High-Resolution Imaging of the Hip Joint in the Age of Deep Learning

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Introduction

Magnetic resonance imaging (MRI) has proven to be an invaluable resource in the diagnosis and management of orthopedic conditions, given its superior soft tissue contrast, lack of ionizing radiation, and ability to obtain high-resolution imaging. In the face of declining reimbursement and rising pressure for increased patient throughput, efforts are ongoing to decrease scan times while maintaining image quality and resolution [1]. This is especially important when patients are unable to tolerate prolonged scan times due to claustrophobia or pain. In these instances, faster scan times may be paramount to patient care.

In recent years, studies have compared faster MRI sequences with a variety of standard protocols, yielding favorable results for the accelerated scans [2–7]. Improvements in imaging resolution and scan time were assisted by new artificial intelligence (AI) techniques. No difference was found in diagnostic confidence or capability and the scans utilizing deep learning (DL) reconstruction were indeed judged to be of better image quality [3–7].

One of the most frequently performed MR examinations at imaging centers specializing in orthopedic imaging, including at our institution, is MRI of the hip. The relatively thin cartilage of the hip requires superior in-plane and through-plane (slice) resolution to maintain diagnostic accuracy, which results in longer scan times [8]. Given the large number of these studies, the option for a more efficient hip MRI protocol would not only improve patient care at the individual level, but would also contribute to overall increased scanning capacity. We have partnered with Siemens Healthineers to use DL reconstruction, reduced echo spacing, and reduced specific absorption rate (SAR) with optimization of radiofrequency (RF) pulses to enable a hip MRI protocol that requires no more than
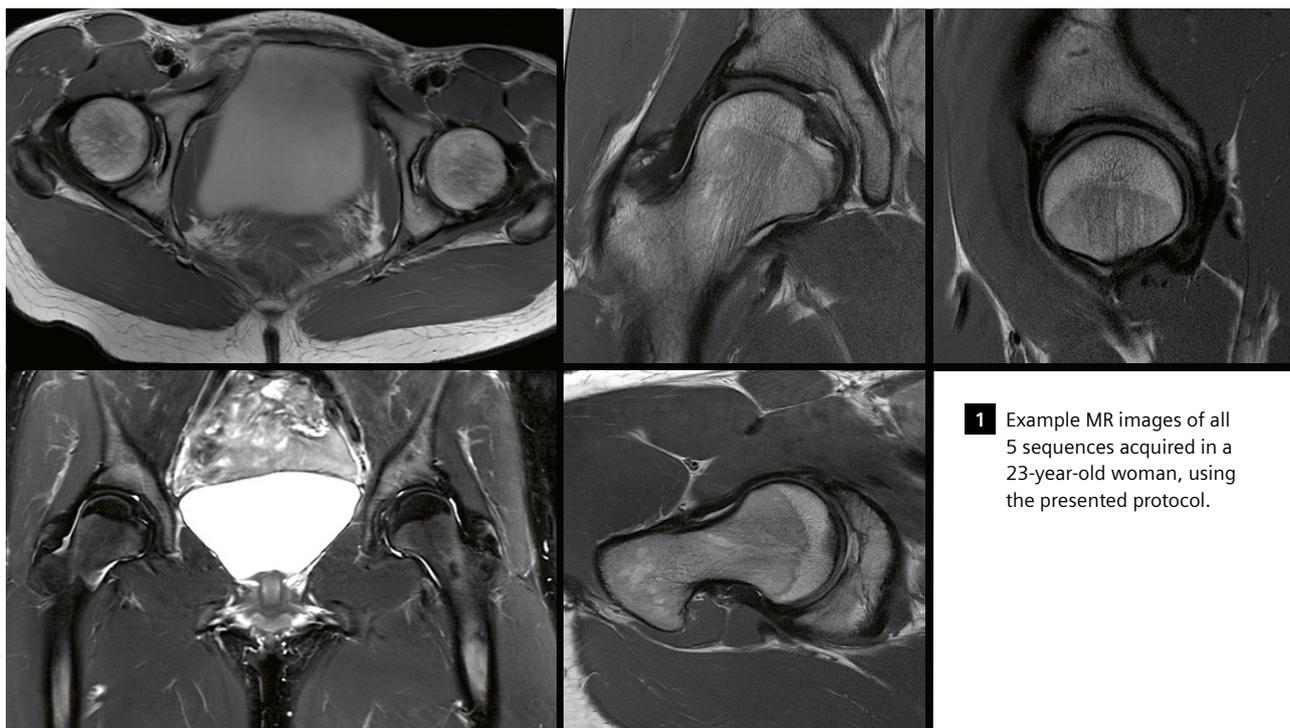
1 Example MR images of all 5 sequences acquired in a 23-year-old woman, using the presented protocol.

