Proton radiography to calibrate relative proton stopping power from X-ray CT in proton radiotherapy

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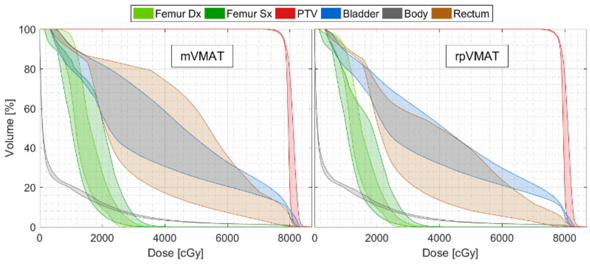
inter-operator variability thus providing a better standard of quality.

Material and Methods

Using Varian RapidPlan two models were created for oropharynx and prostate VMAT treatments with respectively 73 and 90 previously treated patients. Five oropharynx and six prostate test patients, not included in the training database, were anonymized and randomized. Four operators, with different planning expertise, were asked to manually obtain a clinical VMAT plan (mVMAT) for each test patient. Subsequently, each operator replied the planning procedure assisted by RapidPlan DVH predictions obtaining a second VMAT plan (rpVMAT). The potential of RapidPlan to reduce the inter-operator variability was evaluated comparing rpVMAT with mVMAT plans in terms of OAR sparing, target coverage and conformity.

Results

In the case of prostate treatments mVMAT and rpVMAT plans resulted in similar target coverage while a net reduction in OAR sparing variability was seen for rpVMAT plans (a visual example is given in Figure). For the case in figure, rectum V40Gy resulted 34.4±18.1% for mVMAT and 32.1±7.6% for rpVMAT. In general, a 40% reduction in inter-planner OAR sparing variability has been registered when planning was assisted by RapidPlan predictions.



For oropharynx treatments RapidPlan-assisted planning leads to more homogeneous target dose distributions, especially for the low-dose target. The low-dose PTV standard deviation obtained in rpVMAT plans was 2.6±0.6% while it resulted 3.2±1.5% for mVMAT ones. A variability reduction of the order of 10% was also seen in parotids, oral cavity and larynx sparing. For the less experienced planner RapidPlan assistance also induced an overall decrease of OAR mean doses by approximately 15%. Using RapidPlan assistance the overall inter-planner variability is reduced in every single patient and a general improvement of plans statistics is achieved.

Conclusion

The use of RapidPlan predictions in VMAT planning driven a homogenization of the planning outcome both in prostate and oropharynx treatment for a group of 4 planners. OAR sparing variability can be reduced as much as 40% maintaining similar target coverage when RapidPlan is employed. This study provide a quantitative measure of the RapidPlan potential as an instrument to improve plan quality.

This findings states that the use of a knowledge based planning system allow for safer treatments.

EP-1523 Proton radiography to calibrate relative proton stopping power from X-ray CT in proton radiotherapy

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Purpose or Objective

To decrease the uncertainty of the relative proton stopping power (RPSP) determination and optimize the clinical calibration curve for individual patients in proton radiotherapy treatment, by using an alternative novel proton radiography imaging modality.

Material and Methods

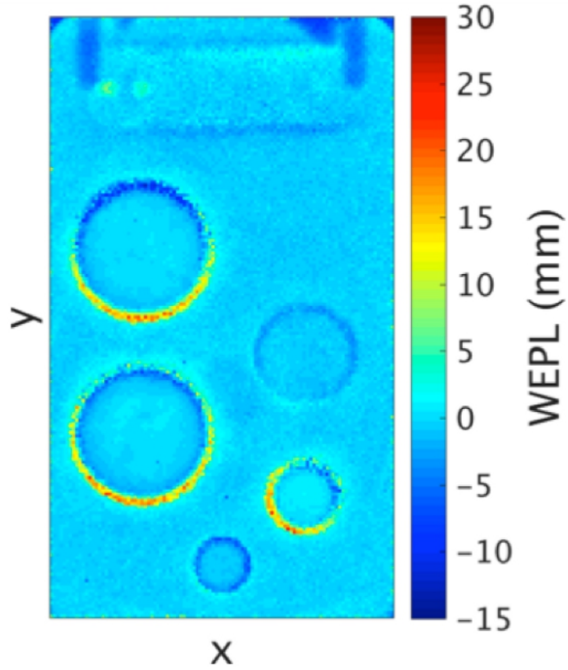
The optimization of a ‘patient-specific’ clinical calibration curve for proton stopping power has been performed on a complex phantom (made in-house) with dimensions of 5.4x9.4x6.0 cm^3, built of polymethyl methacrylate (PMMA) and filled with 6 inserts of different diameters and contents. It comprises 11 materials (including 5 tissue surrogates) of known composition and density. A CT scan (with SOMATOM Definition AS scanner) of the phantom was done at 120 kV X-ray tube voltage. The image reconstruction was executed with the I40 reconstruction kernel and a slice thickness of 0.6 mm. The Field-Of-View was chosen to be 250 mm, at which (for an image size of 512x512 pixels) a spatial resolution was equal to 0.488 mm/pixel. An initial 9-segments calibration curve of RPSP vs. CT number was constructed based on Schneider method and used to obtain a Water Equivalent Path Length (WEPL) map of the phantom, $WEPL_{DRR}$.

