CAIPIRINHA acceleration enables rapid high-spatial-resolution isotropic 3D SPACE of the knee: Comparison with conventional SPACE and 2D TSE

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Purpose

While 2D turbo spin echo (TSE) MRI is standard in musculoskeletal MRI, similar diagnostic performance of MRI of the knee was shown for a 3D TSE-type (SPACE) sequence [1] using a 10:44-min high-spatial-resolution protocol 0.6 × 0.5 × 0.5 mm³ (PAT 2) [2]. We prospectively test the hypothesis that the 2D CAIPIRINHA technique [3] implemented into a SPACE sequence prototype can accelerate data acquisition, thereby achieving similar diagnostic quality in the knee as 2D TSE and standard 3D SPACE sequences.

Methods

20 healthy volunteers underwent 3T MRI (MAGNETOM Skyra, Siemens Healthcare) (Figure 1) using a TX/RX 15-channel knee coil (QED, Mayfield Village, OH, USA), including non-isotropic axial, sagittal and coronal 2D TSE sequences (TR, 4300 ms; TE, 33 ms; pixel size, 0.5 x 0.5 mm²; SL, 2.5 mm; total acquisition time, 10 min), an isotropic sagittal 3D SPACE sequence (TR, 900ms; TE, 23ms; voxel size, 0.5 mm³; MPR slice thickness (SL), 2.5 mm; GRAPPA, 2-fold acceleration; TA, 11 min), and an isotropic sagittal 3D CAIPIRINHA SPACE sequence prototype (TR, 900ms; TE, 23; voxel size, 0.5 mm³; MPR SL, 2.5 mm; CAIPIRINHA 2x2 – shift 1; TA, 5:01 min). The CAIPIRINHA technique enhances parallel imaging results based on a more efficient use of the coil sensitivities and thus allows for higher SNR compared to conventional GRAPPA/SENSE [4]. Figure 2 shows the undersampling patterns for a) GRAPPA/SENSE 2, b) GRAPPA/SENSE 2x2, and c) a CAIPIRINHA 2x2 variant. Three fellowship-trained, full-time musculoskeletal radiologists graded the overall diagnostic quality, artifacts, blurring, 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.

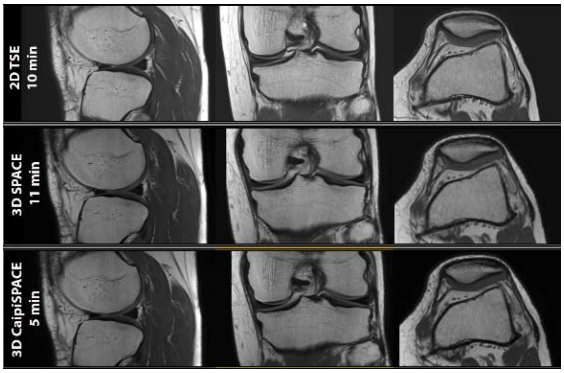

Fig. 1: 2D and 3D MRI of the knee in a 44-year-old man. Top row: sagittal, coronal, and axial 2D TSE images. Middle row: sagittal, coronal, and axial SPACE (PAT2) reconstructions. Bottom row: sagittal, coronal, and axial CAIPIRINHA SPACE (PAT2x2 – shift 1) reconstructions.

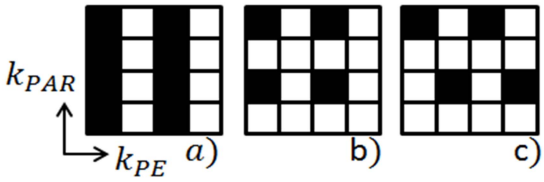

Fig. 2: From left to right: undersampling patterns for a) GRAPPA/SENSE 2, b) GRAPPA/SENSE 2x2, and c) CAIPIRINHA 2x2, shift 1.

Results

The overall diagnostic quality and visibility of cartilage, menisci, ligaments and tendons was good to excellent with no statically significant difference (p=0.348 - 0.891) between the different sequences. 2D TSE sequence had mild vascular flow artifacts, whereas there were no flow artifacts on 3D SPACE MR images. Blurring was absent to mildly present with no statically significant difference (p=0.233).

Discussion

Our data show that 3D MRI data acquisition with the CAIPIRINHA technique allows for substantial acceleration with diagnostic image quality similar to standard sequences. The advantages of a CAIPIRINHA pattern (with shift) compared to a GRAPPA/SENSE pattern without shift have been shown recently in VIBE data [4], and for MRA data [5]. We demonstrate the feasibility of 2x2 CAIPIRINHA acceleration of a 3D SPACE sequence and our initial results demonstrate that 4-fold accelerated SPACE MR images may be suitable to replace more time consuming 2-fold accelerated SPACE and three-plane 2D TSE MRI.

Conclusion

High-spatial-resolution MRI of the knee with a 5-min isotropic CAIPIRINHA SPACE sequence can achieve MR images with diagnostic image qualities similar to 11-min standard SPACE and 10-min standard three plane 2D TSE MRI.

References

[1] Mugler et al., Radiology 216:891–899 (2000) ; [2] Notohamiprodjo et al., EJR 81: 3441– 3449 (2012); [3] Breuer et al., MRM 55: 549-956 (2006); [4] Wright et al., JMRI 39: 189–194 (2014); [5] Bi et al, Proc Intl Soc Mag Reson Med, # 2945 (2012).