respiratory motion whilst using the device, but that interpretation of the visualization schemes can be quite literal. This can lead, for example, to 'target driven' pulsatile breath holding rather than quiescent, smooth motion patterns.

Conclusions: This interim analysis shows that the visual feedback device is well tolerated in lung cancer patients. The optical surface measurement technology delivers fast and accurate skin surface measurements. However, great care must be taken with the psychology of visual feedback schema in order to encourage predictable patient response.

1. G.J. Price *et al.*, doi: 10.1088/0031-9155/57/2/415 (2012).
2. J.M. Parkhurst *et al.*, doi: 10.1016/j.ijrobp.2013.08.048 (2013).

EP-1528

Should we extend the daily image guidance scans for toxicity studies? A VoxTox experience

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Purpose/Objective: Rectal toxicity is one the major constraints in prostate cancer radiotherapy (RT). It has been shown that various manifestations of rectal toxicity strongly correlate with the dose distribution on the surface of the rectum (Buettner at al., Phys. Med. Biol. 2009). IGRT daily images can be used to re-compute rectum doses for each treatment fraction whilst accounting for intra-fraction variations in rectum position. As a part of the VoxTox study we are analyzing re-computed doses and toxicity in over 1000 patients treated with image-guided intensity-modulated radiotherapy (IG-IMRT) using TomoTherapy. The length of the IG scan is kept short for clinical care. We examined whether it was sufficient for this research.

Materials and Methods: We include both retrospective and prospective cohorts of prostate cancer patients and acquire acute and late toxicity data with a follow-up of 5 years. The retrospective cohort was imaged using the standard (STD) protocol that is designed to minimize the imaged area whilst still enabling soft tissue matching to the prostate. For the prospective cohort, we have created a dedicated imaging protocol to extend the scan to cover the entire PTV inclusive of nodal regions and seminal vesicles. We have demonstrated that increases in imaging dose and scan times are negligibly small (Bates et. al., Br J Radiol. 2013). This work compares the differences in imaging data acquired using STD and VoxTox imaging protocols. One oncologist outlined the rectum on the planning CT and 37 daily megavoltage CT images of patients treated to 74 Gy in 37 fractions. The rectum contours on daily images were adjusted to include positional corrections applied by treatment radiographers prior to RT delivery. A median dose to the rectal surface was calculated for all slices in the planning and daily CT images.

Results: The results from retrospective and from prospective cohorts are presented in Figure 1.

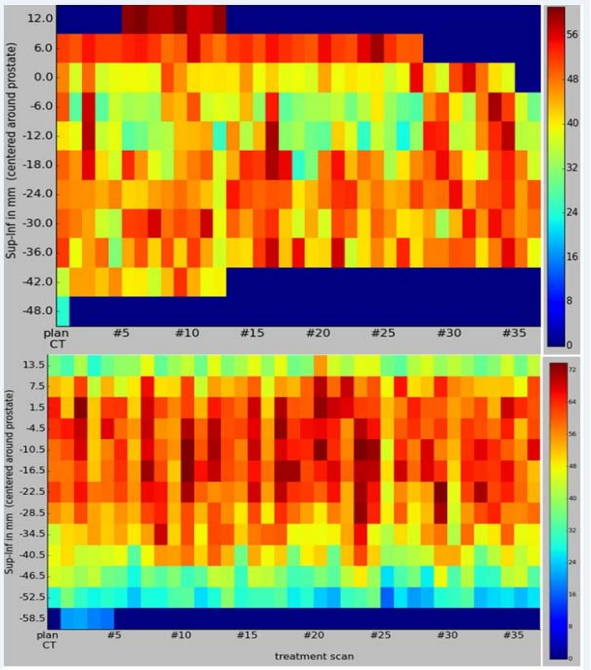

Figure 1. Median doses to rectum surface as imaged per STD (above) and VoxTox study (below) protocols. Doses(in gray) are colour-coded. Each vertical line represents 1 daily IG scan. Vertical axis: superior-inferior extent of scan; horizontal axis: scan number.

Images acquired using the STD protocol truncate the rectum that lies superior of the prostate. In the majority of STD MV scans, large parts of rectum receiving doses of 60 Gy and above are omitted. For patients imaged according to the VoxTox protocol, sufficient coverage of the rectum is achieved to account for daily variations in prostate position and to enclose all areas of rectum that receive median doses of 50 Gy or higher.

Conclusions: A imaging protocol tailored for research is essential to design a prospective study that focuses on rectal toxicity. The imaged area in daily scans can be expanded with negligible increase in imaging dose and scan time, and helps to compensate for daily organ motion. The enhanced scans contain all clinically significant data and are useful in understanding of dose-toxicity links. Median dose per slice evaluation will be useful as a quality assessment tool for stratification and analysis of re-calculated daily doses.