15 minutes of scan time but still maintains spatial resolution and signal-to noise ratio (SNR) on par with our standard-of-care studies. The suggested expedited protocol is outlined in this article, to make it available to any user of a 3T magnet from Siemens Healthineers.

Expedited hip MRI protocol with example images

The suggested protocol contains 5 essential acquisitions using a prototype turbo spin-echo (TSE) sequence. Table 1 lists the acquisition parameters in detail for implementation on a MAGNETOM Vida 3T scanner with an XT gradient system. Following a 3-plane fast localizer, a large field-of-view axial TSE sequence of the pelvis and bilateral hips is acquired with intermediate weighting. Next, a coronal unilateral TSE sequence is acquired focusing on the affected hip, followed by a bilateral hip coronal TSE short tau inversion recovery (STIR) sequence. Unilateral intermediate-weighted sagittal and oblique axial TSE acquisitions are obtained for assessing the hip joint. This protocol is acquired without contrast and with an

18-channel phased-array coil anteriorly and an in-table spine matrix coil posteriorly. All acquisitions utilize Deep Resolve Boost and Deep Resolve Sharp for algorithms for DL-enhanced image reconstruction. This protocol produces high-resolution diagnostic scans, as in Figure 1, which shows high-quality images from each sequence acquired in a 23-year-old woman.

The large field-of-view sequences provide an overview of pelvic and hip structures, allowing comparison to the contralateral side for symmetry of osseous structures and musculature about the hips, as well as identification of potential intrapelvic pathology that may present as groin pain. Inversion recovery weighting highlights areas of edema or fluid, including marrow or soft tissue edema, joint effusions, bursitis, or cysts. Smaller field-of-view intermediate-weighted sequences allow high-resolution anatomic evaluation of the symptomatic hip. The coronal plane optimizes evaluation of the superior joint cartilage, superior acetabular labrum, and hip abductors. The oblique axial plane grants superior visualization of the anterior and posterior cartilage and labrum, as well as the rectus femoris and iliopsoas tendons, and further provides an

Acquisition	Axial TSE	Coronal TSE	Coronal IR	Sagittal TSE	Oblique axial TSE
Coverage	Bilateral	Unilateral	Bilateral	Unilateral	Unilateral
Field of view, mm	380	190	380	190	190
TR/TE, ms	5600 / 30	3500–4800 / 35	3500–5500 / 24	4000 / 35	4000 / 34
TI, ms	–	–	240	–	–
Matrix size (frequency × phase)	512 × 384	512 × 384	352 × 282	512 × 410	512 × 358
Phase encoding direction	R > L	H > F	H > F	H > F	L > R
Acquired in-plane resolution (frequency × phase), mm²	0.74 × 0.99	0.37 × 0.49	1.08 × 1.35	0.37 × 0.46	0.37 × 0.53
Slice thickness/gap, mm	5.5 / 0	3 / 0	5.5 / 0	2.5 / 0	3 / 0
Slices	50	32	36	26	28
Bandwidth, Hz/pixel	257	222	219	222	233
Turbo factor	14	12	15	14	14
Echo spacing, ms	6.94	8.65	7.95	8.65	8.45
iPAT	3	2	3	2	2
DRB and DRS	Yes	Yes	Yes	Yes	Yes
Fat suppression	–	–	STIR	–	–
Scan time, min:sec	2:00	3:20	2:15	2:40	2:15

