MSK MRI on MAGNETOM Free.Max: Initial Experience

Thomas M. Link, M.D., Ph.D. and Daehyun Yoon, Ph.D.

University of California, San Francisco (UCSF), Department of Radiology and Biomedical Imaging, San Francisco, CA, USA

Introduction

The unveiling of the MAGNETOM Free. Platform, with its unique field strength of 0.55T, by Siemens Healthineers has opened new possibilities for MRI. While low field strengths have been explored in past, the combination of 0.55T with new hardware and state-of-the-art deep-learning reconstruction techniques offers the potential for using this system reliably in many clinical conditions.

In this article, we document our experience in using a MAGNETOM Free.Max for musculoskeletal (MSK) applications. Specifically, we focus on situations where the MAGNETOM Free.Max (i) provides comparable diagnostic quality to conventional field strengths and (ii) improves our current imaging capabilities in patients with metal hardware, such as spinal fusions and total joint replacements, where traditional high-field scanners often fall short.

At our institution at UCSF, the MAGNETOM Free.Max is located in an outpatient facility with a high volume of MSK cases, and next to other scanners with conventional field strengths of 1.5T and 3T. This offers a convenient way to directly compare and optimize our experience across field strengths.

Initial findings have shown that the MAGNETOM Free.Max scanner is quite promising in routine spine imaging, where the image quality is quite good. We have a large majority of spine cases that are routinely scanned on the MAGNETOM Free.Max. Our radiology practice, however, still favors 1.5T and 3T for other joints such as knee or ankle, which require imaging with high spatial resolution for detailed visualization of the cartilage and ligaments.

One area where the MAGNETOM Free.Max particularly excels is metal-artifact-suppressed imaging, especially in the spine and in areas around total joint replacements. Most importantly, in patients with multi-level spine fusion, our experience with conventional field strengths of 1.5T and 3T has been quite mixed. Our MAGNETOM Free.Max, on the other hand, has consistently provided better image quality and diagnostic information in this cohort. We believe that the substantially reduced off-resonance and radio-frequency specific-absorption-rate (SAR) burden at 0.55T may provide unique opportunities to enhance visualization of the metal-tissue interface and enable contrasts (e.g., diffusion and post gadolinium) that were previously excluded for patients with extensive spine hardware.

The larger bore size has also facilitated imaging for larger patients, although our experience is limited due to the demography of the community that we serve.

Protocol adaptation for 0.55T

We started with our standard protocols from 3T systems and tweaked them in an iterative process to get our optimized set of parameters at 0.55T. For turbo spin-echo (TSE) protocols, we adjusted the spatial resolution where necessary to maintain the signal-to-noise ratio (SNR). All the protocols had Deep Resolve Boost turned on. Implant protocols for joint arthroplasty applied the TSE WARP feature, which optimizes the sequence to reduce metal-induced distortions employing high bandwidth and View Angle Tilting (VAT).

To remove the fat signal, we used a prototype research TSE-Dixon sequence[1] that supports Deep Resolve Boost, instead of fat-saturated TSE or STIR TSE sequences. The preferred method for fat suppression near metal at 1.5T or 3T is STIR, as fat suppression methods based on chemical shift, such as fat saturation using a spectrally selective

