Case Report: Evaluation of Simultaneous Multi-Slice Accelerated TSE for Knee Joint MR Imaging

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Introduction

The turbo spin echo (TSE) sequence is one of the most utilized sequences in clinical routine MRI, providing high image quality, strong lesion conspicuity and multiple tissue contrasts (T1w, T2w, FLAIR and proton density-weighted (PD)). In musculoskeletal (MSK) imaging, TSE is widely used as it offers excellent depiction of cartilage, ligaments, menisci, and periarticular soft tissues. However, high spatial resolution with a large number of slices is rarely used clinically because of the prolonged acquisition time for complete coverage when using a conventional 2D-TSE sequence.

Simultaneous multi-slice (SMS) is a promising parallel imaging method to increase the acquisition speed without a significant decrease to the signal-to-noise ratio (SNR). SMS has been proved to work well with echo-planar imaging (EPI) readout for both diffusion-weighted and BOLD functional magnetic resonance imaging (fMRI). The SMS method excites multiple spatially distributed slices simultaneously using a multi-band (MB) radiofrequency (RF) pulse and separates the simultaneously acquired slices by parallel imaging reconstruction technique utilizing the multiple receiver coils sensitivities [1-4]. With integration of the 'controlled aliasing in parallel imaging result in higher acceleration' (CAIPIRINHA) method the *g*-factor related SNR penalty is significantly reduced [3, 7; also see articles by the same authors in this issue]. SMS allows an increase in the imaging coverage with higher spatial resolution and shorter acquisition time [2, 3, 5-7].

Several recent studies have addressed the possibility of applying the SMS method to TSE acquisition schemes [8-10]. In this study, we applied the SMS 2D-TSE sequences[1] with gradient-based CAIPIRINHA in MSK examination to assess its value for MSK related diseases.

Method

All MR scans were performed on a 3T MAGNETOM Verio system (Siemens Healthcare, Erlangen, Germany) with an 8-channel knee coil or a 4-channel flex coil. Sagittal T1-weighted TSE, sagittal, coronal and transverse PD-weighted TSE with fat suppression imaging were performed for the whole knee joint to compare the image quality of conventional TSE and SMS TSE sequences.

[1] The product is still under development and not commercially available yet. Its future availability cannot be ensured.

Imaging parameters include field-of-view (FOV) of 160 × 160 mm², matrix of 320 × 256, slice thickness of 3 mm with a gap of 10%, 36 slices, excitation/refocusing flip angle of 90/150°. Slice acceleration factor is 2 and FOV shift factor is 2 for all SMS TSE sequences. Matching imaging parameters including TR/TE and turbo factor were used for conventional and SMS TSE. For covering the 36 slices, SMS TSE used only half number of concatenations as conventional TSE. Sagittal T1w imaging was performed using TR 499 ms, TE of 13 ms and turbo factor of 3. Sagittal T1w imaging with fat saturation was performed using TR 573 ms, TE 13 ms and turbo factor of 3. All T1w imaging acquisitions used 4 concatenations for conventional TSE and 2 concatenations for SMS TSE. Sagittal PD-weighted imaging with fat saturation was performed using TR 3200 ms, TE 40 ms and turbo factor of 8. Coronal PD-weighted imaging with fat saturation was performed using TR 3200 ms, TE 40 ms and a turbo factor of 9. Axial PD-weighted imaging with fat saturation

Parameter	sag-T1	sag-T1+fs	sag-PD+fs	cor-PD+fs	tra-PD+fs
TR/TE (ms)	499/13	573/13	3200/40	3200/40	3200/41
ETL	3	3	8	9	10
Concatenation	4 (Conv.) 2 (SMS)	4 (Conv.) 2 (SMS)	2 (Conv.) 1 (SMS)	2 (Conv.) 1 (SMS)	2 (Conv.) 1 (SMS)

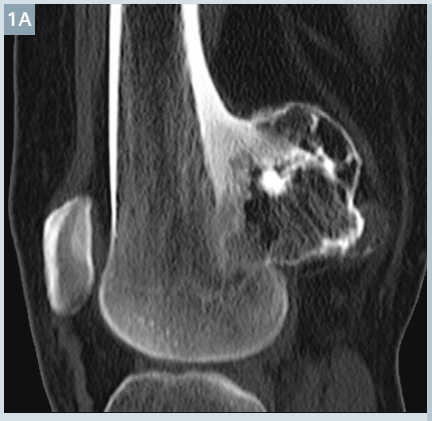
Table 1: Other imaging parameters.

