set plan quality on high-quality output of the KBP software. The validated HN model will be available for use in an upcoming clinical release of the KBP software.

PO-0886

Three phase adaptive 18F-FDG-PET-voxel intensity-based VMAT versus 6-beam IMRT for head-and-neck cancer

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Purpose/Objective: In this study we investigated the implementation of a new class-solution of volumetric modulated arc therapy (VMAT) for a three-phase adaptive ^{18}F-FDG-PET-voxel-based dose-painting-by-numbers (DPBN) dose-escalation treatment. VMAT dose distributions were compared to the ones made using a standard 6-beam static intensity modulated radiotherapy (sIMRT) technique.

Materials and Methods: 10 non-metastatic head-and neck cancer patients, enrolled in the adaptive arm of a phase II DPBN trial were planned both with sIMRT and VMAT. Separate treatment plans based on two pre and per-treatment (after the 8th fraction) ^{18}F-FDG-PET/CTs and one per-treatment CT (after the 18th fraction) were made according to the trial protocol (Table 1). Dose distributions were summed on the pretreatment CT. Plans were evaluated in terms of dose levels, dose painting quality factors (QFs), treatment time and verified with Delta^4 (Scandidos, Uppsala, Sweden) measurements.

Table 1. Prescribed fraction dose for the three phase adaptive treatment protocol. The treatment plans for the first 2 phases were based on the ^{18}F-FDG-PET/CT information, while for the third phase only CT data was used.

Abbreviations: GTV = gross tumor volume; PTV_{HR} = high-risk planning target volume (3 mm expansion of the high-risk clinical target volume - CTV_{HR}); CTV_{HR} = a three-dimensional GTV expansion of 1 cm adjusted to air cavities and uninvolved bones.

	Phase I	Phase II	Phase III
GTV (dose painting range)	2.2 – 3.1 Gy	2.2 – 3.1 Gy	
PTV_{HR}	2.0 Gy	2.0 Gy	2.2 Gy

Results: VMAT plans allowed the same level of dose escalation in the targets, while significantly reducing the dose to organs-at-risk (OARs). On average, the percentage of the ipsilateral parotid volume receiving at least 27 Gy was reduced from 44.0% to 38.8% and its median dose from 22.8 to 19.5 Gy (p<0.05). Gross tumor volume QFs were significantly improved with VMAT. In 17 out of 20 phase I and phase II treatment plans, VMAT QF was better (maximum improvement 2.1%), while for the rest it was similar to sIMRT. Planning time of both techniques was similar and arc treatment delivery was 2 to 3 times faster. The Delta 4 measurements were in very good agreement with the dose calculation for both types of plans.

Conclusions: Biologically-guided volumetric modulated arc therapy is able to increase the sparing of OARs compared to sIMRT without compromising target doses or treatment delivery quality. Thus, it becomes a valuable technique for an adaptive treatment strategy, which follows the anatomical patient changes through the treatment time. The significantly faster VMAT delivery reduces the risk on intra-fraction movement.

PO-0887

Fast and realistic Monte Carlo evaluation of the robustness of proton therapy plans

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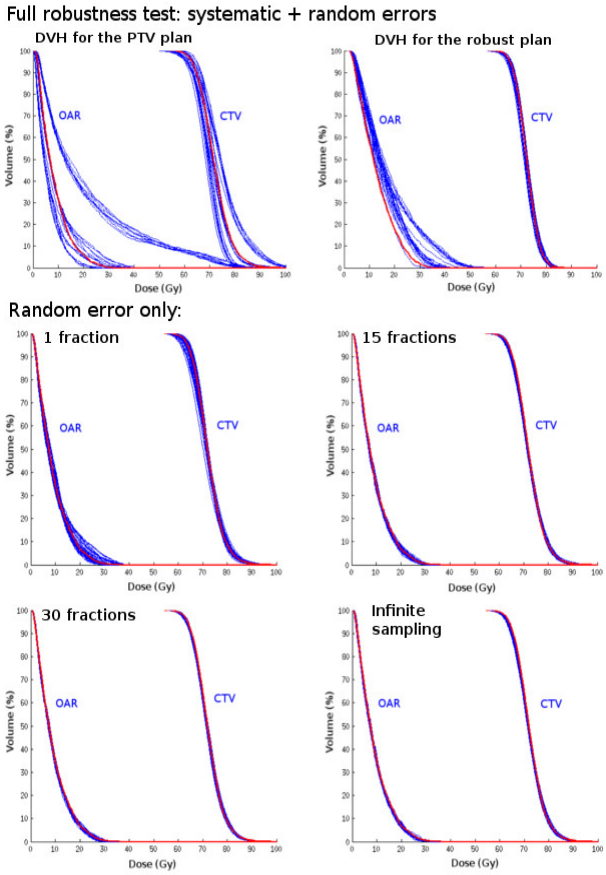
Purpose/Objective: Proton range uncertainties jeopardize the theoretical advantage of intensity modulated proton therapy over photon-based modalities. Depending on the heterogeneity level, this range uncertainty can grow up to 4.6% of the nominal range + 1.2mm with typical analytical dose calculation methods (Paganetti 2012, PMB). The robustness of treatment plans can be further evaluated by simulating possible realizations of uncertainties with systematic and random components. Such a strategy may be a daunting task for analytical algorithms because computation time scales linearly with the number of scenarios simulated, which increases strongly if random errors are considered. Monte Carlo (MC) simulations offer here a double advantage: 1) they reduce the range uncertainty down to 2.4% + 1.2 mm; 2) they potentially allow simulating random errors with no significant increase in computation time. This study employs a fast MC tool, which can compute the impact of random errors in a single simulation.

