selected to further investigate the geometric distortion under large DSV. Its marker deviation distribution is plotted in Fig. c. Although more large error markers appeared in large DSV, the majority of the markers (68%) stayed within 2mm error. In Fig. d, 3D geometric distortion of coronal acquisition was also visualized by deforming a 3D cubic grid (isotropic interval of 75mm) according to marker deviations.

Conclusions: We rigorously assessed 3D geometric distortion of a wide bore MR-sim scanner using a large customized phantom. The results of low average marker deviations indicated that geometry fidelity of this MR-sim has potential to brain applications (DSV<250mm) but yet to be further improved for large-FOV body studies. Further in vivo studies are warranted to investigate the influence of tissue susceptibility and chemical shift on MR image distortion.

PO-0976
Patch-based generation of a pseudo-CT scan for MRI-only based radiotherapy in the pelvic region
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Purpose/Objective: In RT based on MR as the only modality, the information on electron density which is usually contained in the CT must be derived from the MR. This is a challenging task, since no unique relationship between MR and electron density exists. Models used to predict a so-called pseudo CT (pCT) with pre-acquired and correlated MR/CT scans is a promising solution, and has been applied and validated in numerous forms for brain pCT generation. Few attempts, however, have been made to create pCTs of other body parts such as the pelvis. Though the prediction task is fundamentally the same as for brain scans, the pelvic region contains additional challenges. The greater spatial extent means that pelvic MR scans are potentially more affected by geometrical distortions, especially in regions far from the isocenter. Furthermore, the bones and bowels in the pelvic region have a greater heterogeneity than tissue in the skull, which must be accounted for in the pCT. In this pilot study, we apply a patch-based method (PBM) for a fully automatic pCT prediction based on T2-weighted (T2w) turbo spin-echo MR scans of the pelvis.

Materials and Methods: Scans of the pelvis of 10 male RT patients were acquired on a Philips Big Bore CT and a 1 T open MR scanner with a body coil. The T2w scans were acquired with a voxel resolution of 0.5x0.5x4 mm for a matrix of 896x896x35 voxels. The CT scans were acquired with a voxel resolution of 0.8x0.8x2 mm for a matrix of 512x512x259 voxels. The CTs were cropped, resliced and rigidly registered to the T2w scans to ensure spatial correspondence between voxels. The PBM consisted of extracting 9x9x3 voxel patches from the MR scan of the test patient, and for each such patch finding the 8 most similar patches in a database of MR patches with corresponding CT patches. A similarity-weighted average of these database CT patches was then assigned to the voxels of the test patch. For each test patient, a database subset consisting of 5 patients’ MR and CT patches were created. We found the most similar patches within a 2x2x5 voxel volume around each patch. For comparison, we created pCTs by bulk density assignment of all MR voxels within the body outline to 0 HU (MRiw) and by transferring the bone volume from the real CT to the MRiw pCT (MRiw+b). For each pCT, we evaluated the HU deviation from the real CT by the mean absolute error (MAE) and the Dice score of the bone volumes (HU>200).

Results: In Table 1, the patient average MAE indicates that the PBM produces more accurate pCTs than both MRiw and MRiw+b. In the lower graph of the figure, the results using the PBM show a reduction in the patient average MAE for most HU values compared to the MRiw. Still, the PBM has problems predicting cortical bone as revealed by the MAE at HU>1200 and by the Dice score.

Conclusions: In this study, we showed that a pCT of the pelvis could be generated from T2w MR scans using a PBM with greater accuracy than bulk density assignment. Improving cortical bone predictions, investigating geometric distortion, and performing a dosimetric evaluation are parts of our future work.
ATLAAS: A model for optimal auto-segmentation of PET images in RT planning
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Purpose/Objective: Positron Emission Tomography auto-segmentation (PET-AS) methods can provide reliable and reproducible segmentations of the Gross Tumour Volume for radiotherapy planning. However, a large variety of PET-AS methods have been validated on different datasets, making it difficult to recommend a single algorithm. We present a Predictive Model for optimal auto-segmentation of PET images based on machine learning technology. The ATLAAS package (Automatic decision Tree Learning Algorithm for Advanced Segmentation) can select and apply the best PET-AS algorithm from a pool of methods on which it has been trained.

