Fast, High-Resolution, 3-Dimensional Imaging of the Mouse Prostate with bSSFP

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Introduction: Prostate cancer is the most frequently diagnosed malignant neoplasm in men. In our lab, we are interested in imaging the prostate in immune compromised mice for experimental studies of prostate cancer metastasis and cell based immunotherapy. The first step was to optimize the visualization of the prostate in mice. Imaging the mouse prostate is not trivial; it is approximately 3 mm in cross-section and has multiple lobes, which surround the urethra, and moves along with the bladder. Most reports of mouse prostate imaging have produced the best images using T2-weighted spin echo (SE) sequence with fat suppression. Very high resolution is required to delineate the specific lobes of the prostate. This has been achieved by Nastiuk et al., at 7 Tesla with T2w SE images at 117x117x200 micron resolution, however these images required a scan time of 2.5hrs (1). In this paper we describe the first use of a balanced steady state free precession (bSSFP) imaging sequence on a clinical 3 Tesla scanner equipped with a high performance gradient coil insert for imaging the normal mouse prostate in 3D. Excellent in vivo mouse prostate images were produced at 200 micron spatial resolution in less than 30 minutes.

Methods: Male nude mice (nu/nu, 5-14 weeks old) were imaged in a clinical 3T GE scanner using a custom-built gradient-insert and RF coil. Mice were scanned using the 3DSSFP sequence with the flip angle (FA) and bandwidth (BW) varied. SSFP images were compared with T1w SE images and T2w SE with and without fat saturation (1 mm slice, 128x128 matrix, 234 micron in plane resolution, TR/TE=600/25ms (T1), 2000/70ms (T2), ~20min scan time). Muscle and prostate SNR, prostate to fat CNR and image artifact were used to evaluate image quality.

Results: Figure 1 shows a whole-body image of the mouse, which includes view of the prostate and adjacent lymph nodes. In Figure 2, three view s of the prostate are obtained from one 14-minute scan. Figure 3 compares axial views obtained with bSSFP, T1w SE and T2w SE sequences.

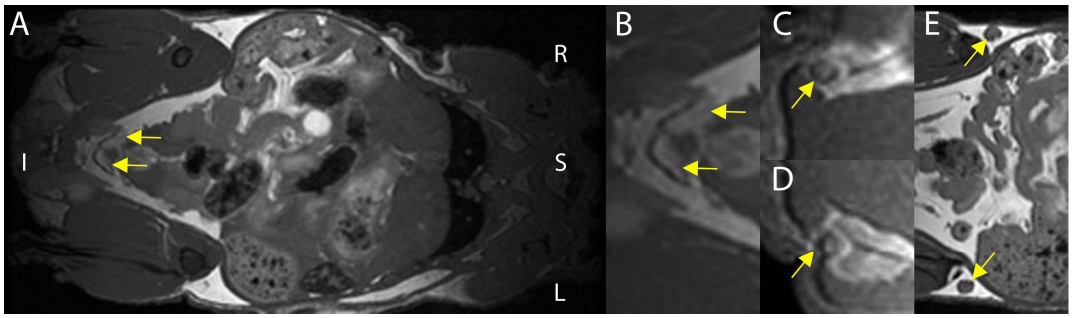


Figure 1: Whole-body mouse image acquired with bSSFP. A) Whole body in plane of prostate, B) enlargement of prostate image, enlargement of right C) and left D) popliteal lymph nodes, E) enlargement of inguinal lymph nodes. Arrows indicate structure of interest for each panel. Parameters: coronal acquisition, TR/TE= 4.6/2.3ms, 6x3.3cm FOV, 200x200x200µm, FA 40º, BW 62.5 kHz, 2 NEX, 8 phase cycles, 26 minutes. SNR=34, CNR=57.

Figure 2: 3D FIESTA images can be re-oriented to clearly visualize the prostate (yellow arrows) from any angle. A) axial, B) coronal, C) sagittal. Parameters: axial acquisition, TR/TE=3.6/1.8ms, FOV 3x3cm, 200x200x200µm, FA 50º, BW 62.5 kHz, 2 NEX, 4 phase cycles, 14 min. SNR=21, CNR=77.

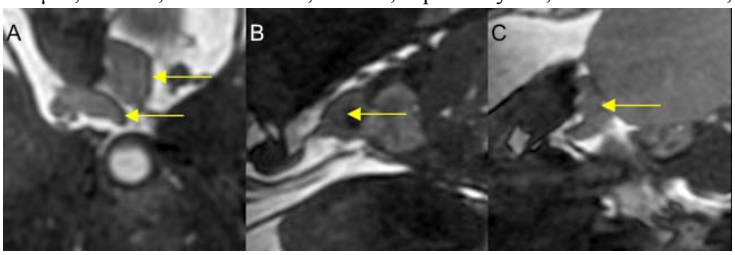
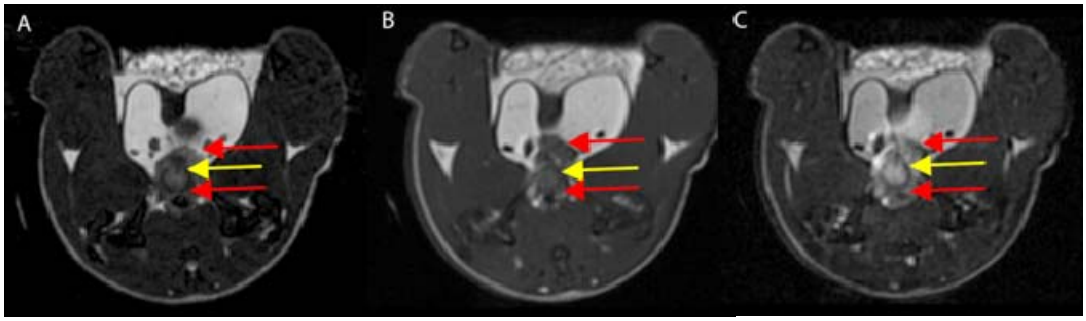


Figure 3: Comparison of axial views acquired with bSSFP (A), T1w SE (B) and T2w SE (C). Red arrows indicate prostate, yellow arrows indicate urethra. Scan parameters for bSSFP as in Figure 2, for T1w SE and T2w SE as in methods. SNR for bSSFP, T1w SE and T2WSE is: 22, 40 and 24, and CNR is 81, 54 and 16. Recall that the slices are 0.2 mm thick for bSSFP and 1 mm thick for T1- and T2w SE scans when comparing SNR. As such, there are 5 slices containing the prostate in the 2-dimensional scan, while the bSSFP scan has over 30.



Conclusions: The bSSFP imaging sequence allows for 3D high resolution imaging of the whole mouse body with high SNR and CNR. The ability to acquire very high resolution images with high SNR in reasonable scan times permits clear visualization of the distinct lobes of the mouse prostate along with the nearby popliteal and inguinal lymph nodes, which will be important for investigating prostate cancer metastasis. The 3D nature allows for measurements of prostate and node volumes, which are expected to change with cancer and in response to immunotherapy. The CNR and SNR normalized to slice thickness are superior for bSSFP compared to T1w SE and T2w SE scans. Future work in our lab, which will focus on tracking iron-labeled immune cells in a mouse prostate cancer model, will benefit from the use of bSSFP imaging since this sequence is also extremely sensitive to intravoxel dephasing caused by the presence of iron labeled cells.

References: 1. Nastiuk K.L. et al. BMC Urology 2007, **7**:12