

Adaptive respiratory triggering for high spatial and temporal resolution 3D DCE-MRI in the mouse.

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Introduction. Respiration induces motion artefacts that necessarily lead to increased noise levels along the timecourse of DCE-MRI data. It is recognized both in the preclinical[1] and clinical[2] imaging that respiration gating can improve DCE-MRI. In this work we describe a combination of techniques that allows us to acquire volumetric data with high temporal and spatial resolutions, which is insensitive to respiratory motion and which is appropriate for the examination of rapid uptake kinetics of Gd contrast agents. A respiratory triggered scan is run which uses dummy RF pulses during the respiratory movement period such that the T1 steady state is maintained between breaths. Imaging only takes place between breaths and the number of lines of data is variable and set according to the duration of the respiration cycle. Adaptive changes to both the number of dummy scans and the number of real scans to acquire per breath can be independently made to accommodate changes in respiration rate and depth.

Methods. MRI was performed at 4.7 T (Agilent VNMRs) and using a 25 mm id quadrature birdcage coil (Rapid). Mice are anaesthetised with isoflurane (1-3%) in air. Respiration was monitored using a pressure balloon interfaced to a signal generator unit (Biopac MP150 and DTU200) which generates a trigger pulse at the leading edge of the respiratory excursion. For fast imaging we use a T1-weighted 3D gradient echo scan with RF and gradient spoiling, but run without slice selection. This allows us to achieve TE=0.65 ms and TR=1.3 ms. A 128x64x64 pixel matrix covered the entire volume of the RF coil and gave a nominal isotropic resolution of 0.42 mm. Following each respiratory trigger signal a block of dummy scans is run followed by a block of real acquisition lines. The number of dummy and real scans is user selectable and both can be changed on-the-fly during the scan in response to changes in the respiration rate and depth, and with a latency of one breath. Most of the dummy scanning is performed during the respiratory movement, during which time data should not be acquired, and the duration of the real scanning is set so that it ends just before the next breath occurs. This maximises the data collection rate and allows regeneration of the T1 steady state following the hiatus that occurs between each breath such that we do not simply replace motion artefacts with T1-related artefacts. Because the sequence duration is dependent upon the instantaneous respiration rate the sequence also generates timestamps for the k=0 data lines so that data can be correctly spaced for dynamic analysis. In the absence of triggering the scan time is 5.32 s, and this increases to ca. 8-9 s with triggering though this is variable depending upon the instantaneous respiration rate. To demonstrate the technique a DCE-MRI scan was run which interleaved triggered and non-triggered acquisitions such that the level of motion artefact could be compared directly and within the same delivery of contrast agent. For demonstration of the benefit of the triggering, 50 pairs of triggered and non-triggered scans of the thorax and abdomen were acquired with contrast agent (Omniscan, 30 ul) infused after the 10th pair of scans. Improved image quality was measured by comparing the average signal to noise of each pixel for data points 15 to 50 on the timecourse (so as to avoid the initial increase as the Gd washes in).

Results and discussion.

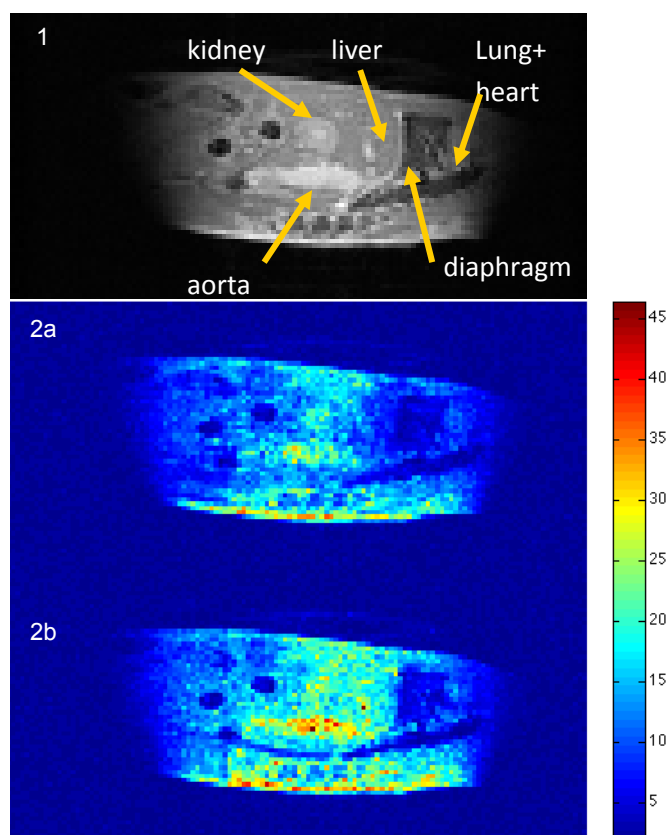


Fig 1 shows a single slice through the centre of the body with anatomical labels.

Fig 2 show maps of the average signal-to-noise along the timecourse from images 15-50. The triggered scan (2b) show higher and more homogeneous signal-to-noise, and shows more complete anatomical features than the non-triggered scan (2a). Note in particular that the liver signal is homogeneous right up to the diaphragm in Fig 2b. The aorta and lungs are clearly identifiable in the respiratory gated scan and show low signal-to-noise due, largely, to cardiac pulsation, a feature that can be used to highlight these tissues.

The interleaving of the triggered and non triggered scans provides a simple method to the comparison of techniques to be used in DCE-MRI scanning and can be performed so long as the time penalty compared to running separate scans is acceptable. However, the benefit of comparing DCE-MRI techniques in the same tissue at the same time during the same bolus transit will often outweigh this cost

Conclusion. The interleaved method scanning has been successfully deployed to assist with development and validation of improved DCE-MRI methods, and reduction of motion artefact in DCE-MRI is achieved through the use of adaptive, user-controlled, rather than static, triggering.

References. 1. Barck et al Proc. ISMRM 2011. Abstr 973. 2. Lin et al. Magn. Reson. Med. 2008 Nov;60(5):1135-46.