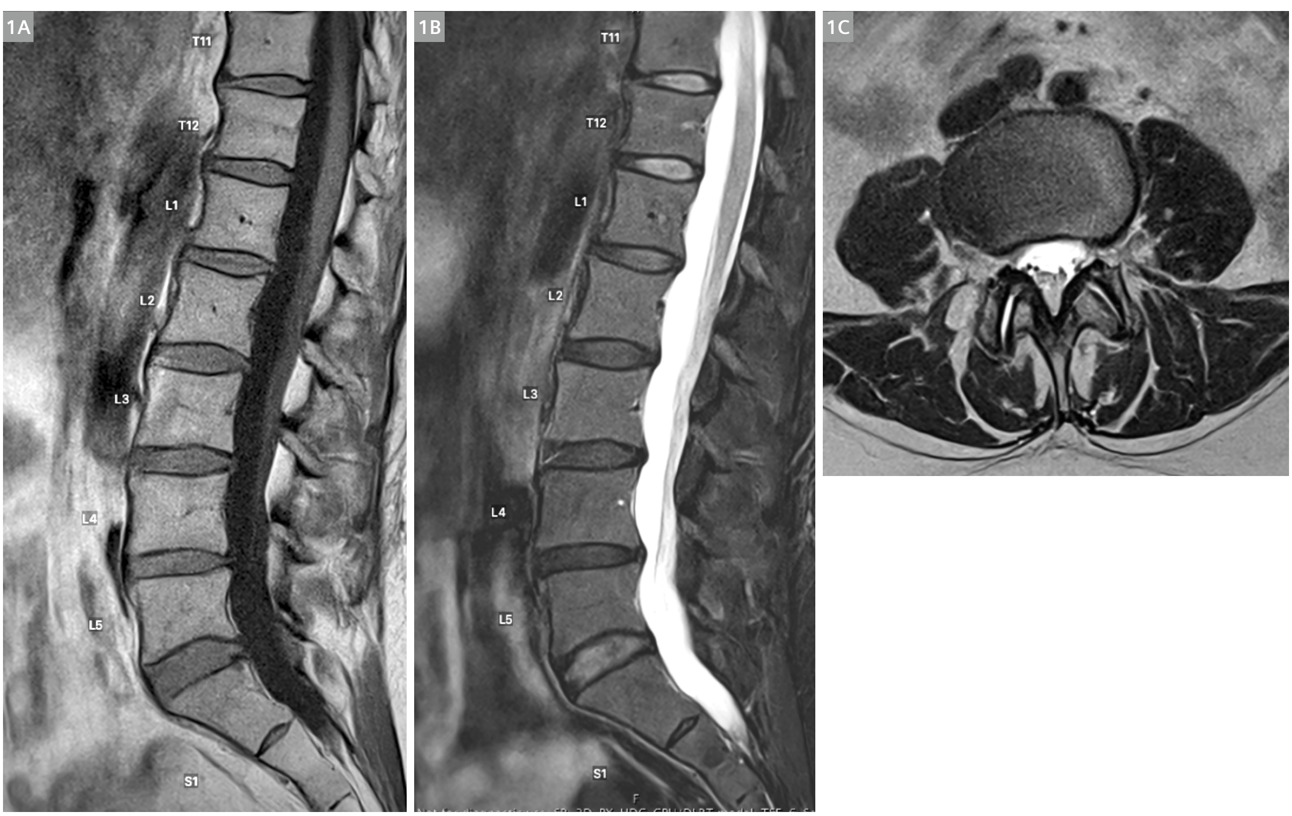
[1] *Although the TSE-Dixon sequence is commercially available, it is not yet available with deep learning-based image reconstruction in our scanner software version. The deep learning based reconstruction of TSE-Dixon is work in progress. The sequence is still under development and not commercially available. Its future availability cannot be ensured.*

RF pulse and fat-water separation using a Dixon-based approach, become unreliable near metal due to strong off-resonance. However, STIR significantly lowers the SNR, making it challenging to incorporate into TSE at 0.55T that employs high pixel bandwidth for metal artifact mitigation. It is because the sequence configuration already has two factors (high pixel bandwidth and 0.55T) that substantially lower the SNR. On the other hand, 0.55T limits the area of strong off-resonance near metal, giving it a second chance for conventional chemical-shift-based fat suppression methods. Unfortunately, the reduced resonance frequency difference between fat and water at 0.55T makes selective fat saturation more challenging than at 1.5T or 3T. TSE-Dixon, although it exhibited fat-water swap artifacts near metal in some cases, shows the best SNR among other options, with Deep Resolve Boost, and has the potential to achieve more accurate fat-water separation later with retrospective application of a more advanced fat-water separation algorithm. Additionally, the in-phase images of TSE-Dixon can serve as simple TSE images without fat suppression. Advanced metal suppression techniques such as SEMAC were not included in the final protocol. This is because our initial scans suggested a lack of additional benefits for the extra scan time. We believe further optimization is needed to develop relevant protocols for the metals known to cause more severe off-resonance, such as cobalt-chromium and stainless steel.

Case studies

We present a selection of clinical cases that demonstrate our experience with MSK MRI on our MAGNETOM Free.Max.

