Motion compensated 4D PET/CT for liver tumors
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Purpose/Objective: To improve PET/CT image quality for small liver tumors by compensating breathing-induced motion.

Materials and Methods: On our Philips Gemini PET/CT system, we acquired 4D CT and 4D PET scans for 6 patients by registering the breathing signal in the liver (Black circle) for the ten separate phases and the MidP PET and CT scan and compared these. For PET we determined the standard deviation in SUV within the tumor region, indicated by the white circle, both for the conventional 3D PET scan and the MidP PET scan. Additionally, we determined the decrease in volume enclosed by 50% SUV max comparing the conventional 3D with the MidP PET datasets.

Results: The motion of the tumor due to breathing was on average 1.8 (σ = 0.7)cm. The relative decrease in standard deviation in a homogeneous region in the original 4D CT data was about 67 (σ = 8%). The standard deviation in the PET signal within the tumor showed an increase of about 5 (σ = 8%). The PET values within the tumor region are in general not evenly distributed. In the conventional 3D reconstruction this contrast is decreased due to motion blurring; for the motion compensated MidP PET dataset it is not. Therefore, the standard deviation in the MidP PET scan may be higher compared to the conventional 3D scan. The volume decrease was on average 8% (σ = 12%). It should be noted that for 4 of the lesions the decrease was almost zero, whereas for others the decrease was over 30%.

Conclusions: Motion compensation in 4D PET/CT is feasible and improves image quality. The size of the lesions shown on the motion-compensated PET images can decrease considerably compared to the conventional, non-compensated 3D PET scan.

Biological image guided brachytherapy of hypoxic cervical cancers
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Purpose/Objective: Dynamic contrast enhanced MRI (DCEMRI) of locally advanced cervical cancers and pharmacokinetic image analysis may be used to identify patients at risk of local relapse [1]. Furthermore, a pharmacokinetic image parameter, ABrix, has been shown to correlate with an hypoxic gene signature in such tumors [2]. Thus, DCEMRI may be used to identify patients with hypoxic disease and potentially to distinguish hypoxic from normoxic tissue. Therefore, it is of interest to explore strategies taking such biological image information into account to improve radiotherapy outcome.

Materials and Methods: DCEMRI images of 23 patients with locally advanced cervical cancers were used. The dynamic image series were analyzed in terms of the pharmacokinetic ‘Brix’ model voxel by voxel in the planning system. The resulting ABrix maps were imported into Oncentra Brachy (Nucletron, the Netherlands) and used to define an hypoxic, or biological, target volume (BTV). T2-weighted images were used to define the gross tumor volume (GTV). Using a ring applicator, including needles when necessary, two brachytherapy treatment planning approaches were investigated. In approach 1, a conventional, non-biological image guided approach was followed where GTV was given the highest dose possible without compromising the dose constraints for the organs at risk. In approach 2, BTV was boosted to the highest dose possible, still without compromising other dose objectives. The results were analyzed in terms of D90 (fraction dose to 90% of volume) to the targets.

Results: The patients presented highly different hypoxic BTVs, both in size and location within the GTV. The hypoxic fraction (BTV/GTV volume ratio) ranged from 0.06 to 0.86. For some patients, it was possible to escalate the dose to the BTV (approach 2) with up to 30% compared to approach 1, while others could not be further escalated without violating the dose constrains to the OARs. For approach 1, D90 to GTV was 9.7±2.0 Gy while D90 for BTV was 11.2±2.9 Gy (cohort-based mean ± 1 s.d.). Following approach 2, these D90’s were 10.2±3.3 Gy and 12.2±3.4 Gy, respectively.

Conclusions: In conventional image guided brachytherapy, the hypoxic subvolume usually receives a higher dose than the rest of the GTV. Further dose escalation is possible for a selection of patients with small and/or centrally located hypoxic BTVs.

1 E. Andersen, K.H. Hole, K.V. Lund et al. Pharmacokinetic parameters derived from dynamic contrast enhanced MRI of cervical cancers predict chemoradiotherapy outcome. Radiother Oncol (accepted).

Comparison of DWI-MRI and DCE-MRI for locally advanced cervical cancer
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Purpose/Objective: Understanding the etiology of tumor response is the key to adaptive radiotherapy. Both Dynamic Contrast Enhanced (DCE)-MRI and Diffusion Weighted (DW)-MRI are techniques to gain information about the microenvironment of tumors. Combining these two techniques opens the possibility to investigate whether they carry similar and complimentary information.

Materials and Methods: A 3T MRI (Philips Achieva 3T-X) was used before start of EBRT in 8 patients with locally advanced cervical cancer. DCE-MRI: 20-24slices, 5mm slice thickness, TE/TR: 1.4ms/2.9 ms, 10° Flip Angle(FA), 2.27mm isotropic in-plane resolution. The bolus injected was 0.1ml/kg Dotarem at 4ml/s, followed by a 5 ml saline flush. 120 dynamic acquisitions, equidistantly spaced by 2.1 sec, were acquired. DWI-MRI: b=[150, 600, 1, 000]s/mm² TR = 1613 ms, TE=75 ms, the number of averages 6, matrix size was 112x112, resolution 2.5x2.5x4 mm. T2w images were used for tumor delineation. A moving average with a kernel of 0.5cc was applied to the images before post processing. The extended Tofts and Brix models were performed on the DCE-MRI. ADC was calculated assuming a log-linear relation between signal intensity and b-values. The correlation between perfusion parameters (Ktrans, Vp, A) and ADC was based on all voxels (figure 1) and evaluated using the Pearson correlation coefficient (r).

