V 1

Intercenter validation of a knowledge based model for automated planning of volumetric modulated arc therapy for prostate cancer: The experience of the German RapidPlan Consortium.

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Purpose: To evaluate the performance of a model-based optimisation process for volumetric modulated arc therapy in a multicentric cooperative group. The Varian RapidPlan (RP) knowledge based engine was tested for the planning of RapidArc treatments on prostate cancer patients. The study was conducted in the frame of the German RapidPlan Consortium (GRC).
Methods and materials: A set of 43 patients from one institute of the GRC was used to build and train a RP model, the PTV including the prostate region and the pelvic lymphnodes. The model was shared with all members of the GRC plus an external site from a different country. An in silico multicentric validation of the model was performed at planning level by comparing RP-based against reference plans optimized according to institutional procedures. A total of 60 patients from 7 institutes were used for this investigation.
Results: On average, the automated RP based plans resulted fully consistent with the manually optimised set with a modest tendency to improvement in the medium-to-high dose region. A site by site evaluation showed different patterns of performance of the model, with some organs at risk resulting better spared with the manual or with the automated approach. In all cases the RP data fulfilled the clinical acceptability requirements. Discrepancies in the performance were due either to different contouring protocols or to different emphasis put in the optimization of the manual cases.
Conclusions: The multicentric validation demonstrated that it was possible to satisfactorily optimize with the knowledge based model patients from all participating centres. Due to possibly significant differences in the contouring protocols, the automated plans, though clinically acceptable and fulfilling the optimization goals, might benefit from further fine tuning of the constraints. The study demonstrates the reliability of the concept of sharing models among different clinical institutes in a cooperative framework.

V 2

Evaluation of the consistency in a clinically implemented plan selection strategy for adaptive radiotherapy in cervix cancer

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Introduction: A plan-of-the-day (POTD) approach based on a library of multiple plans is a promising strategy for online adaptive radiotherapy (ART) in cervix cancer due to daily organ motion. The procedure includes the daily selection of the smallest PTV encompassing the target volume on CBCT images. However, image quality can be deteriorated by artifacts and soft tissue contrast on CBCT is limited. Additionally, inter- and intraobserver variations may exist. The purpose of this study was to evaluate the plan selection consistency of a POTD strategy in cervix patients.
Materials and methods: Nine cervix patients were treated with the POTD-ART approach. Radiation was delivered by VMAT with 45 Gy in 25 fractions followed by brachytherapy. A two stage POTD-ART approach, consisting of two treatment plans, was clinically implemented. One plan was created for an empty bladder and the other one for a full bladder anatomy. The plan library was completed by a motion robust backup plan that included all motion. A daily CBCT was acquired and the POTD was selected by a single observer. To investigate the reproducibility, the selection process was repeated by a group of three experts (oncologists and physicists) without knowledge of the delivered plan after end of treatment. The agreement between expert-group-selected plans and treated plans was determined.
Results: In total 222 adaptively delivered fractions were analyzed. The initial selection consistency between delivered and retrospective plan selection was 84%. However, in 34 fractions empty and full plans were giving sufficient target coverage and the decision was just based on priorities in organ sparing. By considering these fractions, the agreement on adequate treatment selection increased to 93%.
Discussion: This study evaluates the adaption consistency of a POTD-ART strategy for cervix cancer that is based on a library of three VMAT plans. The plan selection agreement is considered high.

V 3

Detection of changes in the patient anatomy using the integrated detector array of a tomotherapy system

