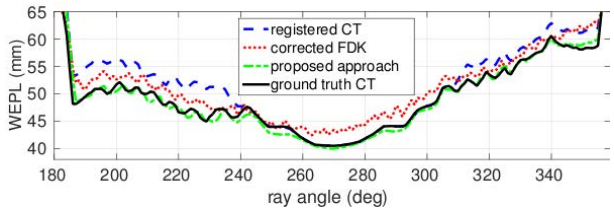
Material and Methods: The proposed framework involves estimating the scatter kernel as a low frequency difference between the CBCT measurements and synthetic projections of the planning CT. After correcting for the scatter contribution the CT is exploited once again as a regularisation in an iterative reconstruction, which promotes an image with a sparse difference image gradient, through minimising the total variation (TV) of this difference.To illustrate the technique's performance, we calculated the proton water equivalent path length (WEPL) through reconstructions of a Phantom Lab SK200 chest phantom. To simulate the planning CT, we manually deformed the original CT image to induce anatomical changes.

Results: The figure below demonstrates the reduction in WEPL error of our proposed approach over other techniques.The calculation was taken through to the centre of each reconstructed volume for 180 equispaced angles, against the non-distorted CT, by using a fixed lookup table to convert from Hounsfield units to proton stopping power.



Conclusion: The technique allows accurate CBCT imaging, which may facilitate its usage in adaptive radiotherapy. Although there still remain a number of improvements in robustness before this could be considered as a clinical framework, these illustrative results are encouraging.

EP-1840

Motion artifacts in 4DCT: frequency and correlation with breathing pattern

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Purpose or Objective: Four dimensional computed tomography (4DCT) is a consolidated simulation technique for lung tumor radiotherapy treatment. Several works report about a relevant incidence of motion artifacts in 4DCT acquisition [1,2,3,4]. In this work we retrospectively analyze 4DCT scans performed in free breathing for 29 lung tumor patient. Our analysis was focused on diaphragm, were artifacts are more frequent and evident [1]. The aim of this work is to evaluate: frequency of motion artifacts in our patient group, critical breathing phases for artifacts and correlation between breathing pattern shape and artifacts incidence.

Material and Methods: 4DCTs have been acquired in free breathing on a Discovery 690 CT-PET (GE) scanner equipped with RPM (Real-time Positioning Management) system. Scan is performed in cine mode with different couch position and ten equally spaced sets of CT images are retrospectively created using phase based sorting in Advantage 4D application. A trained operator visually checked each single phase for all the patient to individuate presence of diaphragm artifacts. A comprehensive description of different aspects of artifacts is given in [1]. We analyze and report here the percentage of patient affected by artifacts in at least one phase and the relative incidence of artifacts for each phase in our patient group. Furthermore we search a relation between breathing pattern and the frequency of artifacts.

Results: At least one phase with artifacts is present in 96% of the patients. The average number of phases with artifacts for patient is 4,1 ± 2,4 (one standard deviation). In fig. 1 we show the frequency of artifacts for each phase calculated as the ratio between number of patient with artifacts in the α phase and total number of patient. Finally, we find a linear correlation between the module of derivative of breathing pattern averaged over all patient and artifact relative incidence.

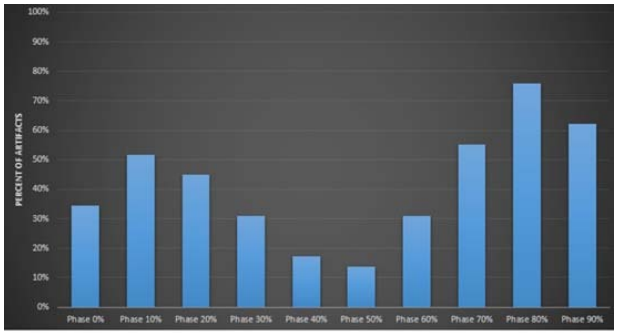

Fig.1

Conclusion: In fig. 1 we can identify two local minimum corresponding to phases 0% and 50%, respectively the end inhale and the end exhale phase of respiration. Local maximum is present around mid inhale and mid exhale (phases 10% and 80%) i. e. when motion of breathing surrogate marker in faster. We find a linear correlation between average of module of derivative of breathing pattern and artifacts incidence. We can argue that the movement speed of patient thorax or abdomen, that is where RPM marker is positioned, seems to play a relevant role in terms of artifacts incidence. Currently 4DCT scan with cine mode and RPM system suffer of a very high incidence of motion artifacts in a critical area like diaphragm given that, in our study, 96% of the patient have this problem.

