High-field MRI for Non-invasive Preclinical Imaging in Free-breathing Mice

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INTRODUCTION

Mouse models of cancer are an invaluable tool for studying the disease and new therapies. T2-weighted MRI is one of the more effective clinical methods for following cancer, but in mice, the smaller size and faster physiological motion make it particularly challenging. Additionally, at higher magnetic fields necessary for these studies, T2* and T2 are shorter while T1 is longer, making T2-weighted imaging even more difficult. We have implemented a technique based on PROPELLER [1] MRI that satisfies the requirements of preclinical cancer imaging; high spatial resolution, good soft tissue differentiation, excellent motion immunity, fast and non-invasive imaging to enable high-throughput, longitudinal studies.

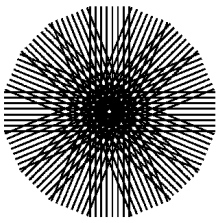

Figure 1: k-space trajectory

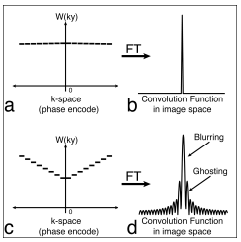

Figure 2: T2-weighting function and its FT. (a, b) conventional spin echo (c, d) multi-echo spin echo.

METHODS

Imaging was carried out on a 7T GE Signa Scanner with high performance gradient coils. Data was acquired along the PROPELLER (Fig. 1) trajectory with a multi-slice, multi-echo sequence using the 2-shot acquisition technique [2]. For an artifact-free reconstruction, T2-weighting along the phase-encoding direction (W(ky)) must be constant (Fig. 2 a, b). Multi-echo 2-shot PROPELLER acquisition, where each phase-encode line has its own echo time, results in discontinuous T2-weighting (Fig. 2c) giving rise to blurring and ghosting (Fig. 2d) [3]. An additional blade with no phase-encoding was acquired to derive W(ky) which was used to scale each of the data blades. Figure 3 outlines the data acquisition and reconstruction process. Mice were anesthetized using Isoflurane but were breathing on their own.

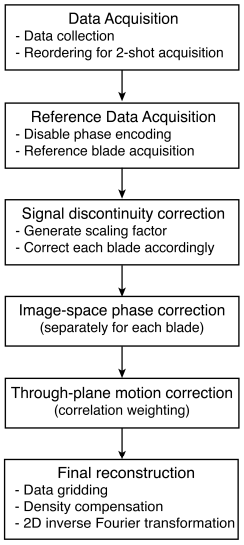

Figure 3: Data acquisition and reconstruction flow

RESULTS AND DISCUSSION

Oversampling in the center of k-space provides inherent motion insensitivity and motion correction ability. In Fig. 4, where respiratory and cardiac motion cause severe ghosting in the Cartesian FSE while the PROPELLER image is free of artifacts. High-field imaging enables higher spatial resolution. High performance gradient coils enable shorter ESP, which reduces signal losses characteristic. Finally, the 2-shot acquisition helps maintain high SNR. Figure 5 illustrates the benefits of correction for the discontinuous T2-weighting. Note the signal drop-off (arrows) in the muscles in Fig. 5a, which is absent in Fig. 5d where the low-frequency information is retrieved by the correction technique. In column 2, the tiny lung lesion (arrow) is visible only after the high-frequency noise (streaking artifacts) caused due to discontinuous T2-weighting has been removed. Figure 5c, 5f show improvement in both the low-frequency (liver parenchyma) and the high-frequency (peripheral vasculature) components of the image.

