carlo algorithm for the spherical applicators and the needle.

Results: The energy spectra for all the spherical applicators and the needle are similar to energy spectra from other Monte Carlo studies and measurements [4]. Dose distributions computed by the fast hybrid Monte Carlo tool are in a good agreement with penEasy full simulations in water and heterogeneous media. The algorithm gives also a good prediction of the measured dose distribution in water, and comparison to measured data in heterogeneous phantoms is being carried out. Computation time is below 5 seconds in a single core of a modern PC.

Conclusions: The hybrid Monte Carlo algorithm is a fast and robust tool to compute dose distributions in a patient geometry. It is being implemented in the Intra-Operative Radiation Therapy Treatment Planning System Radiance® from GMV, and can be used for any XIORT system.

Keywords: Intraoperative radiotherapy, Monte Carlo simulations, dose calculation

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