Conclusion: DIR-based registration methods showed that the vast majority of failures originated in the high dose target volumes and received full prescribed doses suggesting biological rather than technology-related causes of failure. Validated DIR-based registration is recommended for accurate failure characterization and a novel typology-indicative taxonomy is recommended for failure reporting in the IMRT era.

OC-0072
Respiratory time-resolved 4D MR imaging for RT applications with acquisition times below one minute
C.M. Rank1, T. Heußer1, A. Wetscherek1, A. Pfaffenberger1
1German Cancer Research Center DKFZ, Medical Physics in Radiology, Heidelberg, Germany

Purpose or Objective: 4D MRI has been proposed to improve respiratory motion estimation in radiotherapy (RT), aiming to achieve a higher treatment accuracy in the thorax and the upper abdomen. In contrast to 4D CT, acquisition time in 4D MRI is not limited by radiation dose, such that multiple breathing cycles can be imaged routinely. However, standard MR reconstruction methods, such as gated gridding, have limitations in either temporal or spatial resolution, signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR) and artifact level or demand inappropriately long acquisition times. The purpose of this study is to provide high quality 4D MR images from super short acquisitions.

Material and Methods: MR data covering the thorax and upper abdomen of three free-breathing volunteers were acquired at a 1.5 T Siemens Aera system. We applied a gradient echo sequence with radial stack-of-stars sampling and golden angle radial spacing: total acquisition time: 37 s, voxel size: 1.6×1.6×4.0 mm³, TR/TE = 2.48/1.23 ms, 240 spokes per slice, undersampling factor: 16.8, flip angle: 12°. MR data were sorted into 20 overlapping 10% wide motion phase bins employing intrinsic MR gating. Respiratory motion compensated (MoCo) 4D MR images were generated using our newly developed 4D joint MoCo-HDTV algorithm, which alternates between motion estimation and image reconstruction. With MoCo, each motion phase is reconstructed from 100% of the measured rawdata. In the motion estimation step, the motion vector fields (MVF s) are estimated between adjacent motion phases and regularized by cyclic constraints. Results were compared to the standard reconstruction methods 3D gridding and 4D gated gridding.

Results: 3D gridding reconstructions revealed strong blurring of structures in the lungs, in the diaphragm region and in the liver caused by respiratory motion. 4D gated gridding images were deteriorated by noise and severe streak artifacts, arising from high azimuthal undersampling. These artifacts obscured small anatomical structures. In contrast, 4D joint MoCo-HDTV reconstructions yielded appropriate image quality combining low streak artifact levels and high temporal resolution, SNR, CNR and image sharpness. Thus, the displacement between end-exhale and end-inhale of small liver structures could be determined, which was not possible using 4D gated gridding images due to their limited image quality.

Conclusion: 4D joint MoCo-HDTV facilitates 4D respiratory time-resolved MRI and provides respiratory MVFs at acquisition times below one minute. The method is promising for reliable target delineation in radiation therapy, patient-specific margin or gating window definition, and for adaptive planning based on the provided MVFs. The short acquisition time makes it attractive also for online imaging in an MR-LINAC setting.

Proffered Papers: Physics 2: Basic dosimetry

OC-0073
Difference in using the TRS-398 code of practice and TG-51 dosimetry protocol for FFF beams
J. Lye1, D.J. Butler2, C.P. Oliver2, A. Alves1, I.W. Williams1
1Australian Radiation Protection and Nuclear Safety Agency, Australian Clinical Dosimetry Service, Melbourne- Victoria, Australia
2Australian Radiation Protection and Nuclear Safety Agency, Radiotherapy, Melbourne- Victoria, Australia

Purpose or Objective: The two most commonly used protocols for reference dosimetry in external beam radiotherapy are IAEA TRS-398 and AAPM TG-51. Increasingly flattening filter free (FFF) linacs are in clinical use and published theoretical analysis suggests that a difference of 0.5 % is expected between the two protocols (Xiong 2008).

Material and Methods: The Australian Clinical Dosimetry Service (ACDS) has measured FFF beam dose outputs on 11 linacs using both TRS-398 and TG-51 protocols. The response of an NE2561 chamber was modelled using DOSRZnrc. The model was used to study the difference in kQ in Varian and Elekta linacs when the flattening filter was removed, and when the flattening filter was replaced by a thin metal plate.