Materials and Methods: MCsquare, the new software created for this study, implements optimized algorithms on the Xeon Phi coprocessor to accelerate MC computations. MCsquare can compute a dose distribution in less than one minute. Multiple uncertainty scenarios are created. A 2.5 mm systematic setup error is modeled by shifting the CT image in all 6 directions of space. Random setup errors are modeled by a 1 mm random shift for each particle simulated by the MC engine. The uncertainty in the conversion from Hounsfield units to stopping powers is taken into account by applying a +/- 3% uniform bias to the patient densities. The experiment involves a water phantom, considering both a traditional plan with a PTV (2.5mm isotropic margin) and a robust plan (3% density uncertainty, 2.5 mm systematic setup errors). The CTV surrounds a circular organ-at-risk. The random error model employed in this study considers a large number of sampling, meaning an infinite number of fractions. The second experiment aims at determining the minimal number of fractions required to ensure the validity of this approximation. For this purpose, various sequences of fractions are generated, with different random errors.

Results: The robustness of the treatment plan is easily verified by looking at the deviations of the DVH curve with respect to the nominal plan (red curve). The robust plan shows small deviations compared to the traditional PTV plan. Considering only random errors, the DVH distributions no longer vary for treatment with more than 30 fractions. This result validates the assumption of the infinite random sampling for our robustness test for typical fractionation strategies.



Conclusions: Fast and accurate MC tools allow range uncertainties to be reduced and random errors to be integrated efficiently into robustness evaluation. In proton therapy, robust optimization is preferred to traditional PTV margins, which do not suffice to ensure homogeneous coverage of the CTV in case of uncertainties.

PO-0888 Evaluation of 6 proton dose calculation algorithms using a critical experimental phantom

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Purpose/Objective: Pencil Beam Scanning (PBS) delivery enables intensity modulation and has showed a promising potential to improve radiotherapy treatments. However, the dose distributions are very sensitive to range uncertainties. In highly heterogeneous anatomies, range uncertainties can be significantly reduced using Monte Carlo (MC) simulations for dose calculation. Nevertheless, MC is usually too time consuming for clinical practice and it is common to use dose engines based on faster but less accurate analytical models. Lateral inhomogeneities may have a strong influence on the dose distributions depending on how accurate the modeling of proton multiple scattering is. Here, we devised an experimental design in order to maximize this effect and study the behavior of six different dose calculation codes.

Materials and Methods: The inhomogeneous phantom is composed of a water phantom with a 1x10x10cm^3 sliver of bone equivalent material (Gammex SB3) inserted at the center of the phantom. PMMA plates are placed downstream the water-bone box. The beam direction is parallel to the bone sliver. The nominal proton range is 18 g.cm^{-2} and the composite field size is 10x10 cm^2 (fig 1 left). Data are acquired at different depths with a 2D ion chamber array (MatriXX, IBA) for a universal nozzle (MGH, Boston) in PBS mode. Absolute dose measurement is compared to Astroid (by .decimal). Taking advantage of the homogeneous dose region around the bone slab, relative comparisons with five other simulations are performed using: Gate (Geant4 9.5), 4P (Penelope for protons), MCSQUARE, the pencil beam algorithm (PBA) and the future MC (non-clinical) of the RayStation (Raysearch Lab.). Beam models used are close to the MGH beam model.

Results: Simulations are compared to data at 129 mm depth and averaged over 3mm in the y-direction to take into account the spatial resolution of an ion chamber (MattriX). Symmetric 1D Gamma evaluations (Yepes, PMB 2014) are performed to measure differences. MC codes have higher local g-index passing rates than the analytical computation algorithms. 4P shows the best agreement with data regarding gamma indexes. Astroid and Raystation-PBA have g-index passing rates lower than 50%. MCSQUARE and Raystation-MC are within 82.73% and 77.81% for the 5%/3mm criteria. Those codes offer computation times competitive in clinical routine.