First clinical lung MRI using an Active Breathing Coordinator

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Introduction: An Active Breathing Coordinator (ABC) (Elekta Oncology Systems, Crawley, UK) is employed during lung radiotherapy to arrest respiration at a specific lung volume for a preset duration. An ABC apparatus adapted for MR use[1] was applied for the first time to lung MRI in patients with lung cancer. The patient positioning and ABC lung volumes used were the same as during treatment planning and radiotherapy, aiming to acquire MR images to aid treatment planning and response assessments.

	T1-VIBE	T2-HASTE	DW-EPI1	DW-EPI2	TRUFI
number of breath holds	1	4	2	3	-
breath hold duration (s)	17	16	17	16	-
number of slices	80	60	30	30	1
slice thickness (mm)	3	3	5	6	8
TR (ms)	4	1000	3300	4000	2.16
TE (ms)	0.94	100	45	62	1.08
FoV (mm^2)	270*360	261*380	258*376	259*377	360*360
matrix size	144*256	132*256	192*280	88*128	102*128
flip angle (°)	8	170	90	90	49
acceleration factor	GRAPPA 2	GRAPPA 2	GRAPPA 2	GRAPPA 2	GRAPPA 3
b-values (s/mm^2)	-	-	200	100, 400, 750	-
number of averages	1	1	2	1	1

Table 1. Parameters of the MR-ABC patient examination protocol

Materials and methods: Five lung cancer patients underwent MR-ABC lying supine with hands over their head in a 1.5T Siemens Aera, about two weeks after their planning CT scan. An identical positioning board was used and radiotherapy tattoos were aligned using lasers. T1, T2 and Diffusion-Weighted (DW) sequences with parameters shown in table 1 were applied in ABC-controlled breath holds at the same lung volume as set during CT. A dynamic true Fast Imaging with Steady-state Precession (FISP) (TRUFI) sequence with temporal resolution 145 ms was also acquired for 72s in free breathing with simultaneous recording of the ABC volume curve. An imaging session was completed in 20 min.

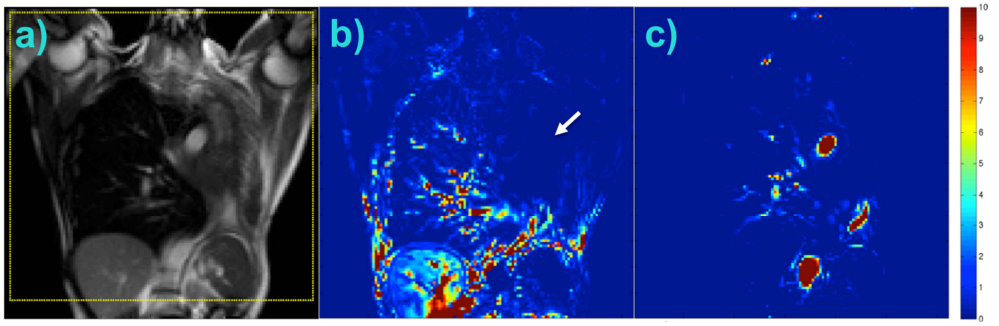

Figure 2. a) TRUFI image of a patient with collapse of the left lung, indicating in yellow the image region used for FDA. b) FDA ventilation map in the frequency range 0.27-0.32Hz, selected from the FFT of the ABC breathing curves. c) FDA perfusion map (1.48-1.49Hz). Both maps have the same color code.

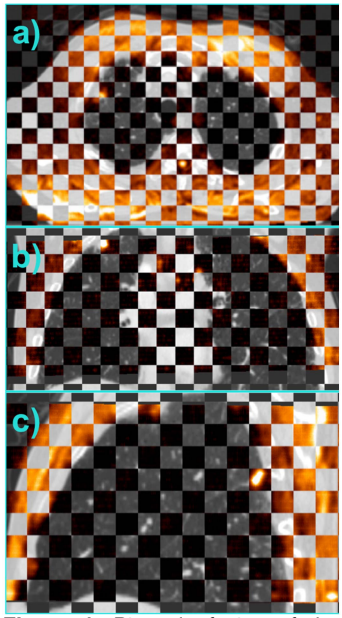

Figure 1. Pinnacle fusion of the DW-EPI1 (orange, day 14) and CT image (grey, day 0) of a patient with a spiculated lung mass in the right upper lobe and lymph-adenopathy. a) Axial, b) coronal and c) sagittal checkerboard view.

Results: All patients tolerated MR-ABC very well. Fusion of morphological or functional MR with CT images by applying a local correlation algorithm in the radiation treatment planning software Pinnacle[3] demonstrated very good agreement of the tumour and of anatomical landmarks between the two modalities in all three orientations. A MR-CT fusion example is displayed in figure 1. Dynamic TRUFI imaging allowed assessment of tumour motion with respiration. Moreover, Fast Fourier Transform (FFT) of the simultaneously acquired ABC volume traces revealed the respiratory frequencies, enabling selection of the frequency range for the production of ventilation maps using Fourier Decomposition Analysis (FDA)[2] after image registration, as shown in figure 2. The involved lung (arrow) is hypointense on the ventilation map, consistent with restricted ventilation in that area.

Discussion: The very good MR-CT intermodality agreement, even for small lesions and with a scan time difference of two weeks, indicates that MRI using ABC can accurately reproduce tumour positions. A combination of T1, T2 and DW sequences may identify and discriminate different pathological tissues, and thus provide additional information to CT. Continuous imaging using MR-ABC as a spirometer offers the possibility to relate tumour motion to respiratory phases and to select the ventilation frequencies for FDA. The FDA technique is currently under evaluation and may help to demonstrate lung ventilation and perfusion anomalies[3]. Overall, the morphological and functional information derived from MR-ABC may provide better delineation of lung tumours from the adjacent lung parenchyma to improve radiotherapy treatment planning and assessment.

Conclusion: The first MR-ABC application on lung cancer patients demonstrated very good agreement in tumour position with CT and the potential for continuous MRI with simultaneous spirometry to inform FDA.

References: 1. Kaza et al, Phys Med Biol, submitted. 2. Bauman at al, Magn Res Med 2009; 62:656-664. 3. Bauman et al, Eur J Radiol. 2013; 82:2371-7

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