Results:
Materials and Methods: biomarkers and could potentially be extended to imaging bulk 3D with antibodies that enable cellular uptake via specific cellular radiosensitivity information (hypoxia, proliferative ability and technique sensitive to tumour characteristics that gives collagen type 1 to construct 3D concentrations of 1.9 nm gold NPs. The NP loaded cells were nested in (HT29) and stromal cells (fibroblasts 3T3) using varying incubation involved NP cellular uptake experiments with colorectal cancer cells. Demonstration of sensitivity to NP uptake in cells was performed; this distinguish two component metals was undertaken; a phantom an energy resolving silicon drift detector. Proof of concept imaging to technique capable of imaging NP concentration. The novel XRF purpose/objective: A quantitative technique for simultaneous imaging of multiple biomarkers. K. Ricketts1, C. Guazzoni2, A. Castoldi2, V. La Rosa1, A. Gibson1, M. Loizidou1, G. Royle1 1University College London, Medical Physics and Bioengineering, London, United Kingdom 2Politecnico di Milano, Electronic Engineering, Milan, Italy 3University College London, Division of Surgical and Interventional Sciences, London, United Kingdom

Purpose/Objective: There is a clinical need for a functional imaging technique sensitive to tumour characteristics that gives radiosensitivity information (hypoxia, proliferative ability and angiogenesis). We investigated the use of nanoparticles (NPs) as a contrast agent for tumour characteristics; NPs can be functionalised with antibodies that enable cellular uptake via specific cellular receptors, thus acting as biomarkers for tumour characteristics. We present a technique that enables simultaneous imaging of multiple biomarkers and could potentially be extended to imaging bulk 3D volumes.

Materials and Methods: We have devised an x-ray fluorescence (XRF) technique capable of imaging NP concentration. The novel XRF imaging module consisted of a focusing polycapillary optic coupled to an energy resolving silicon drift detector. Proof of concept imaging to distinguish two component metals was undertaken; a phantom consisting of gold and tantalum wires was constructed and imaged. Demonstration of sensitivity to NP uptake in cells was performed; this involved NP cellular uptake experiments with colorectal cancer cells (HT29) and stromal cells (fibroblasts 3T3) using varying incubation concentrations of 1.9 nm gold NPs. The NP loaded cells were nested in collagen type 1 to construct 3D in vitro cancer models to demonstrate the sensitivity of the XRF technique to NP concentration and distribution.

Results: The technique demonstrated ability to distinguish two metal types in imaging mode. XRF imaging was performed of several slices of the 3D cancer model (with a challenging GNP concentration ratio of 5:1 between the tumour mass (0.7 million HT29) and surrounding) and all component details could be clearly seen, with a delineated tumour mass emitting at 5x more than the surrounding cellular stroma (Fig 1). The XRF signal was linear with NP concentration down to GNP concentrations of 1ppm.

Figure 1 Gold XRF image of 3D artificial cancer mass with gold NP inclusions

Conclusions: XRF imaging techniques can be used to image the distribution and concentration of NPs at concentrations typically found in NP loaded tumours. The technique can also be used to discriminate between NPs of different metals, suggesting potential for multiple biomarkers to be imaged simultaneously. Further work on functionalising NPs is required.

PROFFERED PAPERS: PHYSICS 4: DOSE VERIFICATION FOR ADVANCED RADIOTHERAPY

OC-0154 A comparison of the gamma index sensitivity in various commercial IMRT/VMAT QA systems M. Hussein1, C.H. Clark1, A. Nisbet1 1Royal Surrey County Hospital NHS Foundation Trust, Medical Physics, Guildford, United Kingdom

Purpose/Objective: QA for IMRT and VMAT has evolved substantially. In recent years, various commercial 2D and 3D ionization chamber or diode detector arrays have become commercially available, allowing for absolute dose verification with near real time results. This has led to a wide uptake to replace point dose and film dosimetry and to facilitate QA streamlining. However, arrays are limited by their spatial resolution which may affect the sensitivity of the gamma index analysis. The purpose of this study was to compare the sensitivity of the gamma index analysis (γ) in the Delta4®, ArcCHECK®, PTW 2D-Array seven29™ and Octavius II™ phantom combination, Gafchromic® EBT2 and composite Varian Portal Dosimetry EPID measurements.

Materials and Methods: To evaluate the sensitivity of the different systems, errors were designed with deliberate changes of 1, 2, 5mm introduced into prostate and head & neck IMRT and RapidArc™ plans throughout all control points in all fields for one 5mm MLC leaf. Collimator rotation errors of 1, 2, and 5° were introduced into a prostate & pelvic nodes RapidArc plan. The errors were designed to test each system. The expected gamma index pass rate was simulated by exporting the normal plan predicted dose and the calculated dose for each error plan. The predicted γ was calculated in Versisoft v5, OmniPro I’mRT v7, Delta4 software, SNC Patient v6, Portal Dosimetry v10, and averaged. Measurements were evaluated against the unperturbed dose distribution calculated using Varian Eclipse™ the relevant phantom. In all cases, global γ was used with a 20% threshold relative to a point selected in a high dose and low gradient region. Various criteria for γ were analysed, including the commonly used 3%/3mm criteria. The γ based on measurement was compared against the predicted to evaluate the sensitivity of each system. The concordance correlation coefficient, pγ, was used to assess statistical agreement.

Results: There was good agreement between the predicted γ from each software (all pγ>0.93 relative to the average prediction). A