Bibliography

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EP-1841

Dose comparison study for CT and MR-only prostate IMRT treatment planning

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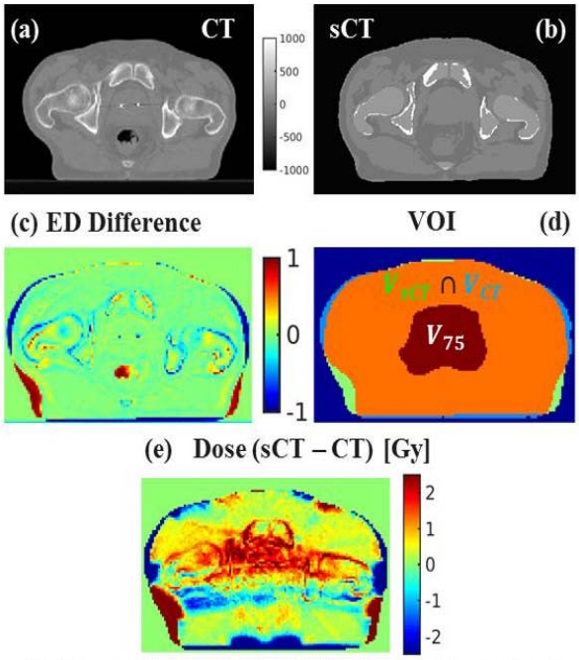
Purpose or Objective: In MR-only RT the planning CT is replaced by MR-based synthetic-CT (sCT). Dose validation is necessary in order to justify the use of sCT for RTTP in terms of accuracy and efficacy. One way to perform such a study is to recalculate the CT-plan on the sCT in order to assess the quality/consistency of the images for accurate dose planning. The feasibility of dose calculation on sCT obtained with model-based segmentation of Dixon MR images has been previously demonstrated [Schadewaldt et al., Med. Phys. 41, 188 (2014)] on VMAT plans. This study aims at evaluation of 5 beams IMRT prostate plans calculated on sCT vs CT using a Monte Carlo based TPS.

Material and Methods: Twelve prostate patients underwent CT **(a)** as well as MRI on the same day within 1-2 hours for RT treatment planning. A 3D multi echo sequence with Dixon reconstruction and high bandwidth, to assure geometric fidelity, was included in the clinical prostate MR exam for sCT generation (adding less than 2.5 min to the actual scan time). All scans were performed on a 3T MR scanner (Philips

Ingenia) with in-house-built flat table top. The sCT **(b)** were generated by the technique described by Schadewaldt et al, using mDixon acquisition and model-based segmentation to assign fixed HU to 5 tissue classes. The RT plans were recalculated in Monaco v5.10 (Elekta) on sCT without any further optimization utilizing the delineations from the planning CT after rigid registration of CT on sCT. The alignment (translation-only) of isocenters of the two plans allowed voxelwise dose comparison and γ-analysis.
CTs and sCTs are inherently different, as they are acquired at different time points and, furthermore, the patient anatomy can slightly vary during the positioning on CT and MR. Fig **(c)** highlights the differences, in terms of ED, of sCT minus CT for a transversal slice of one of the patients: differences in body contour and bone structure can be observed, as well as the lack of prostate markers and air pockets on sCT. VOIs **(d)** defined as the intersection of the body contour of CT and sCT (*VBody*) and as 75% (*V75*) of the prescribed dose (77 Gy) are considered in order to minimize such physiological differences during the comparison **(e)**.



CT **(a)** and sCT **(b)** with the relative Electron Density (ED) difference **(c)**. Fig. **(d)** highlights the VOIs utilized to characterize the voxelwise dose deviations **(e)**.

