Exploring the Potential of Low-Field Musculoskeletal MRI at 0.55T: Preliminary Results in Patients with Large Metal Implants

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Introduction

Low-field MRI scanners are currently experiencing a renaissance, thanks to technical innovations in gradient construction, coil design, and AI-based reconstruction methods [1]. Advantages over the 1.5T and 3T scanners used predominantly in clinical routine include lower acquisition and maintenance costs, and higher patient comfort [2, 3]. Potential advantages of low-field MR imaging include clinical scenarios where imaging using scanners with higher field strengths encounters technical limitations. This is especially the case when imaging patients with metal implants[1] where susceptibility artifacts are expected to be substantially less severe at 0.55T [4, 5]. This may be of particular interest in clinical routine, given an aging global population with an associated higher prevalence of metal implants, e.g., following joint replacement surgery [6]. This patient population has been shown to benefit from MR imaging [7].

The aim of this report is to provide a perspective on the possibilities and potential advantages of using a new-generation 0.55T low-field MRI system in imaging patients with large metal implants.

Materials and methods

Patient population
Three patients underwent complementary MR imaging at 0.55T in addition to their regular clinical imaging work-up.

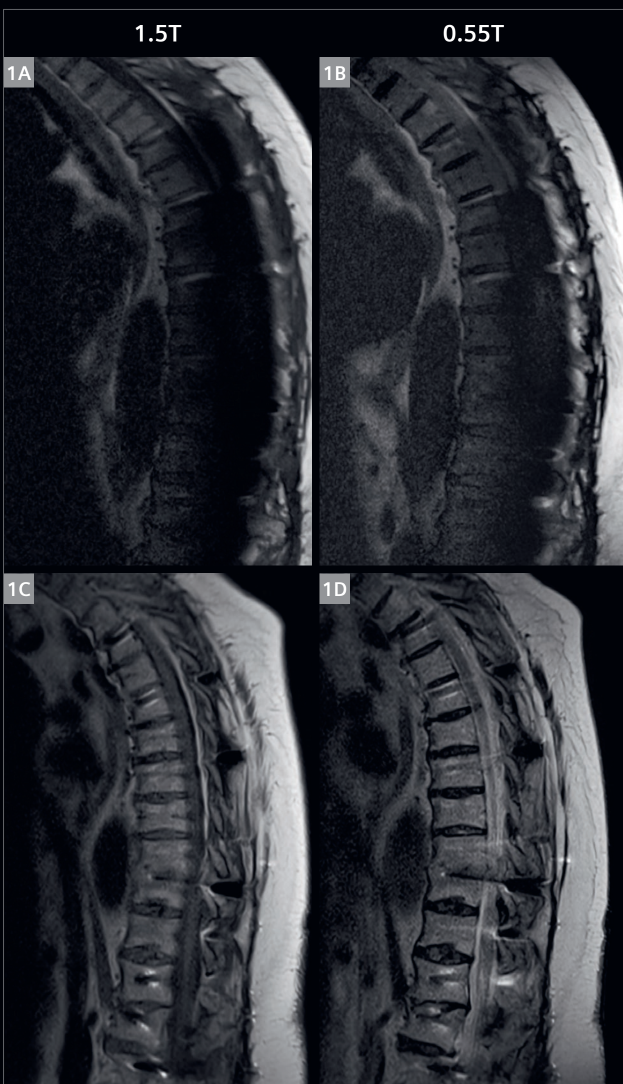
MRI scanners
Low-field MR imaging was performed using a 0.55T MAGNETOM Free.Max scanner (Siemens Shenzhen Magnetic Resonance Ltd., Shenzhen, China, gradient amplitude 26 mT/m, slew rate 45 T/m/s, 80 cm bore). A six-channel flex coil was used for the examination of the knee and the upper limb.

The 1.5T examinations were performed using a MAGNETOM Avanto Fit system (Siemens Healthcare, Erlangen, Germany, gradient amplitude 45 mT/m, slew rate 200 T/m/s, 60 cm bore). The 3T examinations were performed on a MAGNETOM Skyra system (Siemens Healthcare, Erlangen, Germany, gradient amplitude 45 mT/m, slew rate 200 T/m/s, 70 cm bore).

