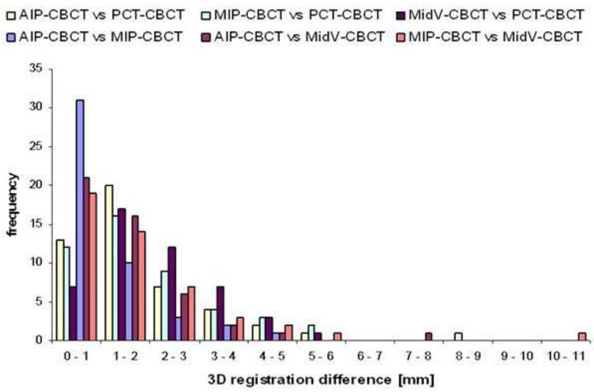
the registrations were analyzed and correlated to different factors, e.g. tumor motion, size and location.

Material and Methods: CT datasets of 47 lung SBRT patients were retrospectively selected for this study. All patients had a PCT and a 4DCT scan. AIP and MIP CT datasets were calculated from the 10 phases of the 4DCTs. Additionally, a MidV CT was selected for each patient representing the mean position of the tumor. These four CT datasets were retrospectivlly registered to free breathing CBCTs which were acquired before patients' first treatments. Automatic image registration was performed with the Eclipse 13.0 registration software (Varian). 3D translational registrations were applied and the coordinates in left-right (x), anterior-posterior (y) and superior-inferior (z) direction were evaluated. Coordinates of each of the registered four CT datasets were compared to the coordinates of the other registered CT datasets (e.g. PCT-CBCT vs MIP-CBCT). Additionally, a 3D movement vector was calculated. Furthermore, we searched for correlations between registration differences and tumour parameters: 3D motion of the tumor, GTV volume and the distance between the carina of trachea and the GTV in z-direction (SI position). The Wilcoxon test was used to identify statistically significant difference between the fusion pairs (p-value <0.05). Correlations were analyzed using Spearman's rank correlation (rs).

Results: The table depicts median, minimal and maximal registration differences in x, y, z, and 3D direction between the CT datasets. Some differences were statistically significant (p<0.05). AIP-CBCT and MIP-CBCT achieved the smallest differences. The largest difference in 3D direction was observed for MIP-CBCT vs MidV-CBCT (10.5 mm). The figure depicts the frequency of shifts in 1 mm step sizes between the image registrations. Only 3D tumor motion showed a good correlation to the registration differences between AIP-CBCT and MIP-CBCT (rs: 0.73) or MIP-CBCT and MidV-CBCT (rs: 0.70).



Δ couch shifts
median (min / max)

registration	Δx [mm]	Δy [mm]	Δz [mm]	Δ3D [mm]
AIP-CBCT vs PCT-CBCT	-0.5 (-2.1 / 2.7)	-0.1 (-2.9 / 2.2)	0.0 (-5.1 / 3.2)	1.4 (0.3 / 5.6)
MIP-CBCT vs PCT-CBCT	-0.5 (-1.3 / 2.9)	-0.4 (-4.0 / 1.8)	-0.3 (-8.7 / 3.3)	1.8 (0.4 / 8.8)
MidV-CBCT vs PCT-CBCT	-0.4 (2.0 / 2.2)	0.0 (-2.9 / 3.9)	-0.4 (-3.9 / 5.8)	1.9 (0.2 / 5.9)
AIP-CBCT vs MIP-CBCT	-0.1 (-1.0 / 1.2)	0.3 (-0.8 / 1.5)	0.1 (-3.0 / 4.3)	0.5 (0.1 / 4.4)
AIP-CBCT vs MidV-CBCT	-0.1 (-3.8 / 1.6)	-0.2 (-2.8 / 2.3)	0.2 (-6.3 / 2.7)	1.1 (0.1 / 7.6)
MIP-CBCT vs MidV-CBCT	-0.2 (-2.8 / 1.6)	-0.5 (-2.8 / 2.2)	0.0 (-9.9 / 5.7)	1.3 (0.1 / 10.5)

Conclusion: Using different CT datasets for image registration with free breathing CBCTs can result in distinctly different couch shifts. Automatic AIP-CBCT and MIP-CBCT fusion achieved the best agreement. Differences > 5mm were observed, which can be larger than the safety margins. This has to be considered if the CT dataset for treatment planning and image registration is chosen.

