10 minute isotropic MRI of the knee using accelerated 3D SPACE with incoherent undersampling and iterative reconstruction: Comparison with standard 2D TSE MRI

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Purpose

The accepted standard in musculoskeletal MRI are 2D TSE sequences. While similar diagnostic performance of knee MRI was found for a 3D TSE-type (SPACE) sequence [1], the acquisition of high resolution isotropic 3D data can be time-consuming and may conflict with available magnet time. We therefore prospectively tested the hypothesis that a knee protocol consisting of SPACE sequence prototypes with implementation of k-space undersampling and iterative reconstruction can result in substantially faster acquisition times, but image quality similar to 2D TSE sequence protocols.

Methods

15 volunteers underwent 3T MRI (MAGNETOM Skyra, Siemens Healthcare) (Figure 1) using a transmit/receive 15 channel knee coil (QED, Mayfield Village, OH, USA)., including standard sagittal, coronal and axial non-isotropic intermediate-weighted 2D TSE (TR, 4300 ms; TE, 33 ms; pixel size, 0.5 x 0.5 mm²; SL, 2.5 mm; total acquisition time (TA), 10 min) and T2-weighted fat-saturated 2D TSE (TR, 4000 ms; TE, 51 ms; pixel size, 0.6 x 0.6 mm²; SL, 3 mm; total TA, 10 min) sequences as well as an isotropic sagittal intermediate-weighted accelerated SPACE sequence prototype (TR, 900ms; TE, 31; voxel size, 0.5x0.5x0.5 mm³; MPR SL, 2.5 mm; TA, 4:45 min) and an isotropic sagittal T2-weighted fat-saturated accelerated SPACE sequence prototype (TR, 900ms; TE, 86ms; voxel size, 0.6x0.6x0.6 mm³; MPR SL, 3 mm; TA, 4:55 min) (Figure). The accelerated SPACE sequence was equipped with an optional variable-density Poisson-disc pattern as an undersampling mask [2]. An undersampling factor of 0.2 was chosen (5-fold acceleration compared to an acquisition with full sampling). An iterative, SENSE-type reconstruction with L1-Norm-based regularization term as in reference [3] was used. Three fellowship-trained, full-time musculoskeletal radiologists graded the overall diagnostic quality, artifacts, blurring, fat saturation, and visibility of cartilage, menisci, ligaments and tendons using standardized 5-point Likert scales. Qualitative and quantitative measurements were statistically analyzed using non-parametric tests. P values of less than 0.05 were considered significant.

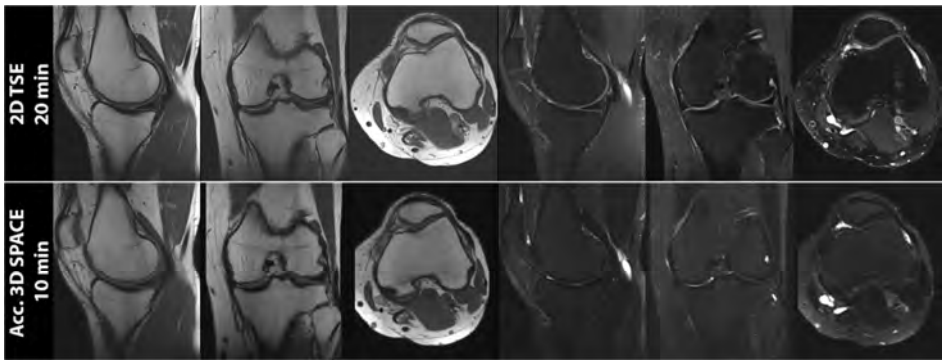

Fig.: Comprehenisve high-spatial resolution MRI protocol of the knee in a 44 year old man. The top row shows sagittal, coronal, and axial intermediate-weighted and fat saturated T2-weighted 2D TSE images. The bottom row shows sagittal, coronal, and axial reconstructions from intermediate-weighted and fat saturated T2-weighted 3D SPACE sequences with acceleration of acquisition times though k-space undersampling and iterative reconstruction. The total acquisition time of the 2D and 3D protocol is given.

Results

The overall diagnostic quality, fat suppression and visibility of cartilage, menisci, ligaments and tendons was good to excellent with no statistically significant difference between 3D SPACE and 2D TSE images (p=0.192-0.749). 2D TSE images had mild vascular flow artifacts, whereas there were no flow artifacts on the accelerated 3D SPACE MRI (p<0.05). Blurring was absent on 2D TSE images and mildly present on accelerated SPACE images (p<0.05).

Discussion

Our data demonstrate that isotropic SPACE data acquisition with pseudo-random k-space undersampling and iterative reconstruction allows for a substantially accelerated clinical 3D MRI of the knee with image qualities that can be similar to standard 2D TSE images. Aliasing artifacts seen in standard 3D imaging with high acceleration factor are mitigated by high undersampling combined with L1-Norm-based regularization in the wavelet domain [1]. The regularization counteracts noise amplification that can occur when using high acceleration factors with conventional parallel imaging techniques.

Conclusion

We demonstrate the successful implementation of k-space undersampling and iterative reconstruction for an accelerated, comprehensive, high spatial resolution 3D SPACE MRI protocol of less than 10 min. Initial results suggest image quality similar to standard 2D TSE images and the potential to replace a more time-consuming 20 min standard 2D TSE MRI protocol.

References

[1] Notohamiprodjo et al., EJR 81: 3441– 3449 (2012); [2] Liu et al., Proc Intl Soc Mag Reson Med, #2237, (2012); [3] Li et al., Proc Intl Soc Mag Reson Med, #3711, 2012.