[1] *The MRI restrictions (if any) of the metal implant must be considered prior to patient undergoing MRI exam. MR imaging of patients with metallic implants brings specific risks. However, certain implants are approved by the governing regulatory bodies to be MR conditionally safe. For such implants, the previously mentioned warning may not be applicable. Please contact the implant manufacturer for the specific conditional information. The conditions for MR safety are the responsibility of the implant manufacturer, not of Siemens Healthineers.*

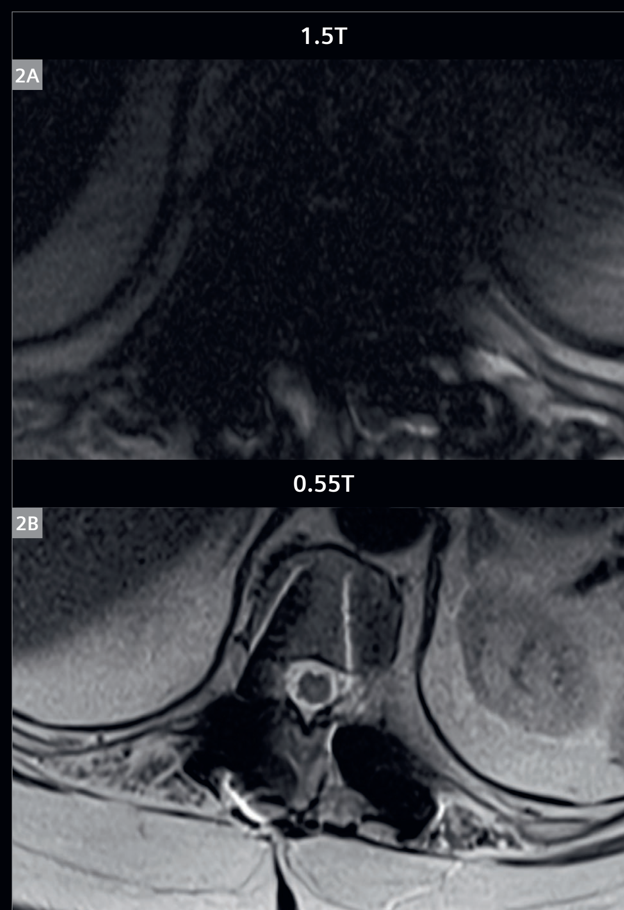
Case 1

A 59-year-old patient with several prior surgical procedures of the thoracic spine, including multi-level decompression and spinal fusion, presented with back pain refractory to medication. MR imaging of the thoracic spine was requested for the assessment of the spinal canal prior to epidural catheter placement. Routine imaging was performed at 1.5T, followed by a supplemental MR examination at 0.55T.



1 Preoperative imaging in a 59-year-old patient with multiple prior surgical procedures of the spine, prior to epidural pain catheter placement. Due to susceptibility artifact superimposition, the spinal canal was not assessable at 1.5T, neither in T2-weighted **(1A)** nor T1-weighted **(1C)** sequences. Artifact severity was substantially lower at 0.55T, allowing for assessment with high diagnostic confidence **(1B, 1D)**.

Due to severe susceptibility artifacts, the spinal canal was not assessable at 1.5T, neither on sagittal or axial T2-weighted sequences, nor on the T1-weighted sequence in the sagittal plane. At 0.55T, visibility and assessability of the spinal canal was substantially improved. Artifact superimposition was only minor, allowing for conclusive evaluation. Contraindications for epidural pain catheter placement could therefore be ruled out at 0.55T. Representative slices from 1.5T and 0.55T imaging are shown in Figures 1 and 2.