EP-1838

Proton therapy planning for brain tumors using MRI-generated PseudoCT

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Purpose or Objective: To investigate the dosimetric and range accuracy of using MRI pseudoCT for proton therapy planning vs. single energy x-ray CT, for brain tumors.

Material and Methods: A cohort of 15 gliobastoma patients with CT and MRI (T1 and T2) imaged after surgical resection. T1-weighted 3D-MPRAGE was used to delineate the GTV, which was subsequently rigidly registered to the CT volume. A pseudoCT was generated from the aligned MRI by combining segmentation- and atlas-based approaches. The spatial resolution both for pseudo- and real CT was 0.6x0.6x2.5mm. Three orthogonal proton beams were simulated on the pseudo CT. Two co-planar beams were set on the axial plane. The third one was planned parallel to the cranio-caudal (CC) direction. Each beam was set to cover the GTV at 98% of the nominal dose (18Gy). The proton plan was copied and transferred to the real CT, including aperture/compensator geometry. Dose comparison between pseudoCT and CT plan was performed beam-by-beam by quantifying the range shift of dose profile on each slice of the GTV. The GTV's relative V98 was computed for the CT.

Results: For beams in axial plane the median absolute value of the range shift was 0.3mm, with 0.9mm and 1.4mm as 95th percentile and maximum, respectively. Worst scenarios were found for the CC beam, where we measured 1.1mm (median), 2.7mm (95th-percentile) and 5mm (maximum). Regardless the direction, beams passing through the surgical site, where metal (Titanium MRI compatible) staples were present, were mostly affected by range shift. GTV's V98 for CT was not lower than 99.3%.

Conclusion: The study showed the feasibility of an MRI-alone based proton plan. Advantages include the possibility to rely on better soft tissue contrast for target and organs at risk delineation without the need of further CT scan and image registration. Additional investigation is required in presence of metal implants along the beam path and to account for partial volume effects due to slice thickness.

EP-1839

exploiting planning CT data for accurate WEPL on CBCT reconstructions used in adaptive radiotherapy

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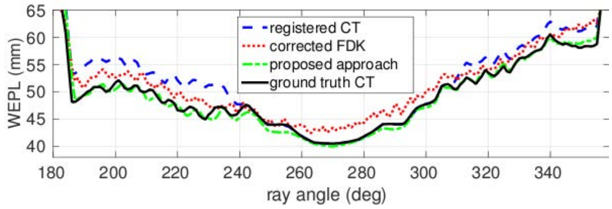
Purpose or Objective: To allow the use of cone beam computerised tomographic (CBCT) imaging for adaptive radiotherapy, its quantitative accuracy must be improved. However, since it is physically hindered by data insufficiency and large scatter contributions, this a difficult task without incorporating additional information. Here we propose a framework for utilising planning CT images within the reconstruction process to significantly improve the accuracy of CBCT and illustrate its potential use in proton therapy.

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.

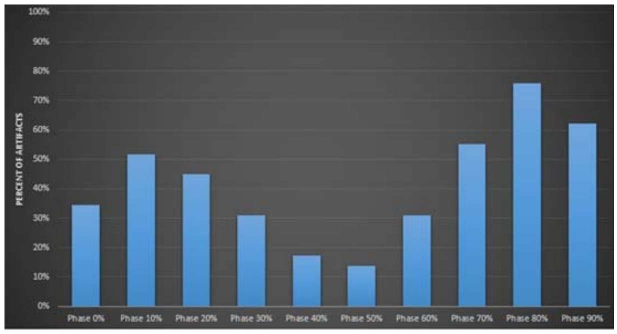

Fig.1

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
[1] Yamamoto et al. – Int. Journal Radiation Oncology Biol. Phys 72 (4), 2008, pag. 1250-1258
[2] Castillo et al. – Journal of applied medical Physics 16 (2), 2015, pag. 23-32

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