Multiband Slice Accelerated TSE for High Resolution Knee Imaging

Dingxin Wang[1,2], Abraham Padua Jr[3], Jutta Ellermann[2], Xiufeng Li[2], Kamil Ugurbil[2], and Vibhas Deshpande[4]
[1]Siemens Medical Solutions USA, Inc., Minneapolis, MN, United States, [2]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States, [3]Siemens Medical Solutions USA, Inc., Houston, TX, United States, [4]Siemens Medical Solutions USA, Inc., Austin, TX, United States

Purpose: Turbo spin echo (TSE) is the most widely utilized sequence for clinical musculoskeletal (MSK) imaging, including the knee. TSE sequences are used to generate T1, proton density (PD), and T2 weighted contrasts with high image quality. Due to multiple refocusing RF pulses and echoes, the minimum TR of TSE sequences can be long, even for limited numbers of slices and moderate echo train length (ETL). Despite TSE's efficient acquisition schemes, typical high resolution clinical TSE knee imaging can still take as long as 4-5 minutes for each contrast and imaging plane, respectively. In-plane parallel imaging can improve acquisition speed through k-space under-sampling. However, SNR loss induced by signal under-sampling and the g-factor noise amplification prohibit a high parallel imaging acceleration factor, especially given that SNR may be limited with the very high spatial resolution required for MSK applications. Recently developed multiband slice acceleration techniques, which simultaneously excite, acquire, and reconstruct multiple slices [1-3], can reduce volume acquisition time (TR), and may be extended to SE/TSE imaging [4]. While slice acceleration allows more slices per TR or permits shorter TR and/or longer ETL for the same slice coverage, there is no signal under-sampling associated SNR loss. In addition, with multi-slice CAIPIRINHA for controlled aliasing [2], the g-factor penalty may be reduced. In our study, we demonstrate a new multiband slice accelerated TSE sequence with gradient based CAIPIRINHA [5] and compare it to a traditional TSE approach for high resolution clinical knee imaging at 3T.

Methods: Knee imaging was performed on 3 subjects using a 3T Siemens MRI scanner (MAGNETOM Trio; Siemens Healthcare, Erlangen, Germany) with an 8-channel transmit-receive knee coil (Invivio, Orlando, FL). Multiband RF pulses were generated for simultaneous multi-slice excitation and echo refocusing. A low resolution multislice 2D GRE scan (TA $\approx$ 6 seconds) was used as the reference scan to obtain the coil sensitivities [4]. Imaging parameters for the TSE scans were as follows: FOV = 150×150 mm^2, matrix size = 384×384, slice thickness = 2.5 mm, voxel size = 0.39×0.39×2.5 mm^3, total 34 slices, 10% slice spacing, 100% phase oversampling, excitation/refocusing flip angle = 90º/150º, readout bandwidth = 200-303 Hz/pixel, echo spacing = 9.3-10.2 ms, iPAT acceleration factor = 2, 2 averages; **Multiband Slice Accelerated TSE:** slice acceleration factor = 2, CAIPIRINHA FOV shift factor = 2; <u>T1-W:</u> TR/TE = 592/9.3 ms, ETL = 3, TA = 2:35 min; <u>PD-W:</u> TR/TE = 3000/37 ms, ETL = 16, TA = 2:12 min; <u>PD-W with spectral fat saturation:</u> TR/TE = 3000/37 ms, ETL = 12, TA = 2:48 min; **Standard TSE:** <u>T1-W:</u> TR/TE = 693/9.3 ms, ETL = 3, 2 concatenations, TA = 5:23 min; <u>PD-W:</u> TR/TE = 3420/37 ms, ETL = 10, TA = 4:30 min; <u>PD-W with spectral fat saturation:</u> TR/TE = 4580/37 ms, ETL = 12, TA = 4:55 min. Due to an absence of slice encoding capability of the 8-channel knee coil along the foot-head direction, axial multiband TSE images were not evaluated. Image reconstruction was performed online at the console.