Table 1: Acquisition parameters of the recommended hip protocol on a MAGNETOM Vida 3T with an XT gradient system.
TSE: turbo spin echo; TR: repetition time; TE: echo time; TI: inversion time; iPAT: integrated Parallel Acquisition Technique; DRB: Deep Resolve Boost; DRS: Deep Resolve Sharp; STIR: short tau inversion recovery.

assessment of the neck-head offset. The sagittal plane provides another look at the anterior and posterior joint cartilage, and is the optimal plane for evaluating the anterior labrum.

The coronal STIR and intermediate-weighted TSE images of a 65-year-old woman in Figure 2 reveal hyperintense bursitis from low-signal calcium hydroxyapatite deposition as well as a small amount of joint fluid. Multiplanar intermediate-weighted TSE images show multifocal chondral and labral pathologies in the same subject in Figure 3. Figure 4 illustrates a labral tear with an associated paralabral cyst on an oblique axial intermediate-weighted TSE sequence in a 25-year-old woman.

The prototype TSE sequence includes several improvements to reduce echo spacing with improved sequence timing, and reduced SAR with variable-rate selective excitation [9]. The scan time of these acquisitions is between 1:30 and 3:00 minutes, depending on the desired spatial
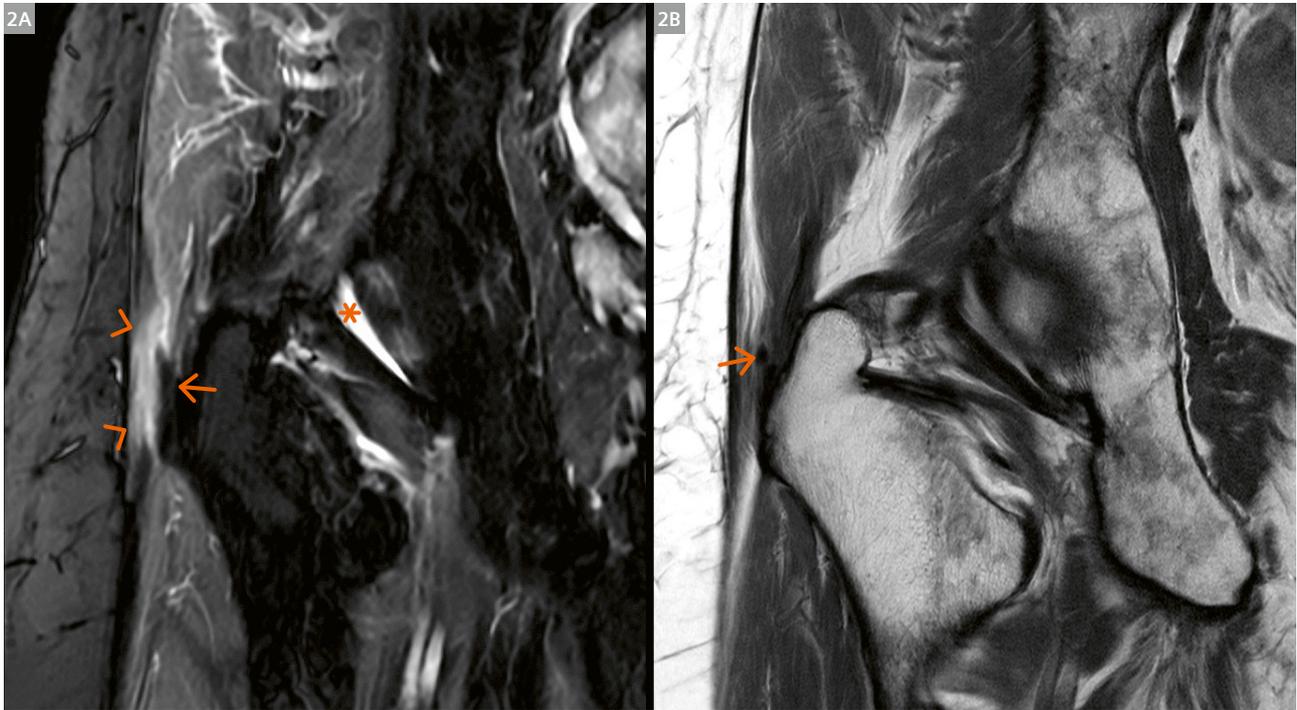
2 Coronal STIR **(2A)** and intermediate-weighted TSE **(2B)** images of the right hip in a 65-year-old woman, acquired in 1:30 minutes and 2:22 minutes respectively, show a low signal focus of calcium hydroxyapatite deposition along the gluteus medius insertion (arrows) with adjacent greater trochanteric bursa thickening (arrowheads), reflecting calcific tendinosis and bursitis. A small amount of fluid in the joint is indicated by an asterisk.