Materials and Methods: For each PET-AS included in the model, ATLAAS predicts its accuracy in segmenting a given target lesion. This is based on the analysis of several image parameters describing the lesion. The prediction is done using a set of rules (decision tree) derived by training ATLAAS on a large number of synthetic images representing realistic data generated using a fast PET Simulator. The accuracy of the PET-AS is quantified with the Dice Similarity Coefficient (DSC), using the known ground truth extracted from the synthetic lesion. A total of 25 PET-AS algorithms are currently implemented in ATLAAS. These include adaptive thresholding, region-growing, gradient-based and clustering methods. ATLAAS was optimized for H&N and was built using more than 1000 images. The validation of ATLAAS was carried out on 115 PET scans acquired using fillable spherical and more than 1000 images. The validation of ATLAAS was carried out on 115 PET scans acquired using fillable spherical and non-spherical inserts and printed subresolution sandwich phantoms. Both homogeneous and heterogeneous uptakes were modeled. The segmentation of 10 H&N patients with ATLAAS was also compared to manual delineation carried out on PET/CT data.

Results: Nine image parameters were used in the ATLAAS predictive model, including the lesion volume, peak intensity, peak-to-background ratio, coefficient of variation, regional Haralick texture features and geometrical complexity indices. The mean accuracy of the decision tree method was 0.82 DSC for the phantom dataset, with a range of 0.36-0.96. In 80% of the cases, our method selected an algorithm providing a DSC within 5% of the best DSC across algorithms. The average DSC comparing the results of ATLAAS to manual PET/CT segmentation was 0.70, ranging between 0.65 and 0.92. Differences were mainly due to absence of CT component in ATLAAS.

Conclusions: We have developed a method that identified the most accurate auto-segmentation algorithm for FDG PET images. The accuracy and robustness of ATLAAS has been shown on a large range of synthetic and experimental data. ATLAAS is a useful tool for optimal segmentation of PET images used for RT planning and can be further optimized to include different anatomical regions and tracers. Patent pending.

Testing the C-RAD Catalyst elastic image registration software using a deformable female phantom
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Purpose/Objective: C-RAD Catalyst is a recently introduced system that uses a patient’s optical maps to check positioning and to manage intra-fraction motion. One of its key feature is the possibility to perform elastic registration. Since the patient’s external surface can easily be deformed during the course of treatment, a deformable registration algorithm could potentially provide a more accurate target volume registration than a global rigid approach.

In this study, we propose a quantitative validation of the deformable image registration algorithm implemented in Catalyst. The validation has been performed using Portal Images (PI), and a deformable female phantom, ‘Sliced Mary’, designed and developed expressly for this project.

Materials and Methods: Phantom: ‘Sliced Mary’ is a deformable phantom, containing anatomical structures and hidden targets, designed for both optical and x-ray imaging (Figure). The phantom was made of 30 slices held together by a rope running inside the phantom. Arms were also constructed and fixed to the phantom torso. The sliced phantom was finally covered with a white tissue. Independent and realistic head rotation, arms flexion as well as body torsion around a longitudinal axis and bending around lateral and vertical axes can be achieved.

Tests: A CT acquisition of ‘Sliced Mary’ was performed and, for each target, AP and LL DRRs were created and sent to iViewGT (Elekta PI system). The external phantom surface and RT plans, one for each target, were sent to Catalyst. The phantom was put on the linac couch with the isocentre positioned on the target that simulates a breast lesion, and 5 head and left arm displacements were applied. PI and Catalyst acquisitions were performed and the registration results were compared.

Bending of Sliced Mary's body around lateral and vertical axes were then applied. The linac isocentre was positioned on each target, and PI and Catalyst registration results were compared. When elastic deformations occur, the iViewGT global rigid registration algorithm can provide registration parameters valid only for a part and not for the entire image. Privileging the target registration instead of the surrounding anatomical structures, it is possible to obtain a local rigid transformation that should enable the best target set-up.