Motorised 3D printed water tank designed for measurements in MR linear accelerators

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mimic the lung parenchyma tissue, embedded with a solid region shaped from a patient's lung tumour and six nitro-glycerine capsules as reference landmarks. The full internal mesh structure is covered with a thin layer of polyorganosiloxane gel making the complex pattern visible in MR imaging. The phantom is completed with a liver mould shaped by a thin casing of silicon, filled with gel and elastic plastic internal structures. Once fitted into a pre-existent rib-cage and skin models, stationary and 4D CT and T1 weighted MR imaging sequences were acquired to evaluate the structure visibility and mechanical properties of each component of the phantom.

Results

Contrast of the 3D printed flexible material and the polyorganosiloxane gel was good on the T1 weighted MRI with image intensities of -500 – -400 and 0 – 100 respectively. The silicon liver casing had an image intensity range of 600 – 800. Good contrast is also confirmed on CT images with 0 – 150 HU for the printed plastic, 50 – 200 HU for gel and 650 – 800 HU for the silicon-based liver casing. The range of motion between exhale and inhale breathing phases evaluated as magnitude of the deformable image registration vector field was around 4 mm at the upper lobes and 15 mm in the inferiors. Similar deformation was seen for the liver and the surface skin, mechanically connected with the lung and ribcage (Figure 1.).

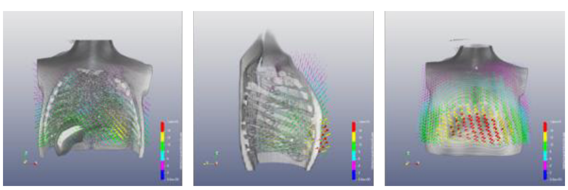

Figure 1 : Time resolved imaging of Lung Cancer phantom: volume rendering from lateral and frontal perspective of 4D MR images. Vector field describes the displacement of voxels between exhale and inhale breathing phases; scale in millimetres goes from no-motion (blue) to 16 mm (red). Coronal (left-hand panel), lateral (central panel) cuts and surface motion (right-hand panel).

Conclusion

A ventilated thoracic dosimetry phantom has been updated to allow for enhanced imaging with MR and CT by the addition of new lung and liver models. These additions will allow for reliable validation of 4D imaging techniques and treatments as well as deformable image registration quality assurance.

PO-0896 Motorised 3D printed water tank designed for measurements in MR linear accelerators

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Purpose or Objective

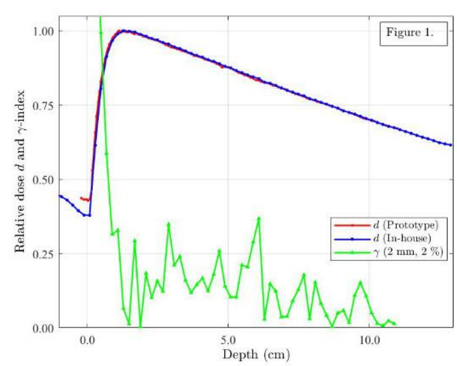
The resent introduction of MR linear accelerators (MR-linacs) for clinical treatment of patients opens new possibilities and challenges in radiotherapy. Beam data collection in a water tank for commissioning of dose planning systems for an MR-linac is more challenging compared to a conventional linear accelerator. The bore diameter, the isocentre height, the lack of room lasers, light field and cross-hair makes the setup of a water tank more complex on an MR-linac. The presence of a strong magnetic field in an MR-linac requires, for safety and handling, that water tanks to be used on MR-linacs are constructed of non-ferromagnetic materials. This work demonstrates that an MR-compatible motorized in-house designed water tank can be used at the high-field MR-linac Unity from Elekta based mainly on 3D printed parts.

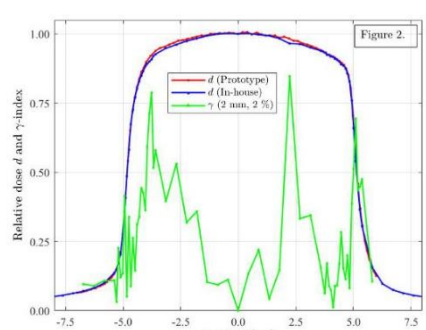
Material and Methods

An in-house designed and developed water tank was produced. The water tank consists of around 60 parts. Three ultrasonic motors manufactured by SHINSEI Corporation, toothed wheels, belts, aluminium spindlers, carbon rods and bearings were bought commercially. Arms and detector holders were printed in plastic using 3D printers. The outer dimension of the tank was 44×33×50 cm^3 with Perspex walls of 12 mm in thickness. Data collection uses Mephysto mc^2 (PTW) as interface in line with data collection on all our conventional accelerators. The data acquired using the in-house water tank was compared with data collected by Elekta, during commissioning, using a prototyped MR-compatible water tank developed in collaboration between Philips, Elekta and PTW. Scans in both water tanks were carried out using a PTW microDiamond detector as field detector and a reference detector. The scans were all performed on the same Elekta Unity MR-linac with 7 MV FFF x-ray energy characterised by a beam quality index of 0.70.

Results

Depth dose as well as profile scans at gantry 0° at the depths 5 and 10 cm for the square field sizes 2×2, 5×5 and 10×10 cm^2 were carried out at a source-to-surface (SSD) distance of 133.5 cm (SAD=143.5 cm). In Figure 1 and 2, examples of the depth dose and cross-plane profiles at 10 cm are shown, respectively, for a 10×10 cm^2 field. The comparison is evaluated via γ-index calculations using the criteria 2 mm/2 %. The γ-index was found to be < 1 except in the build-up region of the depth dose curve, Figure 1. The two microDiamond detectors seem responding differently in the air to water region resulting in γ > 1. Figures show a good agreement between the data measured in the two water tanks.





