Slice ordering for cardio-respiratory triggered imaging of the whole liver in the mouse

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Introduction

In preclinical respiratory-triggered MRI it is now quite usual to acquire data from one or more lines of k-space from one or more slices following each trigger event[1]. In preclinical cardio-respiratory triggered MRI it is more usual to acquire lines from a single slice following each trigger[2]. In this report we describe a combined slice-ordering and cardio-respiratory triggering scheme that gives motion artefact free images for the whole liver in the mouse. We show that this scheme is appropriate for reducing the imaging time and for the examination of tumour growth over the entire volume of the liver in a mouse model of metastatic cancer.

Methods

MRI was performed at 4.7 T (Varian VNMRS) using a 40 mm quadrature birdcage coil (Rapid). Animal experiments were performed in accordance with ASPA regulations. Anaesthesia was induced and maintained with 1-3% isoflurane in oxygen. Respiration was monitored using a pressure balloon placed beneath the animal and ECG using subdermal electrodes placed under the shoulders. Triggering signals were generated using a Biopac MP150 controller and DTU200 trigger unit.

Previous experiments[3] have shown that a 2-echo CPMG sequence with TEs of ca. 10 and 20 ms is adequate for the detection of this type of liver metastasis. This sequence was run with 256x256 image points covering a FOV of 32x32 mm, giving an in place resolution of 125x125 microns, using 64 contiguous axial slices each 300 microns thick. This number of slices ensured each slice was fully relaxed before subsequent excitations. Respiration was maintained at 30-50 breaths per minute and the cardiac R-R interval was stable at around 130-160 ms. The number of cardiac triggers utilised per breath was adjusted manually so that the maximum number of cardiac triggers were used per respiratory cycle and so that respiratory cycle overruns were avoided. Each slice acquisition lasted ca. 30 ms, meaning that we could acquire up to 4 slices per cardiac cycle. In this work we only acquired two slices to ensure that no cardiac cycle overruns were encountered. The slice ordering was arranged such that the first slice acquired immediately after the cardiac trigger was in the top half of the liver, proximal to the heart, and the second slice was in the bottom of the liver and distal to the heart. Normal slice interleaving was imposed on top of this trigger interleaf so the slice order was 1,33,3,35…..2,34, 4,36….. where data from slices 1-32 were acquired immediately after the trigger events. This double interleaving ensures that volumes of tissue proximal to the heart have a higher quality cardiac triggering than distal regions, and so that adjacent slice overlap problems are avoided.

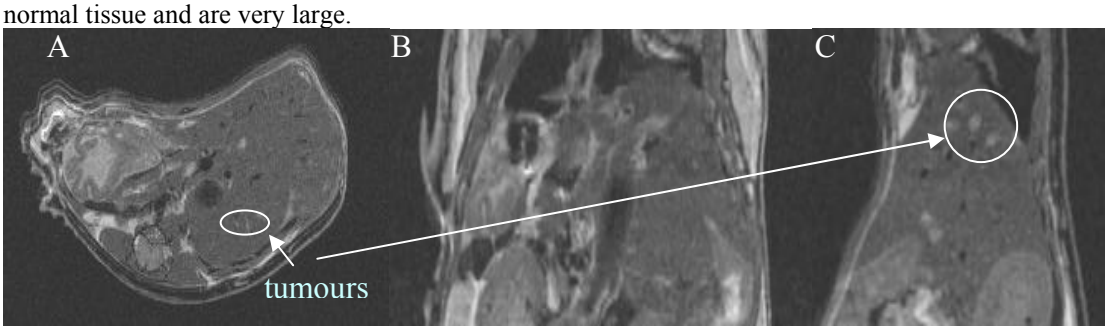
The scan time, including animal preparation/recovery and MRI calibrations was below one hour per animal.

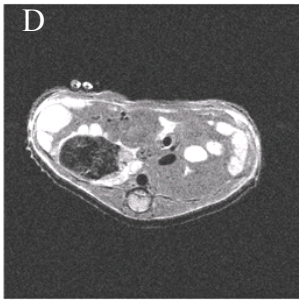
Liver metastasis was induced by intrasplenic injection of $5x10^5$ B16F1 -GFP cells followed immediately by splenectomy. Mice were imaged at days 6, 8, 10 and 12 following tumour generation and all mice recovered from anaesthesia without incident.

Results

Fig A shows the axial images acquired at 6 days post tumour seeding (when the tumours are least well developed), and Figs B and C show the orthogonally resliced coronal and sagittal images respectively. Neither motion artefact nor stepping artefact between adjacent slices are apparent. Images acquired in the absence of cardiac triggering show severe motion artefact in the vicinity of the heart, and aortic ghosting throughout the entire liver volume.

Metastatic tumours are visible at this resolution either as large, well defined blobs, or as fine streaks aligned along major blood vessels. Threshold-based tumour volume measurements are in progress. At later times, Fig D, the tumours are very well contrasted from the normal tissue and are very large.





Conclusion

Redistribution of the slice ordering, in conjunction with the acquisition of data from multiple slices per cardiac trigger allows the production of high-resolution images of the entire liver volume within an acceptable imaging time, and motion artefacts are not evident, even in the orthogonal views indicating the success of this acquisition scheme.

By distributing the quality of triggering, by rearranged slice ordering according to the expected cardiac and respiratory motions, we can shorter scan times without compromising the image quality, and this has been applied for high-resolution, whole liver imaging in the mouse.

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