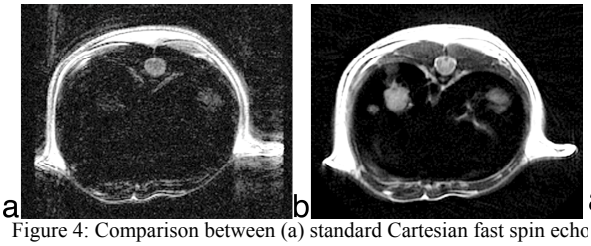

Figure 4: Comparison between (a) standard Cartesian fast spin echo and (b) 2-shot PROPELLER. Multi-slice datasets with similar imaging parameters were acquired in a free-breathing mouse at 7T. 117µm in-plane, 1mm slice thickness (21 slices), TE/TR/BW = 68ms/3s/125kHz, ETL = 10, imaging time ~ 13 minutes.

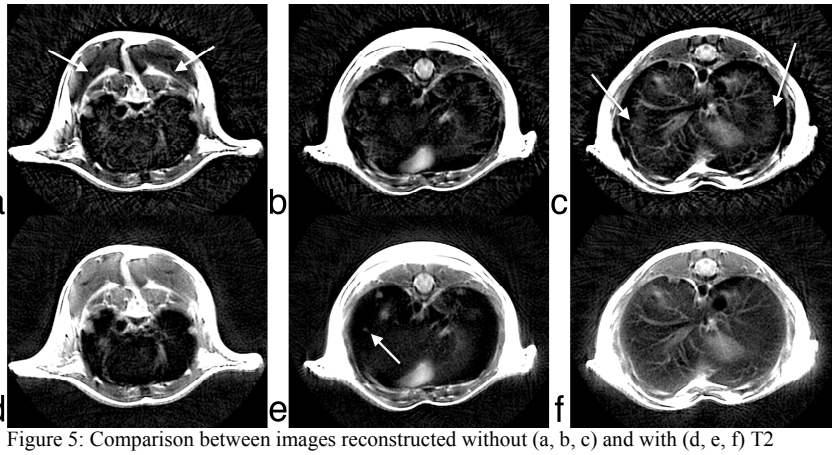

Figure 5: Comparison between images reconstructed without (a, b, c) and with (d, e, f) T2 discontinuity correction. Each column shows a different slice from a multi-slice dataset acquired in a free-breathing mouse. 117µm in-plane, 1mm slice thickness (21 slices), TE/TR/BW = 68ms/3s/125kHz, ETL = 10, imaging time ~ 40 minutes. Arrows point to specific aspects in the slice that show improvement due to the correction algorithm.

Figure 6 shows the results of a longitudinal experiment. Arrows track the same lesion, which grows from 0.1mm^3 (day 1) to 0.38mm^3 (day 12), and 0.71mm^3 (day 23).

CONCLUSION

High-resolution, non-invasive T2-weighted imaging in free-breathing mice is made possible with 2-shot PROPELLER MRI at high-fields. The unique technique overcomes the adverse effects of physiological motion and provides excellent tissue contrast. Rapid setup and acquisition (~40 minutes) makes this technique ideal for high-throughput, longitudinal studies.

REFERENCES [1] Pipe JG (1999) MRM 42(5): 963-969
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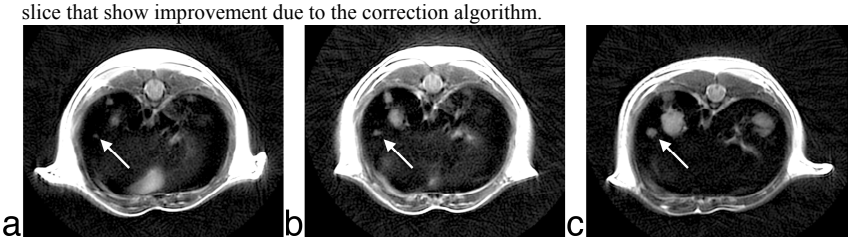

Figure 6: Lung tumor images from a free-breathing mouse acquired over three timepoints. 117µm in-plane, 1mm slice thickness (21 slices), TE/TR/BW = 68ms/3s/125kHz, ETL = 10, imaging time ~ 40 minutes. (a) day 1, (b) day 12, (c) day 23. Arrows tracks the growth of the same lesion.