Sequences	sag-T1	sag-T1+fs	sag-PD+fs	cor-PD+fs	tra-PD+fs
conventional TSE	5:11	5:57	5:41	5:32	4:24
SMS TSE	2:36	2:58	2:48	2:47	2:38

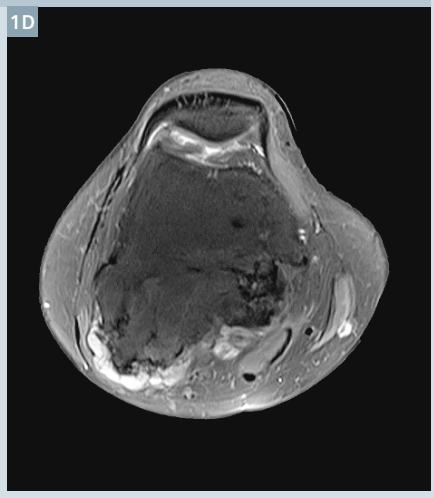
Table 2: Acquisition time for conventional TSE and SMS TSE (in minutes).

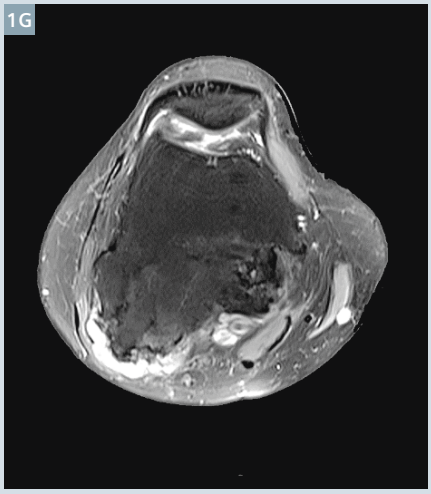
Case 1

40-year-old female with a painless slow-growing swelling for 10 years in the right distal femur. CT sagittal image demonstrated an irregular bone protuberance with a wide base in the posterior of right distal femur. Calcification shadow and continuity of the lesion with the cortical bone were seen in the lesion (Fig. 1A). MRI with both SMS TSE and conventional TSE demonstrated a local thickened cartilaginous cover in the rim of the bone protuberance (Figs. 1B-G). The cortical and medullary continuity between the osteochondroma and host bone can be observed. Calcified areas of the cover presented low signal intensity in T1 and PD-weighted images with fat saturation. Water in the non-calcified portion showed a low signal to the surrounding bone on T1w images and a high signal on PD-weighted images with fat saturation.



1 A patient (40-year-old, female) with osteochondroma in the bone of the distal femoral. **(1A)** is the CT sagittal image. **(1B-D)** are SMS TSE and **E**, **F**, and **G** are conventional TSE images for sagittal T1-weighted imaging **(1B, E)**, sagittal PD-weighted imaging with fat saturation **(1C, F)** and axial PD-weighted imaging with fat saturation **(1D, G)**.