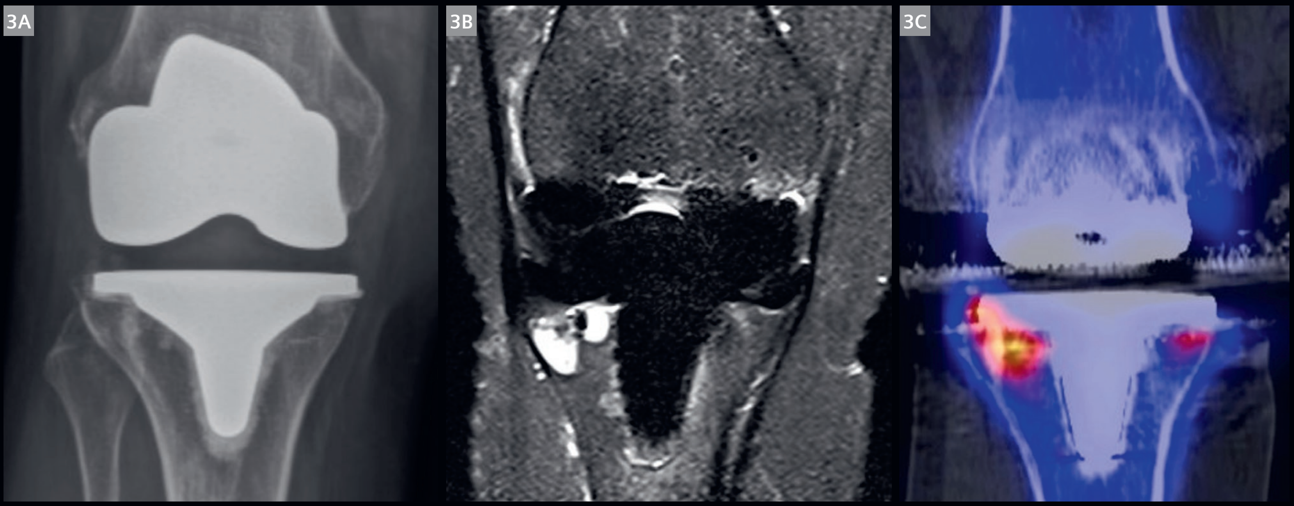


2 Similar to the sagittal images shown in Figure 1, the evaluation of the spinal canal was also only possible using the axial T2-weighted images acquired at 0.55T **(2B)**; while 1.5T did not allow for assessment due to artifact superimposition **(2A)**.

Case 2

A 59-year-old female patient presented with persistent knee pain five years after total knee arthroplasty. Given unremarkable radiographic examinations without signs of loosening, SPECT/CT and supplemental MR imaging at 0.55T were performed.

Radiography did not show signs of implant loosening or other postoperative complications (Fig. 3A). In contrast, MR imaging at 0.55T clearly depicted edema-equivalent signal changes adjacent to the tibial implant component in the lateral tibial plateau, and to a lesser extent also in the medial tibial plateau, indicative of implant loosening. Findings were consistent with the results from SPECT/CT imaging, which showed increased tracer uptake in the aforementioned locations. This was interpreted as implant loosening by a board-certified nuclear medicine physician (Figs. 3B, C).