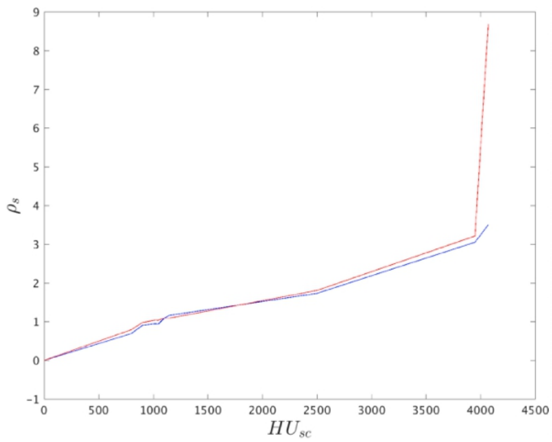
A proton energy loss radiograph of the same phantom was obtained from Geant4 Monte Carlo simulations, in which a novel proton radiography imaging system was implemented. Protons with a large scattering angle due to Multiple Coulomb scattering, causing blurring of the radiography image, were discarded. Thus, only protons traveling along almost straight lines, with scattering angles less than 5.2 mrad, were used to build the radiography image. A WEPL map of the phantom from the proton radiography simulations, $WEPL_{pRG}$, was obtained.

The difference between the two maps of $WEPL_{DRR}$ and $WEPL_{pRG}$ was evaluated by means of RMSE and x^2 statistic. The x^2 statistic was used to iteratively modify the segments of the calibration curve. **Results**

A small difference between $WEPL_{DRR}$ and $WEPL_{pRG}$ at the borders of some inserts of the phantom are observed, which are caused by imperfect alignment of the phantom in the CT scanner (figure 1).

Using the iterative optimization on WEPLs, both measures RMSE and x^2 statistic decreased significantly. A decrease by 34.33% and 55.01% in RMSE and x^2 statistic, respectively, is observed. After discarding PMMA material from the phantom materials, which is not among materials used to construct the clinical calibration curve, a further decrease in RMSE and x^2 by 48.34% and 73.18%, respectively, is obtained. The x^2 statistic was used to acquire an iteratively optimized calibration curve, and a new $WEPL_{DRR}$. A more homogeneous distribution of the difference between $WEPL_{DRR}$ and $WEPL_{pRG}$ maps is observed for both cases, with and without PMMA material considered.





Conclusion
The iterative optimization of the ‘patient-specific’ CT calibration curve has been performed with the use of the alternative proton radiography imaging technique. An improvement in distribution of the WEPL differences obtained in the two imaging techniques is observed. Further development based on real patient data will be done.

EP-1524 Automated treatment planning for breast and locoregional lymph nodes using Hybrid RapidArc

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Purpose or Objective
Breast cancer accounts for a substantial proportion of the workload in many radiotherapy departments. Treatment planning, especially for breast and locoregional lymph nodes (LLNs) can be complex and time-consuming. Automated planning techniques can improve planning efficiency and consistency. Automated planning of tangential field breast-only irradiations has been previously described. We developed a script using the Eclipse API to automatically plan a more complex hybrid RapidArc (hRA) technique for breast plus LLNs that includes the integration of RapidPlan (RP) into the workflow.

Material and Methods
The script uses the clinician delineated breast planning target volume (PTV_b) and LLN PTV (PTV_{LLN}) as input to automate field setup (Figure).
The hRA technique consists of two combined plans:

1. Two tangential fields (TFs) with a 2cm cranial slip-zone that deliver 85% of the prescribed dose (PD) to 95% of PTV_b. Optimal gantry angles and field settings of the TFs are automatically determined by minimizing the organ-at-risk (OAR) surfaces in the beam’s eye view. Optimal beam energy is based on PTV dose homogeneity, and field weightings are based on symmetry of dose distribution.
2. Three 80° RA arcs deliver the remaining dose to the PTV_b and slip-zone, and the full PD to the PTV_{LLN}, while sparing tissue outside the PTV. RA fields are positioned automatically using standard gantry angles. Optimization objectives for the relevant OARs (ipsilateral (IL) and contralateral (CL) lung, heart, CL breast, esophagus, thyroid, spinal canal) are automatically placed using dose predictions generated by RP. RA optimization is currently started manually as the scripting API does not yet allow for the inclusion of a previously calculated dose, but interaction during optimization is not required.

Results
Treatment plans were generated by the script in ~40 minutes (of which 2 minutes were user interaction), while the estimated corresponding manual time was 100-200 minutes. The automated workflow was capable of generating a plan for all patients. However, a number of improvements to the scripting environment have been suggested to the vendor. The dosimetric data was averaged over all 5 patients and was generally comparable between the automated and manual plans (Table), although for individual patients it was evident that the RP model requires further refinements to reduce some OAR doses.