3 Coronal **(3A)**, sagittal **(3B)**, and oblique axial **(3C)** intermediate-weighted TSE sequences of the same woman, with acquisition times of 2:22 minutes, 2:28 minutes, and 2:22 minutes respectively, demonstrate areas of full thickness cartilage loss (arrowheads) over both the acetabulum and the femoral head. A subchondral cyst, high-grade chondral fissure, and anterior labral tear are indicated by arrows in 3A, 3B, and 3C, respectively.
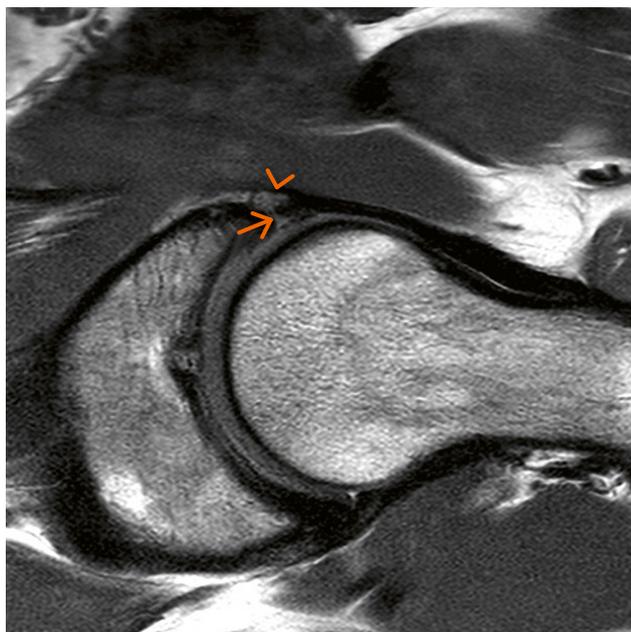
4 An oblique axial intermediate-weighted TSE sequence of the left hip in a 24-year-old woman, with an acquisition time of 2:05 minutes, shows an anterior labral tear (arrow) generating a small paralabral cyst (arrowhead).

resolution. The total exam time is estimated at 12 minutes, with slight variations from subject to subject due to coverage differences and prescribed SAR limits.

Conclusion and future directions

Advances in deep learning techniques have facilitated the development of new MRI protocols aimed at improving clinical outcomes and increasing throughput. As this technology evolves, it can continue to help us improve our protocols so we can keep up with increasing patient volumes while maintaining high diagnostic quality. To that end, we have presented a suggested protocol that allows users of 3T magnets from Siemens Healthineers to implement a faster and enhanced scan for hip MR evaluation.

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