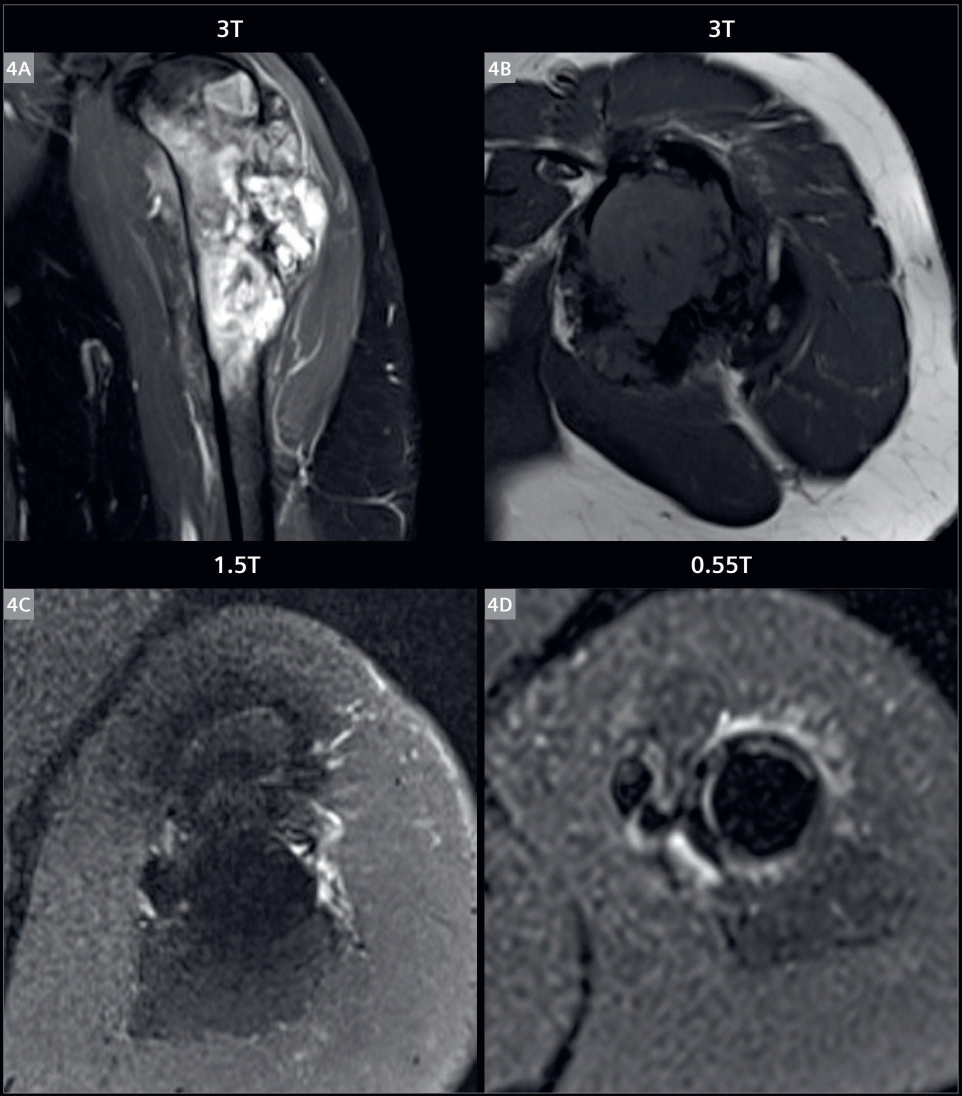


3 A 59-year-old female patient with persistent knee pain five years after total knee replacement. In contrast to conventional radiography **(3A)**, both 0.55T MR imaging **(3B)** and SPECT/CT imaging **(3C)** demonstrated implant loosening of the tibial implant component. The 0.55T MRI also allowed for assessment of ligamentous structures around the knee.

Case 3

A 39-year-old patient presented for routine follow-up imaging after resection of an osteosarcoma of the proximal left humerus and placement of a tumor prosthesis two years ago. Preoperative imaging was first performed at 3T. Follow-up imaging after surgery was performed at 1.5T and 0.55T.

The patient underwent regular postoperative follow-up imaging at 1.5T and supplemental imaging at 0.55T following osteosarcoma resection and tumor prosthesis implantation in the proximal left humerus. Preoperative imaging was performed at 3T (Figs. 4A, B). Comparing the follow-up MRI examinations, especially the soft tissues immediately adjacent to the tumor prosthesis shaft can be delineated clearly better at 0.55T (Fig. 3D) than at 1.5T (Fig. 3C) in the axial T2-weighted fat-suppressed sequences. In the scenario of patients undergoing follow-up imaging after bone tumor resection, potential local tumor recurrence close to the stem can be diagnosed or ruled out with greater confidence at low-field MRI, thanks to better delineation of adjacent structures due to fewer susceptibility artifacts.



4 A 39-year-old patient who was diagnosed with osteosarcoma of the proximal humerus at 3T **(4A, 4B)**. Following tumor resection and tumor prosthesis implantation, follow-up imaging to assess for local tumor recurrence with axial T2-weighted fat-suppressed sequences is improved at 0.55T **(4D)** compared to 1.5T **(4C)**, with better delineation of the soft tissue structures immediately adjacent to the shaft.

Discussion

In order to achieve the best image quality, the acquisition protocol for handling metal implant imaging must be carefully optimized, regardless of the field strength. In the cases reported here, we employed our optimized clinical protocols for all field strengths used for the image acquisitions. Certain protocol features could contribute to more robust acquisition despite of the metal, while others can correct the resulting artifacts. Metal artifact correction methods, however, are often SAR intensive and result in longer acquisition times. By imaging at 0.55T one can also reduce the concern associated with increased SAR, while often being able to get good clinical results by employing a high-bandwidth protocol.

This brief case series emphasizes the potential of low-field MR imaging at 0.55T in patients with large metal implants. This is in accordance with recently published literature that outlines, for example, the advantages of low-field MR imaging over imaging at higher field strengths in patients with total hip arthroplasty [8]. Our initial experiences as demonstrated in this case series also suggest diagnostic benefits of 0.55T MR imaging in patient groups with other types of large metal implants, such as extensive thoracic or thoracolumbar spondylodesis. Reducing metal-implant-related susceptibility artifacts allows for improved assessment of structures and soft tissues immediately adjacent to the implants, which is of particular importance for detecting local recurrence following tumor resections. Additionally, low-field MR imaging may be helpful in the detection of implant loosening and could complement SPECT/CT imaging by providing details on soft-tissue structures around the knee prior to revising total knee replacements.

In conclusion, it appears to be worth conducting dedicated studies to asses potential applications and opportunities in metal implant imaging – especially in cases of large metal implants – to establish a role for 0.55T low-field MR imaging in clinical routine.

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