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Technical Set-Up of a Fully IntegratedPET/MR system for Radiotherapy Applications

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Abstract

Multimodality imaging has become an important adjunct of state-of-the-art radiation therapy (RT) treatment planning. Simultaneous PET/MR hybrid imaging has become clinically available and may also contribute to target volume delineation and biological individualization in RT planning. For integration of PET/MR hybrid imaging into RT treatment planning, compatible dedicated RT devices are required for accurate patient positioning and immobilization.

In this work hardware and software tools needed to set-up afully-integrated PET/MR system for RT applications have been evaluated and implemented. A home prototype flat RT table-top (FTT) and a radiofrequency (RF) coil holder (CH) were developed and tested towards PET/MR system integration. Attenuation correction (AC) of all individual developed RTcomponents and a flexible coil (C) was performed by generating CT-based template models to compensate for their presence in the scanner field of view. All RTdevices were evaluated in phantom experiments with regards to MR image quality, PET attenuation correction and PET quantification. In particular the activity accuracy in PET imaging was evaluated with and without the developed ACs.

The photon attenuation of the full setup with all RT components (FTT, CH, C) was calculated to be 13% on average. Applying the CT-based AC for all RT devices an activity difference of 2.5% has resulted with respect to the reference scan with the only phantom on PET/MR couch. The SNR of the MR images was reduced

by 8% using the table-top, coil holder and RF coil.

In addition Deep-Learning (DL) techniques have been implemented to generate synthetic CT (sCT) based on MR images in viewof a PET/MR-only based treatment planning in RT. In this work a Convolutional Neural Network (CNN) based on a U-Net model has been used.

The patient database used for network training includedT2-weightedMR and CT images of 19 patients in treatment position from three different sites. Images were taken from the public dataset Gold Atlas project. The Mean Absolute Errors (MAE) for each patient were evaluated between real and synthetic CTs. The average MAE in HU was 39.37 ± 8.17 HU. A RTplan was simulated and optimized for three study patients (randomly selected from the DB) using the original CT and then copied on sCT to assess the dose distribution in terms of Dose Volume Histograms (DVH) analysis. The mean absolute difference between the dose distributions calculated on sCT and a reference CT was measured in the RT target volume and organs at risk for each of the three patients.

The dose plans showed excellent agreement for all Dose Volume Histogram (DVH) metrics with a mean absolute difference below 0.5% both for the Planning Target Volume (PTV) and for the organs at risks (OARs) considered (0.5%). This demonstrates a high dosimetric accuracy for the generated sCT images.

The results obtained in this study suggest that multiparametric PET/MR can be successfully integratedas a one-stop-shopin the RT workflow from a technical point of view, nevertheless further improvements canbe achievedbothfor AC corrections and for sCT generation. However, clinical studies are still needed to confirm its role and feasibility in the RT workflow.