Conclusion

It is demonstrated that it is technically possible to replace a commercial non-MR-compatible water tank with an in-house MR-compatible printed water tank. This work also proves that the accuracy of an in-house built water tank is comparable to a prototyped MR-compatible tank. Furthermore, special requests on design and dimensions as well as an ability of repair and future improvements are in our view an advantage of in-house fabrication of water tanks.

PO-0897 Development of an anthropomorphic lung phantom for imaging and radiotherapy

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Purpose or Objective

Aim of this work is to develop an anthropomorphic, maneuverable and flexible lung phantom which can be used for end-to-end-tests in the radiation therapy. Furthermore, the lung phantom should be durable and the manufacturing process reproducible.

Material and Methods

As a basis for the lung phantom, anonymized CT image data of patients were used, which were downloaded from the following website "http://www.cancerimagingarchive.net/". To achieve CT and MRI characteristics of human lung as well as the flexibility, a silicone is used which was optimized by means of its magnitude of elasticity, stability and imaging properties in MRI and CT. First, the DICOM data was opened in Medical Imaging Interaction Toolkit (MITK) and the lung was segmented and transformed into a virtual model. Based on this model the lung phantom could be constructed with the CAD software AutoCAD Inventor and the tool freeform. The internal structure of the lung, thus the bronchia and the alveola, were carried out by a grid structure. First an outer casting mold was constructed and 3D printed using the Objet30 Pro Polyjet 3D printer. To facilitate the internal structure, a core was constructed as an insertion for the outer casting mold. It consists of a grid structure with 5mm by 5mm by 5mm and was 3D printed with a water soluble polyvinyl alcohol (PVA) material by using the Ultimaker 3 Extended 3D printer (Fig. 1 (a) in red). To realize silicone model with an internal grid structure, the core was placed precisely in the outer casting mold and filed out with silicone. After the silicone was hardened, the silicone lung phantom can be removed from the outer casting mold and put into water to dissolve the core composed of water soluble PVA material (Fig. 1 (b)). Using a catheter, a tumor model was inserted into the lung phantom. Afterwards MRI and CT Imaging were performed using a T2 - sequence for the MRI respectively a thorax sequence for the CT imaging (Fig. 2).

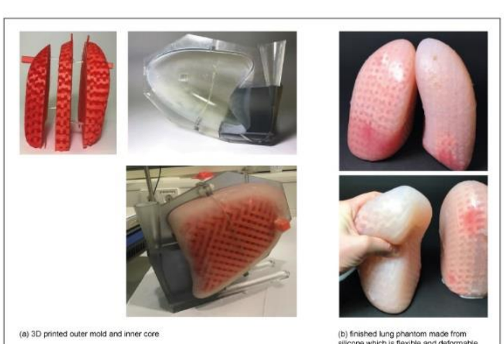

Figure 1: 3D print and finished lung phantom made of silicone

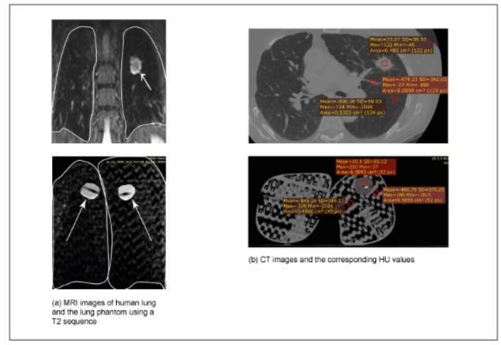

Figure 2: Comparison of human lung and lung phantom with the two imaging methods MRI and CT

Results

The HU values of the internal structure of the lung phantom indicate a deviation of 7% compared to the human lung (Fig. 2 (b)). The comparison of the MRI images ((Fig. 2 (a)) shows, that the contrast of the silicone lung phantom is the same as of a human lung.

Conclusion

A method to manufacture such an anthropomorphic lung phantom was developed, which allows a reproducible manufacturing process. In this manner the lung model can be used to perform experiments with an implanted tumor model. Due to the reproducibility determined by the steady geometry of the lung model and the consistent manufacturing process, it is possible to achieve constantly good requirements for experiments. Further on, a tumor model in the form of dosimetry gel could be inserted into the lung phantom and normal respiration could be simulated.

PO-0898 Advanced Diamond Dosimeter for quality Assurance in Radiotherapy

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Purpose or Objective

The aim of this study is to test a novel diamond device, 3DDOSE, to be used for high precision and high reliability machine quality assurance.

Material and Methods

3DDOSE is a polycrystalline chemical vapor deposited 3D diamond detector with graphitic in bulk electrodes, fabricated using a pulsed laser technique. Main advantages of such solution are the low voltage working point (tens of V), the all-carbon material presented to the photon beam, the relatively high sensitive volume with respect to the planar electrodes devices (0.125 mm3 for 0.5 mm2 area) allowing for an higher signal. Also being a volume detector, it should have small dependence from its orientation with respect to the beam. For these reasons it is a good candidate to a dosimeter for beam QA. Tests of the 3DDOSE diamond dosimeter, developed at University of Florence, were performed by means of an Elekta Synergy LINAC at the University Hospital of Florence with conventional 6MV photon beams. The 3DDOSE was placed at the isocenter and inserted in a precisely motorized PMMA phantom at a depth of 10cm with field size variable from 1.6x1.6cm2 to 10x10cm2 to be used for relative dose measurements. A very