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The assumption of a constant patient anatomy throughout the course of a radiation therapy treatment is fundamental for the process of treatment planning. If the anatomy is changing an adaption of the treatment plan might be necessary. Presently adaptive radiation therapy is still time consuming and is not applied to every patient by default.
For the later simulation of anatomical changes a cylindrical phantom, partially covered with 2cm flab material, three treatment plans (Head-and-Neck-like, central and superficial PTV) were generated. All treatment plans were delivered 5 times with varying flab thicknesses from 1cm to 3cm. The data of the CT-detector-array acquired during these treatments was analyzed with the delivery analysis software using the 2cm-flab situation as reference. The calculated parameters were the mean signal on the detector, a gamma analysis and a direct difference comparison of the detector sinograms. Additionally the MVCT scans acquired before each treatment were used to calculate the dosimetric effect of the changes in the anatomy.
The measured mean signal on the detector changed significantly with the thickness of the flab. The gamma analysis and the difference comparison clearly identified the changed anatomical situations, depending on the chosen parameters (distance to agreement, signal difference). The MVCT based calculated dosimetric changes for the Head-and-Neck-like and the central PTV were +/- 2% for the median dose, maximum dose and the dose covering 95% of the PTV. The superficial PTV showed a more extreme behavior because the anatomical changes were in the PTV itself, or in the immediate proximity.
In this phantom study the detector signals recorded during plan delivery were used to detect ‘anatomical’ changes. Furthermore the evaluated parameters correlated with the calculated dosimetric effects. For the transfer to real patient cases more scenarios, including patient positioning, need to be investigated.

V 4

Photon fluence reconstruction for online dose verification

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To verify the dose delivered during an external photon radiation treatment it is necessary to calculate the initial photon fluence applied by a linear accelerator in front of the patient. In this work a calculation algorithm was develop to reconstruct the photon fluence from EPID images acquired during the treatment.
A dose calibration of the EPID image was performed to determine the absorbed dose in the EPID. The EPID images were corrected for scatter from patient and EPID by an iterative deconvolution using Monte Carlo calculated point spread functions (PSF) to determine the dose deposition Di by initial unscattered photons inside the EPID. The initial photon fluence was calculated based on the patient geometry from CT data and the deconvoluted dose Di.
To verify the algorithm RW3 phantoms with a thickness between 3 cm and 15 cm were irradiated by 6 MV photon fields of different field sizes and the resulting EPID images were evaluated with our algorithm.
The deviation between the reconstructed relative photon fluence for the phantoms and the flood field image was below 2.3% for field sizes of 5x5 cm² and 10x10 cm². For larger treatment fields of 20x20 cm² the deviation was below 4%.
In the clinical experiments the algorithm accomplished acceptable accuracy. In further studies the algorithm has to be optimized, eg. reconstruction parameters have to be adapted to the investigated clinical linear accelerator. Moreover, dose calculations using the reconstructed fluence as a particle source will be compered to dose measurements.

V 6

A tissue-equivalent test environment for malfunctions of active medical implants and electronic devices due to radiation

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Introduction and Aim: The demographic change has caused an increase in age-related diseases that need a active implants, e.g. pacemakers, defibrillators for therapy. Furthermore, the number of patients with tumors treated in radiation therapy also increased. The implanted medical device (iMD) is often in close proximity to the target volume (PTV) and its functionality can be temporarily or permanently disturbed radiation.
Material and Methods: For the standardized investigation of malfunctions, a body phantom with tissue-like materials was developed for broad energy range (70keV-15MeV). In the phantom, organ structures such as heart, ribs, spine and lung were made of materials which are equivalent to tissue regarding the interaction with radiation. A CT data set of the phantom was used for treatment planning (Pinnacle, Philips Medical Systems). Thus, dose caused by scatter at the iMD can be simulated. In addition to iMDs, electronic components can be inserted into the phantom and tested for malfunctions. Flash memory modules and lithium batteries were treated with 6MV by 3Gy. The verification of the planned dose was done with a 0.125cc dose chamber (Semiflex, PTW).
Results and Conclusion: Various materials were tested and evaluated for their tissue-equivalency. The materials (soft tissue: 10±2HU, lung: -903±13HU, heart: 25±3HU, bone: 832±16HU at 130keV) were validated by a CT scan and a Monte-Carlo simulations using pyPENELOPE. About 40% of the tested flash memory modules and 50% of the batteries showed an irreversible, atypical functional behavior. Errors were different reading speed or increased discharge duration. A valid test environment was developed, to test iMD and electronic assemblies. In the further course of the project*, different electronic components, iMD's and treatment options are investigated.
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