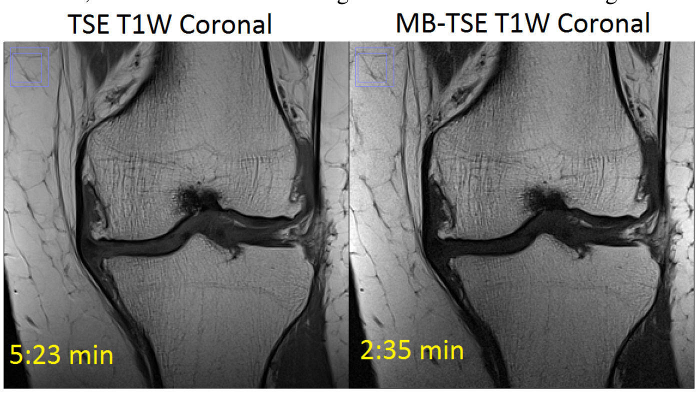

Figure 1. Representative coronal TSE and MB-TSE T1-weighted images of the knee showing identical detail of the trabecular bone architecture.

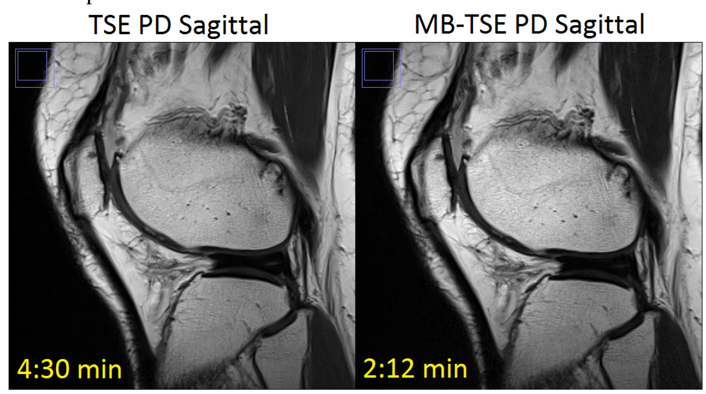

Figure 2. Representative sagittal TSE and MB-TSE PD-weighted images of the knee. With 50% reduction in time, the MB-TSE image provides almost identical information to the standard TSE image.

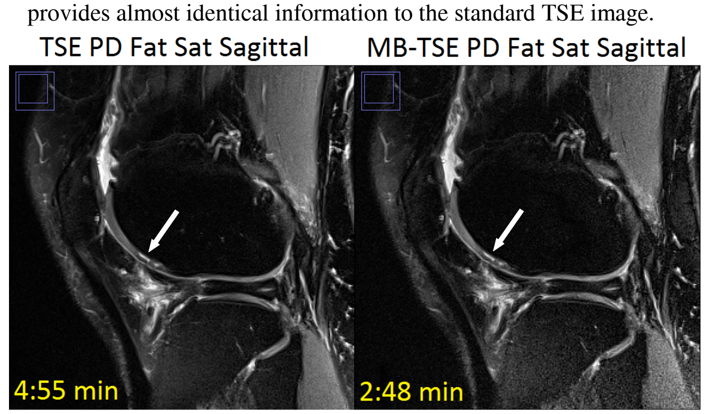

Figure 3. Representative sagittal TSE and MB-TSE PD-weighted knee images with fat saturation, showing similar results. On both images, a focal area of cartilage abnormality in the weight-bearing aspect of the lateral femoral condyle is depicted (arrow).

Results: All multiband slice accelerated TSE sequences executed and reconstructed successfully. The efficient local transmit-receive knee coil ensured that the multiband TSE scans were within the SAR safety limit, even with the shortest Siemens equipped RF pulse. With reduced total acquisition time, the multiband TSE sequence demonstrates similar results as a standard TSE sequence in T1-W (Fig. 1), PD-W (Fig. 2), and PD-W with fat saturation (Fig. 3) contrasts. There is no visible artifact or residual aliasing in the reconstructed images. The image contrasts are very similar between the corresponding standard TSE and slice accelerated TSE scans.

Conclusion: Our study demonstrates the clinical application of multiband slice accelerated TSE combined with in-plane parallel imaging for high resolution knee imaging at 3T, achieving a total of 4 times acceleration using an 8-channel knee coil. Multiband slice acceleration improves the acquisition efficiency of TSE. Future studies need to evaluate the diagnostic accuracy of multiband slice accelerated TSE.

References: [1] Larkman, JMRI 2001 [2] Breuer MRM 2005 [3] Moeller, MRM 2010 [4] Wang, ISMRM 2013 [5] Setsompop MRM 2012

Acknowledgements: Grant support from NIH P41 EB015894