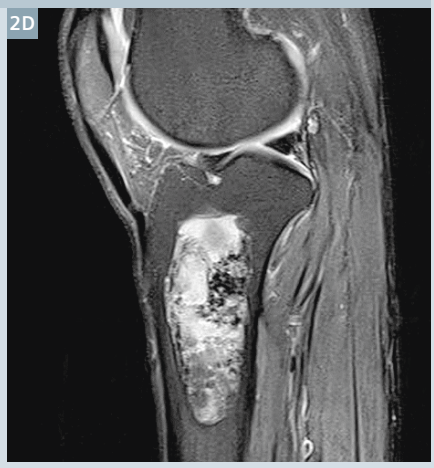


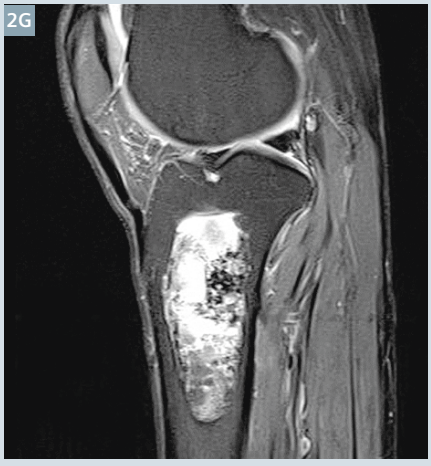


Case 2

68-year-old male with pain in the right leg for half a year without an adequate history of corresponding trauma. CT coronal image demonstrated a round-shaped lesion with a sclerosis rim (Fig. 2A). The size of the lesion was 3 × 4 × 7 cm^3. A calcification shadow was seen in the lesion with a sharp rim. MRI with both SMS TSE and conventional TSE demonstrated the lesion of inhomogeneous isointense to surrounding muscles on T1w images (Figs. 2B (SMS) and E (conventional)). Foliated hyperintensity signals were also seen in the lower lesion. On PD-weighted images with fat saturation (Figs. 2C (SMS) and F (conventional)), the lesion predominantly presented high signal intensity, within punctiform hypo- and isointensity. Post-Gadoteridol T1w images with fat saturation showed partly slightly enhancement intensity (Figs. 2D (SMS) and G (conventional)). The diagnosis was fibrous dysplasia in the bone of proximal tibia.

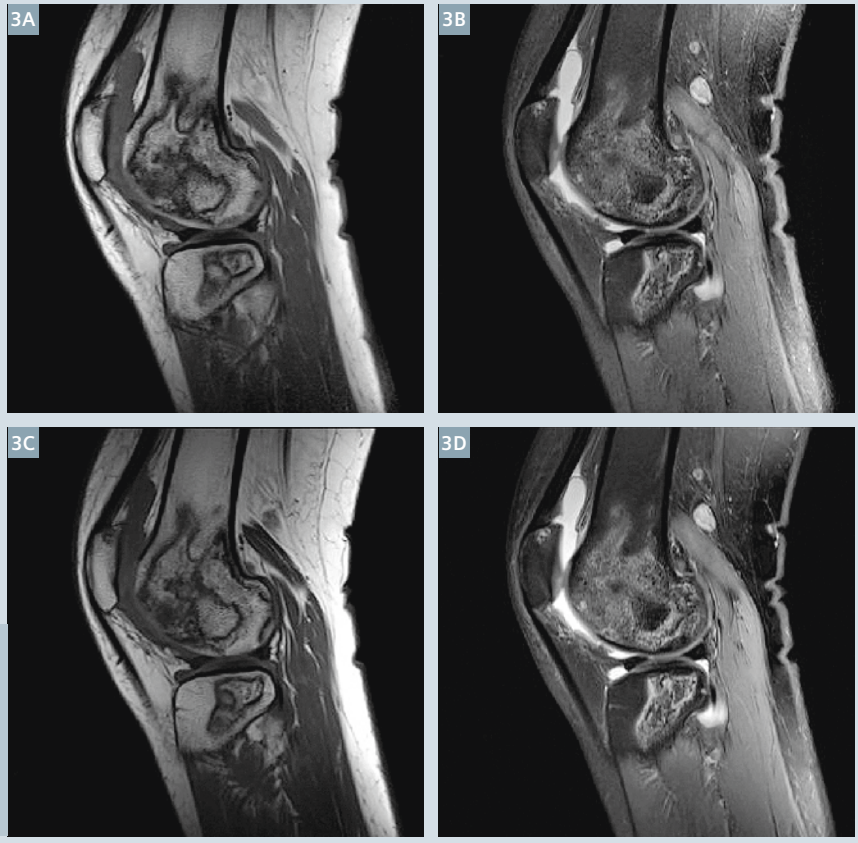
2 A patient (68-year-old, male) with fibrous dysplasia of proximal tibia. **(2A)** is the coronal CT image. **(2B-D)** are SMS TSE and **(2E-G)** are conventional TSE images for sagittal T1w imaging **(2B, E)**, sagittal T1w imaging with fat saturation after contrast agent injection **(2C, F)**, and PDw imaging with fat saturation **(2D, G)**.





