MR and CT image registration under Active Breathing Coordinator motion control

E. Kaza, DJ. Collins, R. Symonds-Tayler, F. McDonald, H. McNair, E. Scurr, MO. Leach

Introduction: Breathing motion causes artifacts in thoracic and abdominal MRI, which can be alleviated by post-processing methods or prevented by gating or breath holding (BH) during MR acquisition. The usual BH practice depends on patient compliance and does not guarantee the same level of inspiration or expiration between repeated BHs. MR-compatible respiratory control devices have already been successfully used for volunteer MRI [1], [2]. A commercial Active Breathing Coordinator (ABC) (Elekta Oncology Systems, Crawley, UK) is used during lung Radiotherapy (RT) to arrest respiration at a preset air volume for a specified duration. Modification of an ABC system for MR use has demonstrated image quality improvements for segmented sequences under ABC-controlled BHs compared to self-sustained BHs [2] and very good organ position reproducibility between different functional MR measurements [3] on healthy volunteers. In a clinical evaluation we now are testing the assumption that MR-ABC with the same settings as used for CT can reproduce the same lung volumes and provide matching morphological and functional MR images that can inform RT treatment planning and assess tumour response.

Methods: Patients with lung adenocarcinoma were scanned in a 1.5T Siemens Aera, using the same positioning devices and tattoo alignment as during RT. Imaging included the use of the MR-ABC, holding their respiration for MR acquisition at the same inspirational volume as for CT (~70% of deep inhalation). Eighty 3mm thick slices of a T1-weighted Volume Interpolated Breath-hold Examination (VIBE) (TR 4ms, TE 0.94ms, FOV 270*360mm, matrix 144*256, α=8°, GRAPPA factor 2) were acquired during one BH of 17s duration. A T2-weighted selective single slab 3D Sampling Perfection with Application optimized Contrasts using different flip angle Evolution (SPACE) sequence [3] (TR 1000ms, TE 79ms, TI 180ms, 52 slices à 5mm thickness, FOV 360*360mm, matrix 173*192, α=150°, GRAPPA 2) was automatically acquired in six segments, each externally triggered by a 16s long ABC-induced BH. Two segments of a diffusion-weighted echo planar imaging (DW-EPI) sequence were also externally triggered by two 18s long ABC-controlled BHs (TR 3.3s, TE 45ms, α = 90°, FOV 258*376, matrix 192*280, GRAPPA 2, 2 averages, b =200s/mm^2).

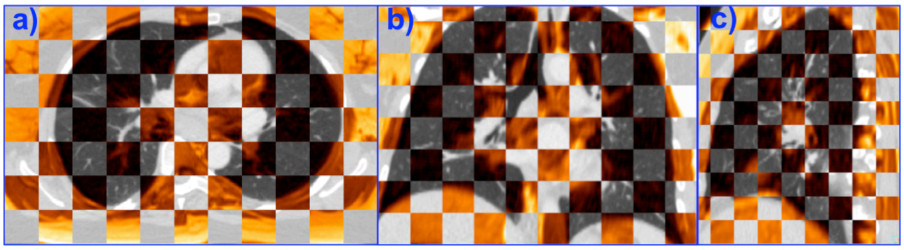

Figure 1. a) Axial, b) coronal and c) sagittal checkerboard view of the 3D T1w-VIBE (orange) and CT image (grey) fusion of a lung adenocarcinoma patient in Pinnacle.

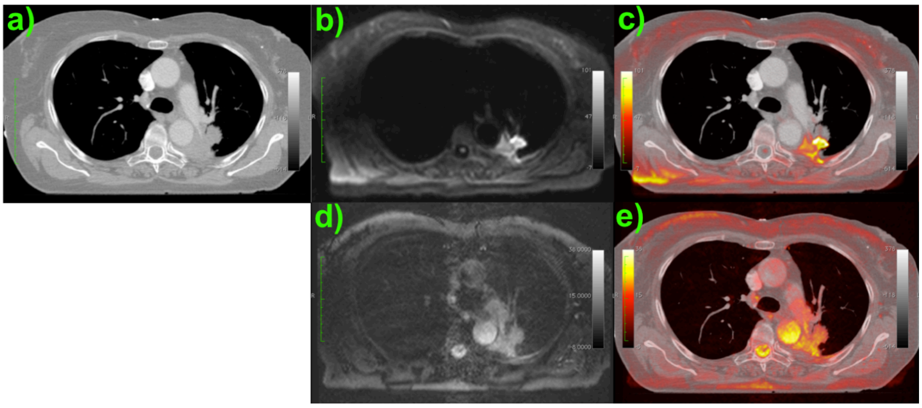

Figure 2. a) CT and b) DW-EPI of a patient with a tumour in the left upper lung lobe. c) Fusion of a) and b) in Osirix. d) 3D T2w-SPACE image of the same patient and e) its fusion with a) in

Results: Patients tolerated MR-ABC very well. In all cases, MRI intra-session slice position reproducibility was very good. Moreover, comparing a patient's T1w-VIBE and CT images by automatically fusing them in the RT planning software Pinnacle (Philips Radiation Oncology Systems, Fitchburg, WI) using a local correlation algorithm (Figure 1) shows a very good match of thoracic wall, tumour and diaphragm position in all three directions. Figure 2 illustrates a fusion example of a DW and T2w-SPACE with a CT image in Osirix applying a rigid body transformation, which also provides a good registration as lung volumes are fixed in all examinations. Taking into account EPI distortions in the anterior-posterior direction, DWI agrees with CT and provides additional information about tumour focal areas. Despite some sensitivity to cardiac motion artifacts, T2w-SPACE reproduces tumour position well and delineates tumour areas more accurately than CT.

Discussion: Immobilisation is the most straightforward method to reduce motion artifacts during MRI. Initial patient application of MR-ABC, which holds respiration at a specific air volume, showed not only very good organ position repeatability between different measurements of the same session, but also registered with CT images acquired at the same lung volume for both patients. These comparisons suggest precise motion control using the MR-ABC. MR/CT inter-modality registration seems promising for a more accurate detection, evaluation and staging of pulmonary nodules. ABC acquired data may be used as a gold standard to assess post processing motion correction schemes.

Conclusion: Initial clinical application of an MR-compatible ABC provided functional and morphological images in very good agreement with CT, indicating good and reproducible motion control and providing additional information for RT treatment planning and tumour response assessments.

References: [1] Arnold J et al, MagResMed 58, 1092-8, 2007. [2] Kaza E. et al, in Proc ISMRM 2013, 1488. [3] Kaza E. et al, in Proc ISMRM 2014, 4552.

Acknowledgements: EPSRC grant EP/H046410/1; CRUK and EPSRC Cancer Imaging Centre in association with the MRC and Department of Health (England) grant C1060/A10334, C1060/16464; NHS funding to the NIHR Biomedical Research Centre and the NIHR Clinical Research Facility. MOL is an NIHR Senior Investigator.