Results: Measured differences in dose output derived from TRS-398 and TG-51 protocols were less than 0.1 % for 6 MV FFF beams and less than 0.2 % for 10 MV FFF beams. Figure 1 shows the measured response from the NE2561 for Elekta and Varian beams with the flattening filter, with the flattening filter removed, and with a thin metal plate replacing the flattening filter. The modelled FFF kQ as a function of TPR20,10 is 0.6 % lower than the kQ with flattening filter (WFF). This difference is reduced to 0.3 % when considering kQ as a function of kdd(10)x. Thus the measured difference in the TRS-398 and TG-51 protocols should be 0.3% according to the modelled results, however the average measured difference is less than 0.1 %.

The commercial realisation of FFF beams includes a thin metal filter in the place of the flattening filter. When a 2.3 mm metal plate was included in the model, the difference between the FFF kQ and the WFF kQ was reduced to approximately 0.1%.
Purpose or Objective: Aprilia, Italy

Element (see figure). Therefore such device can measure in radiation protection disc, composed by a PTFE and a steel plastic scintillators positioned between the two parts of the protection with respect to the applicator is a critical aspect. Furthermore the correct positioning of the radiation with the effective coverage degree of the whole PTV.

Discussion on the efficacy of the technique is mainly related to the dosimetric performance of the currently available dosimetry systems. The present work is aimed at comparing two different dosimetric systems as a preliminary assessment of the dosimetric performances of the above described in vivo dosimeter - that cannot presently be determined in real time. The dosimetry system will be engineered in order to meet the standards required for a temporarily implanted medical device too (biocompatibility, sterilizability, etc.) and will undergo the certification process in 2016.

Material and Methods: Measurements were performed on an MR-linac and replicated on an energy-matched Agility linac. The variation of chamber response as the chambers were rotated about the longitudinal chamber axis was investigated. The sensitivity of the chamber response to the distribution of intrinsic anisotropy of the chamber response to radiation. The anisotropic dose distribution in a magnetic field and any Lorentz force is greater in the air-filled chamber than the surrounding phantom. Solid water (SW) phantoms are used for dosimetry measurements on the MR-linac, but a small volume of air is present between the chamber wall and phantom insert.

Results: The behavior of the plastic scintillator has been measured with the IORT accelerator electron beam. Several tests have been performed, comparing the reading of the system with the reading of the plane parallel ionization chamber in a PMMA phantom. On the basis of the preliminary measurements, the system fully complies with the standards requirements (see figure).

Conclusion: The above described in vivo dosimeter significantly improves the IORT clinical documentation, allowing the real time check of the dose delivery over the whole PTV. Furthermore, since the device sensitivity is high enough to produce a precise dose map with an overall delivery of less than 1 cGy, the correct positioning of the disc with respect to the PTV and the applicator can be checked before delivering the treatment, allowing the surgeon to correct it should the symmetry on the PTV be out of tolerance levels. The system will be engineered in order to meet the standards required for a temporarily implanted medical device too (biocompatibility, sterilizability, etc.) and will undergo the certification process in 2016. It is planned to organize a multicentre study for verifying in the clinical practice the efficacy and safety of the new dosimeter.

Material and Methods: The accelerator employed is a mobile IORT dedicated electron accelerator capable of producing a 4, 6, 8 and 10 MeV electron beam, collimated by means of PMMA applicators. Measurements have been performed with a prototype based on a plastic scintillator tile placed in a PMMA phantom, with the signal processed and integrated by dedicated electronics. The plastic scintillator data has been compared with the standard dose measurements, performed by means of the PTW Roos ionization chamber and the Unidos E electrometer.

Purpose or Objective: IORT breast carcinoma treatment clinical practice has evidenced the need of real time monitoring the dose delivery on the target. The actual discussion on the efficacy of the technique is mainly related with the effective coverage degree of the whole PTV. Furthermore the correct positioning of the radiation protection with respect to the applicator is a critical aspect that cannot presently be determined in real time. The commercially available in vivo dosimetry technologies allow either a real time measurement in one point (MOSFET type detectors) or a non real time measurement over a surface (radio chromic films). A cooperation between a clinical hospital, a research institute and an industrial company has led to the conceptual design of a new device capable of satisfying the above mentioned needs. Such device has been patented. The new dosimeter consists in four leaf shaped plastic scintillators positioned between the two parts of the radiation protection disc, composed by a PTFE and a steel element (see figure). Therefore such device can measure in real time the dose in the four sectors, providing both the integral dose and a measurement of the field symmetry on the target.

Material and Methods: The accelerator employed is a mobile IORT dedicated electron accelerator capable of producing a 4, 6, 8 and 10 MeV electron beam, collimated by means of PMMA applicators. Measurements have been performed with a prototype based on a plastic scintillator tile placed in a PMMA phantom, with the signal processed and integrated by dedicated electronics. The plastic scintillator data has been compared with the standard dose measurements, performed by means of the PTW Roos ionization chamber and the Unidos E electrometer.