Case 3

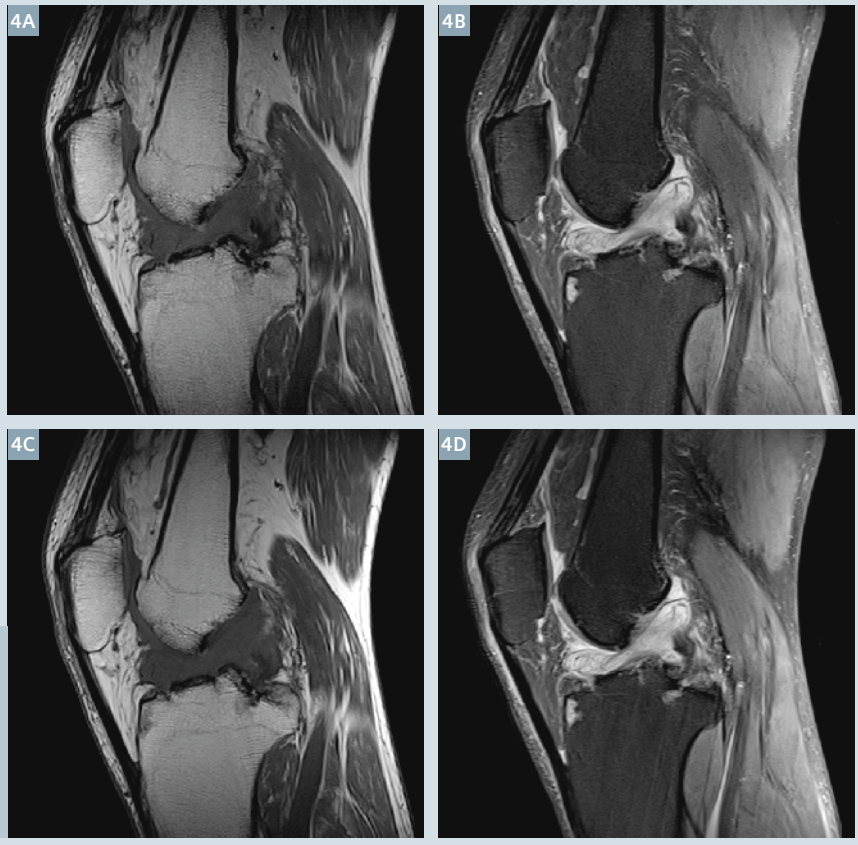
31-year-old female with pain in the left knee since 2 months. Both SMS TSE and conventional TSE MR sagittal images demonstrate a geographic lesion in the distal femur and proximal tibia with slight hypointensity of the skeletal muscle on T1w images (Figs. 3B (SMS) and D (conventional)) and hyperintensity in PDw fat saturation images (Figs. 3A (SMS) and C (conventional)). The diagnosis was bone infarction.



3 A patient (31-year-old, female) with fibrous bone infarction. **(3A, B)** are SMS TSE, **(3C, D)** are conventional TSE images for sagittal T1w imaging **(3A, C)**, and sagittal PDw imaging with fat saturation **(3B, D)**.

Case 4

71-year-old male with pain in the right knee since 10 years after sprain. Both SMS TSE and conventional TSE MR sagittal images demonstrate an anterior cruciate ligament tear and multiple bone proliferation which supports the diagnosis of osteoarthritis. There was a slight hypointensity to skeletal muscle on T1w images (Figs. 4A (SMS) and C (conventional)) and hyperintensity with slightly low intense clumps on PDw images (Figs. 4B (SMS) and D (conventional)).



4 A patient (71-year-old, male) with osteoarthritis. **(4A, B)** are SMS TSE, and **(4C, D)** are conventional TSE images for sagittal T1w imaging **(4A, C)**, and sagittal PDw imaging with fat saturation **(4B, D)**.

was performed using TR 3200 ms, TE 41 ms, and turbo factor of 10. All PD-weighted imaging acquisitions used 2 concatenations for conventional TSE and 1 concatenation for SMS TSE. Other imaging parameters are shown in Table 1 and 2.

Conclusion

SMS TSE reduced the scanning time for TSE imaging significantly without compromise to diagnostic image quality, bringing strong value to routine musculoskeletal examinations. This especially benefits patients with larger tumors where full coverage may be difficult to achieve using conventional TSE sequence and also for patients with small injuries to ligaments and cartilage who will require higher spatial resolution imaging for an accurate diagnosis.

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