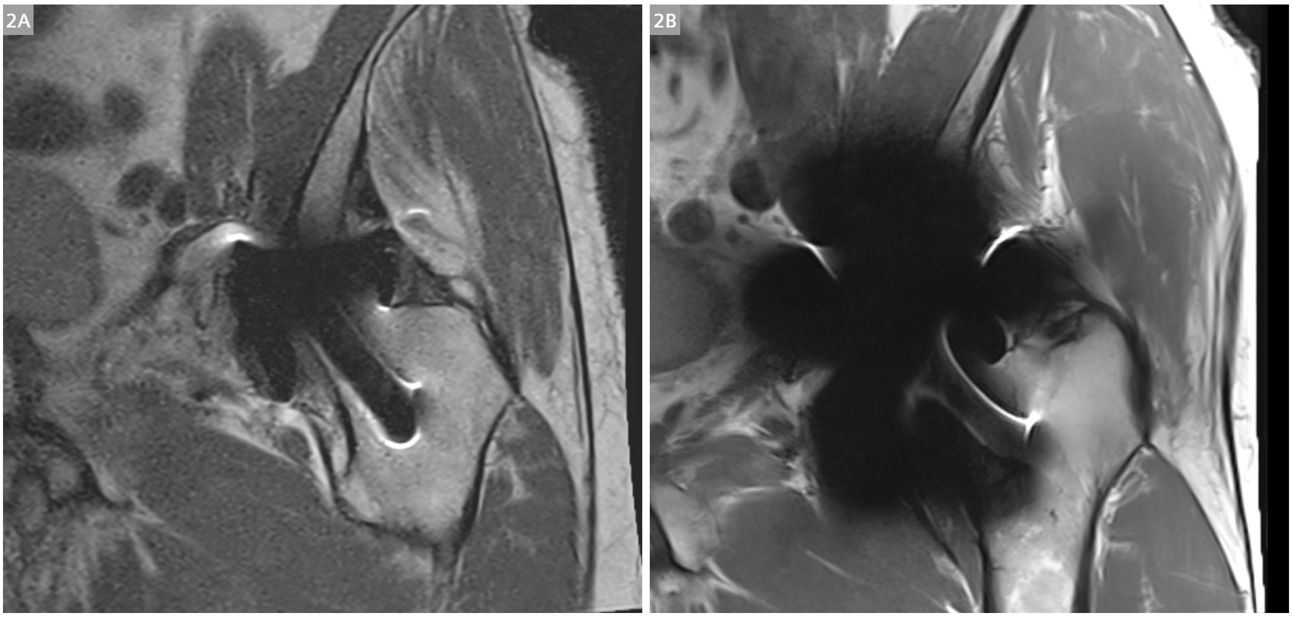
Case 1
Clinical spine study of the lumbar spine with no significant imaging abnormalities.



1 Lumbar spine 0.55T MRI, **(1A)** sag T1-weighted TSE, **(1B)** sag T2-weighted TSE-water from fast-Dixon, and **(1C)** axial T2-weighted TSE sequences.

Case 2

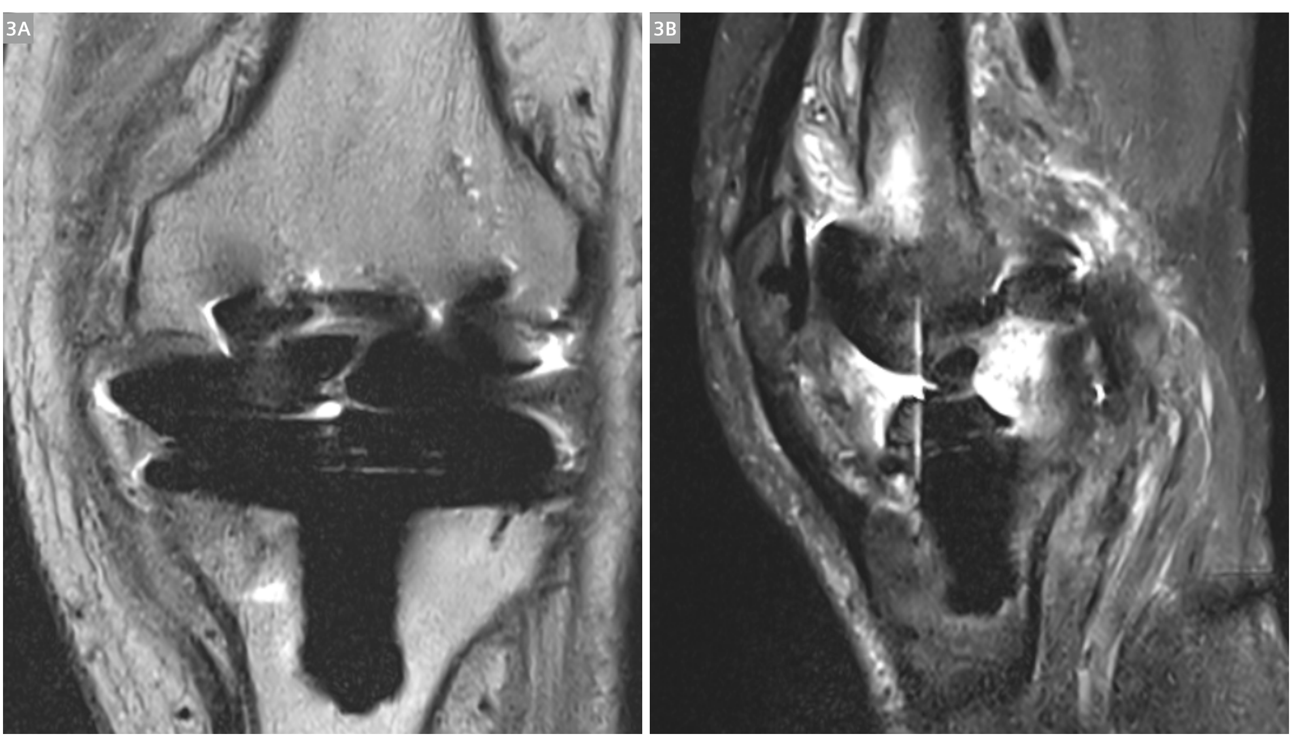
Status post left total hip resurfacing (cobalt-chromium, metal on metal)



