# ABSTRACT SUBMISSION FORM

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**PRESENTATION TITLE**

Implementation of a 4D MRI workflow for abdominal radiotherapy treatment planning

**AUTHOR(S)**

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**ABSTRACT**

**Purpose:**

4DCT is widely used in radiation therapy (RT) to visualise organ and tumour motion. It is used to quantify the internal tumour volume during the planning process and to assess methods to minimise organ motion and control respiratory amplitude including abdominal compression (AC). 4DCT has many limitations including poor soft tissue contrast, additional radiation exposure and sensitivity to breathing variations that can result in artefacts which ageometric accuracy of the scan. Here we propose the utilisation of a novel time-resolved volumetric MRI with self-gated respiratory binning (4DMRI) for quantification of tumour and organ motion in an abdominal RT planning (RTP) workflow.

The aims of this study are to: [1] quantify the accuracy of 4DMRI using a respiratory motion simulator, [2] explore the feasibility of using AC with 4DMRI and; [3] compare image quality and organ delineation of 4DMRI and 4DCT in patients and volunteers.

**Materials & Methods:**

The 4DMRI sequence used in this study is a prototype T1 weighted 3D gradient echo with radial self-gating (Siemens, Erlangen, Germany). In the phantom experiments, a multimodality respiratory motion simulator was used that can be programmed to move a 3 cm diameter sphere filled with gadolinium doped water. The phantom was imaged on both CT (10 respiratory bins – expiration to expiration) and MRI (reconstructed at 3, 5, 7 and 10 bins – expiration to inspiration). The volume was segmented and quantified in image processing software (MiM Maestro) for each respiratory phase on MRI and CT. The amplitude and frequency of the sphere for CT and MRI were compared to the ground truth sinusoidal waveform of 15 mm amplitude and 20 breaths per minute.

Ten patients and ten volunteers were scanned using the 4DMRI sequence. In the volunteer study,
4DMRI was utilised to assess lung volumes and diaphragm motion with and without AC. Additionally, overall image quality, noise, artefacts and structural delineation were scored using a four-point scale (where 1 is the highest and 4 is lowest) for organs of interest. In the patient study, a tumour or a surrogate of tumour position was selected and the range of motion on 4DCT and 4DMRI was compared. The Euclidian distance between inspiratory and expiratory centroids was calculated. The same four-point scoring system was utilised to compare image quality for both 4DCT and 4DMRI.

**Results:**
In the phantom study, increasing the number of bins improved the capability to capture the maximum amplitude and also improved the accuracy of 4DMRI compared to the ground truth (Fig 1). In volunteers, AC was shown to reduce change in lung volumes and diaphragm motion in 60% of volunteers. 4DMRI provided excellent image quality in liver, right kidney and pancreas, each with a mean score of 2 compared to duodenum (mean=3).
In the patient cohort the mean amplitude of movement on 4DCT and 4DMRI was 1.17cm and 1.13 cm respectively. Artefact and noise were comparable between 4DCT and 4DMRI however 4DMRI had superior edge detection and overall image quality compared to 4DCT (Fig 2).

![Figure 1: Phantom amplitude versus time for both CT (10 bins) and MRI (3, 5, 7 and 10 bins) compared to ground truth waveform. For 4DMRI only maximum expiration and inspiration are displayed due to the reconstruction scheme of the sequence.](image1)

![Figure 2: Comparison of 4DMRI and 4DCT in a patient with solitary nodal recurrence of colorectal cancer receiving high dose radiotherapy. In this case artefacts are seen in 4DCT (yellow arrow) over the area of interest. Gadolinium enhanced 4D-MRI provided excellent soft tissue delineation (red arrow) and visualization of motion.](image2)

**Conclusions:**
4DMRI shows great potential as a replacement for 4DCT in the motion management of patients receiving abdominal RT. It has the potential for use during real time image guidance and identifying normal structures and tumour, with larger potential benefits for stereotactic body radiotherapy treatments of liver and pancreas cancers. Future work includes collecting a greater number of prospective patient datasets with the aim of assessing utility for liver, pancreas, adrenal and stomach treatments and potentially replacing 4DCT with 4DMRI.