EP-1529

Automated landmarks detection for rigid registration between the simulation-CT and the treatment CBCT

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Purpose/Objective: As a part of the Radiotherapy (RT) process, CBCT-scans are acquired on a daily basis, so as to place the patient at the reference position of the computed treatment plan: This positioning is done through rigid image registration with the simulation CT-scan. The golden standard of algorithms for the registration of 3D images are inherently iterative and based on the value of the voxels. In the context of 2D images, it is now well known that rigid registration can be dramatically improved and accelerated by detecting, then matching highly informative spots in the images that are known as 'landmarks.' [LDM]. Our goal is to transpose this 2D approach to real-world 3D medical imaging by introducing novel, automated algorithms for LDM detection in 3D images.

Materials and Methods: We propose to exploit machine learning to automate LDM detection. From a set of training images of a given modality where LDMs have been manually located, a regression model is trained that can predict the distance of any point in a new image to the (unknown) position of the LDM. Randomized Trees are used as the model, as they have shown to be very efficient in many computer vision tasks. On a new image, the position of the LDM is then predicted as the point with the closest predicted distance. Input features to describe a LDM are the values of its neighboring voxels in 3D. We performed our study using 51 pairs of pelvis CT and CBCT from 29 patients, where we manually annotated 8 LDM in each modality. Two detection models were built: one for the CT and one for the CBCT modality. For each patient, we detected the position of each LDM using a model trained from the images of the 28 remaining patients, then we performed rigid registration accross modalities using these LDM through simple linear algebra. The accuracy of both LDM detection and registration was then evaluated and averaged over the 29 patients. Registration accuracy is measured by the averaged distance, over all 8 LDM, between the (true) position of the LDM in CT and in CBCT after registration.

Results: The mean accuracy of our LDM detection was between 4.5 and 6 voxels for CBCT, and between 2.9 and 3.3 voxels for CT (IC 99%). We explain this difference by the higher resolutions of our CBCTs, whose voxel size is 1x1x1mm, whereas typical CT resolution is 1.6x1.6x5mm. Low voxel resolution makes the detection easier, but gives less information concerning LDM position. Registration accuracy was between 4.42 and 5.26mm with manually annotated LDMs and between 7.92 and 9.59mm (IC 99%) with automatically detected LDMs. Given the detection results, we argue that a large part of this error comes from the low resolution of the images: A 2-voxels error on the CT can result in an error >10mm.

Conclusions: In this work, a novel rigid registration algorithm for 3D multimodal medical images is introduced. It is based on LDM detection using machine learning. Our first results are very promising given the low resolution of our test images.

EP-1530

Limitations of deformable image registration in 4D PET V/Q imaging for functional assessment in lung radiotherapy

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Purpose/Objective: Radiotherapy with curative intent for non-smallcell lung cancer (NSCLC) is hindered by side effects such as radiation-inducedpneumonitis. Functional imaging techniques such as ventilation/perfusion (V/Q)images allow visualization of lung function. This work investigates the role ofdeformable image registration (DIR) in repeat 4D PET V/Q imaging for assessmentof changes in lung V/Q due to radiotherapy in NSCLC.

Materials and Methods: 4D PET V/Q with co-registered 4DCT images were obtained prior to, during and post-radiotherapy for five NSCLC patients receiving 60 Gy in 30 fractions. Rigid registration and DIR were used to register all V/Q images to the treatment planning scan and dose distribution. Contours and corresponding anatomical features in the CT component of each V/Q scan were outlined on all CT images. The registration from rigid and DIR techniques was used to warp the V/Q data and contour/anatomical feature data to the planning CT scan. The accuracy of the contour propagation, anatomical feature mapping was measured, and the effect of the different registrations on the functional image was determined.

Results: DIR improved the image registration accuracy as based on contour and corresponding feature mapping accuracy for the pre- and mid-treatment images. Table 1 shows reduction in the registration error of corresponding features for these images. For post-treatment images, the registration accuracy improvements were not as significant with DIR. This was due to DIR inaccuracies in regions subject to structural changes such as fibrosis and loss of tumour mass. There was no improvement in quantification of changes in lung function with DIR (Figure 1).

Conclusion: DIR for mapping 4D PET V/Q image data from pre-, mid- and post-treatment time points showed improved registration accuracy with the exception of regions where structural lung changes such as fibrosis and large tumour regression are apparent. In these situations, uncertainties with DIR outweigh any benefit in functional response assessment. More advanced DIR algorithms taking non-conservation of mass into account may be of more use in these situations. The utility of DIR remains however for mid-treatment images in which the structural changes of the lung are not as severe.

Table 1: Registration error in mm between corresponding anatomical features with rigid and DIR when mapping from each pre-, mid- and post-treatment image to the planning CT scan.