Results: The dose on sCT results in a slightly systematic higher dose (1.3%, 0.9%) in *V75* and in *VBody*, respectively, when compared to CT, as shown in the Table in terms of dose difference and relative dose difference over the whole study population. The highest average dose calculated in a patient (i.e. worst case scenario) is lower than 1.5 and 0.2 Gy in *V75* and *VBody* respectively. In this type of comparison, differences in patient positioning between CT and sCT contribute to the observed difference in dose.

	Average Deviation $sCT - CT$ [Gy]	Average Rel Deviation $\frac{sCT-CT}{CT}$ [%]	$\gamma_{3\%/3mm}$ [%]	$\gamma_{2\%/2mm}$ [%]
$V_{75\%}$	0.92 ± 0.25	1.30 ± 0.36	99.3 ± 0.8	94.5 ± 4.1
V_{Body}	0.10 ± 0.04	0.86 ± 0.58	98.8 ± 0.9	95.8 ± 2.3

Average Deviation, Average Relative Deviation and Gamma passed rate (mean ± std) over all the patients for $V_{75\%}$ & V_{Body}.

Conclusion: This study evaluated the accuracy of dose calculation on sCT MR-only generated for prostate IMRT plans. Further investigations on the contributions to the observed differences are subject of current and on going research.

EP-1842

A dosimetric analysis of MRI only treatment planning of the brain

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Purpose or Objective: MRI only treatment planning is gaining interest as it removes errors associated with image registration from the planning pathway. As access to MRI becomes more widespread in radiotherapy departments, it will become more feasible to carry out MRI only planning. This study aimed to assess the dosimetric accuracy of treatment plans calculated using an MRI only approach for 3D conformal radiotherapy (3DCRT) and volumetric modulated arc therapy (VMAT) brain treatments.

Material and Methods: Ten retrospective patients (five glioblastoma multiforme (GBM) patients treated with 3DCRT, and five meningioma patients treated with VMAT) were selected. A synthetic CT (sCT) was created for each patient by manually contouring the patient external, bone and sinus. The electron density (ED) of the patient, bone and sinus were forced to 1.0, 1.68 and 0.11 g/cm3 respectively, these values were derived by contouring the structures in ten representative CT study-sets. A treatment plan was calculated for each patient using the sCT, the original planning CT, and using the MRI study-set with a homogenous ED of unity. The resulting dose distributions were quantitatively analysed using the dose to the isocentre and clinically relevant DVH statistics (fig 2). A qualitative analysis of dose difference maps and DVHs was also undertaken.

Results: A paired, two-tailed student t-test found that the dose to the isocentre was statistically indistinguishable ($p<0.05$) between the sCT and the CT based dose distributions for all plans, whereas this was not the case for the homogenous density calculation. A mixed linear regression analysis of the DVH statistics showed that the ED map was a significant predictor of the dose values ($p<0.05$) when comparing CT to homogenous density, but did not find the ED to be a significant predictor of the DVH statistics when comparing sCT and CT calculated dose distributions.
The qualitative analysis supported these findings: the dose difference maps showed that there was generally good agreement between the CT and the sCT calculated dose distributions, with the main areas of difference between them occurring near the patient external (see fig. 1). Comparison of the CT and sCT DVHs also showed them to be similar, with marked differences to those calculated assuming homogenous density

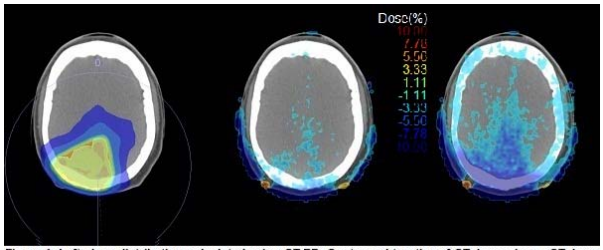

Figure 1: Left, dose distribution calculated using CT ED. Centre, subtraction of CT dose minus sCT dose. Right, subtraction of CT dose minus homogeneous ED dose.