# Abdominal imaging in free-breathing mice using PROPELLER

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## INTRODUCTION

Mouse models of human cancer are an invaluable tool for studying the mechanism of the disease and the effects of new proposed therapies. T2-weighted and diffusion-weighted imaging has been shown to be effective for tumor visualization. But translation of these techniques to the mouse is challenging. The higher resolution and physiologic motion make conventional approaches very susceptible to phase artifacts. At higher magnetic fields required for these studies, T2* and T2 are significantly shorter, while T1 is longer. Thus, the requirements for *in vivo* cancer imaging in mice, especially for abdominal imaging are: immunity to cardiac and respiratory motion; short TE to minimize T2* decay; and short scan time with long TR to maximize T1 recovery. In this work, we have implemented a Periodically Rotated Overlapping ParallEL Lines with Enhanced Reconstruction (PROPELLER) [1] sequence on a 7T scanner with high-performance gradient coils to acquire abdominal images in free-breathing mice.

## METHODS

All animal procedures were approved by the Duke Institutional Animal Care and Use Committee. Mice were anesthetized using Isoflurane delivered by nose cone. The animals were breathing on their own and all physiologic signals were monitored continuously (SA Instruments Inc., Stony Brook, NY). Imaging was carried out on a 7T GE Signa Scanner that uses high duty cycle gradient coils (Resonance Research Inc., Billerica, MA) with maximum gradient strength of 770mT/m and rise time of 100µs. The PROPELLER sequence was implemented as a multi-slice multi-echo sequence on the GE EPIC Lx12M4 software. Images were acquired at a receiver bandwidth of 125KHz, TR = 3000ms, FOV = 5cm and slice thickness = 1mm. The view ordering within a blade (red in Figure 1), as well as the number of lines per blade (ETL), were varied to obtain different effective TE and hence, T2-weighting. The number of blades per image was calculated as $\lceil$image resolution x $\pi/2$ / ETL$\rceil$. Images were reconstructed in MATLAB using a convolution gridding algorithm [2] with an analytical density compensation function based on the symmetric blade geometry of the PROPELLER trajectory.

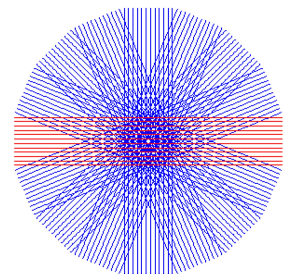

**Figure 1:** K-space Trajectory

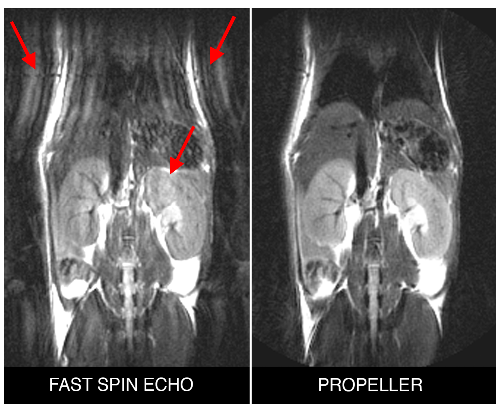


**Figure 2**: Identical slices from a free-breathing mouse acquired with a standard FSE and the PROPELLER sequence at 7T. TR/TE = 3s/58ms, ETL = 24 with ~5ms echo spacing. In-plane resolution is 195µm x 195µm; slice thickness is 1mm. Acquisition time < 10 minutes.

## RESULTS AND DISCUSSION

Figure 1 shows the k-space trajectory used in the PROPELLER sequence. The oversampling of the central region provides inherent motion insensitivity and motion correction ability. This is illustrated in Figure 2, where respiratory and cardiac motion cause severe ghosting (arrows) in the Cartesian FSE image, while the dataset acquired with PROPELLER is artifact-free.

Echo spacing as low as 4.6ms was achieved due to the high-performance gradient coils. This minimized T2* decay, thus providing better T2-weighting. Multi-slice, multi-echo implementation of PROPELLER allowed a long TR without significant increase in scan time.

Figure 3 shows three identical slices from whole-body multi-slice datasets acquired with effective echo times of 39ms, 52ms, and 79ms respectively. The T2 contrast enhancement within the renal cortex and the medulla can be clearly seen as the echo time increases (ovals).

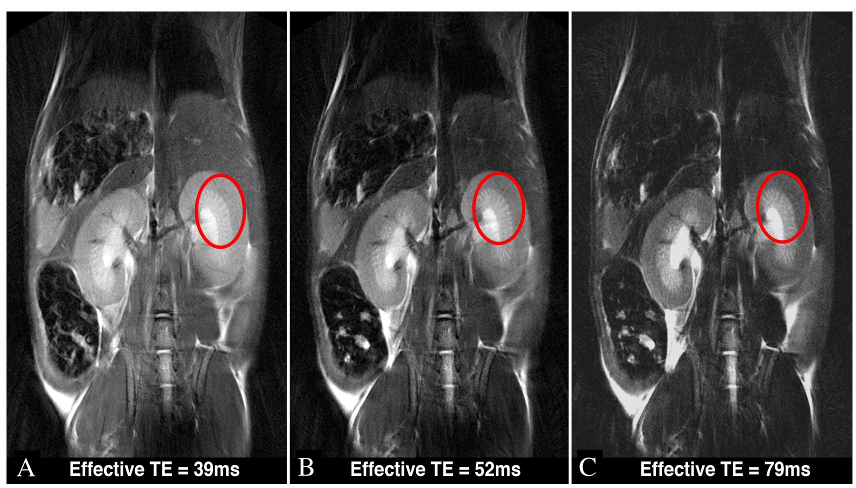


**Figure 3:** Coronal T2-weighted abdominal images of a free-breathing mouse acquired with a multi-slice PROPELLER sequence. TR/ESP = 3s/6.4ms, BW = 125 KHz. In-plane resolution is 97µm x 97µm; slice thickness is 1mm. Acquisition time ~40 minutes. (A) ETL of 12 with 66 blades. (B) ETL of 16 with 50 blades. (C) ETL of 24 with 32 blades.

## CONCLUSION

The images show good spatial and contrast resolution in free-breathing mice. Artifacts in the PROPELLER images are considerably reduced relative to more conventional sampling. The short inter-echo spacing permits more heavily T2-weighted scans by minimizing susceptibility-induced losses. Work has begun on implementing PROPELLER-based diffusion-weighted imaging [3], which in conjunction with the described work, promises to be an invaluable tool for tumor visualization in mice.

## REFERENCES

[1] Pipe JD. (1999) *Magn Reson Med.* (42) 963-969
[2] O'Sullivan JD. (1985) IEEE TMI (4) 200-207
[3] Pipe JD. *Et al.* (2002) *Magn Reson Med.* (47) 42-52

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