2 **(2A)** PD-weighted WARP TSE imaging at 0.55T and **(2B)** at 3T.

Case 3

Status post total left knee replacement (titanium alloy).



3 Images obtained at 0.55T with WARP TSE, **(3A)** PD-weighted and **(3B)** STIR. Bone marrow signal abnormalities and synovitis are clearly shown on the STIR sequence.

Case 4
Status post lumbar spinal fusion (titanium).

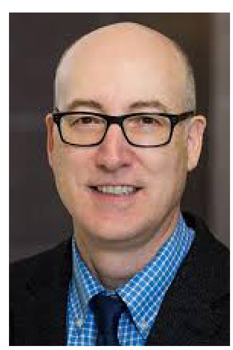
4 Sagittal T2-weighted TSE sequences at **(4A)** 0.55T and **(4B)** 1.5T.
Note: as explained above, TSE-Dixon (fast-Dixon option) was used at 0.55T. The image shown here is the in-phase image, which is equivalent to TSE.

Summary

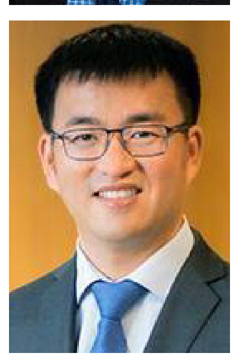
The MAGNETOM Free.Max has been a great addition to our fleet of MR scanners for MSK applications. While we handle routine spine cases using any of the three available field strengths (0.55T, 1.5T, 3T) at our outpatient center, our imaging practice has developed a preference for the MAGNETOM Free.Max when it comes to patients with metal hardware – specifically, multi-level spinal fusions. This is because of the improved image quality that we have been able to achieve with this platform. As of this writing, we are also actively encouraging and educating our clinicians to consider scheduling their patients with metal hardware on the MAGNETOM Free.Max, due to its superior and consistent image quality, shorter scan protocol, and shorter imaging times.

Overall, the MAGNETOM Free.Max scanner has demonstrated its potential to significantly improve imaging outcomes in challenging MSK cases, making it a valuable asset in the diagnostic toolkit at UCSF.

Contact



Professor Thomas M. Link, M.D., Ph.D.
Chief of the Musculoskeletal Imaging Section and Clinical Director of the Musculoskeletal and Quantitative Imaging Research Group
Department of Radiology & Biomedical Imaging
University of California, San Francisco
505 Parnassus Avenue, M-391
San Francisco, CA 94143-0628
USA
thomas.link@ucsf.edu



Daehyun Yoon, Ph.D.
Assistant Professor of Radiology
Department of Radiology & Biomedical Imaging
University of California, San Francisco
505 Parnassus Avenue, M-391
San Francisco, CA 94143-0628
USA
daehyun.yoon@ucsf.edu