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From Better Images to Better Decisions: The Next Step for MSK MRI

Musculoskeletal MRI has never offered better images than it does today. Contemporary examinations combine high-field systems, optimized pulse sequences, three-dimensional acquisitions, and advanced acceleration and reconstruction. Structures that were once indistinct can now be displayed with remarkable clarity. Examinations that previously occupied long scanner slots can be completed within clinically practical times. Even in the presence of orthopedic hardware, diagnostic information can often be recovered from regions that were formerly obscured. This progress reflects years of collaboration between radiologists, physicists, engineers, technologists, and industry.

Yet better images are not the ultimate objective of medical imaging. A sharper cartilage surface, a more conspicuous nerve fascicle, or an image with less noise has value only if it helps us make a more accurate diagnosis, increases relevant diagnostic confidence, changes management, or improves patient experience or outcomes. Image quality is immediately visible. Clinical value is harder to demonstrate.

This year's International Skeletal Society (ISS) edition of MAGNETOM Flash highlights the extraordinary momentum of musculoskeletal MRI. It also provides an opportunity

to consider what should come next. I am convinced that the next step will not be defined by a single field strength, sequence, or artificial intelligence application, but rather by the transition from optimizing images to optimizing decisions. That transition requires us to ask not only whether a new technique performs better, but also what problem it solves, for whom, and with what consequences.

Image quality is the beginning, not the endpoint

Technical image quality remains essential. An examination affected by motion, insufficient resolution, inhomogeneous fat suppression, or severe susceptibility artifacts may conceal the relevant finding. Improvements in signal-to-noise ratio, contrast, sharpness, and artifact reduction therefore form the foundation of diagnostic progress. But that foundation is only the beginning.

The classic hierarchy proposed by Fryback and Thornbury remains strikingly relevant [1]. It begins with technical efficacy and then moves through diagnostic accuracy, influence on diagnostic thinking, influence on management, patient outcomes, and societal benefit. Success at a lower level is necessary, but it does not guarantee success at the level above. A sequence may receive excellent image-quality scores without improving

¹ Work in progress. The application is currently under development and is not for sale in the U.S. and in other countries. Its future availability cannot be ensured.

² 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.

lesion detection. Greater sensitivity may identify abnormalities whose natural history is uncertain. Additional findings may increase downstream testing without improving care.

For MSK MRI, this is not an abstract concern. We image many abnormalities that are common in asymptomatic individuals, including degenerative tendon changes, labral and meniscal variants, cartilage defects, and postoperative findings. As spatial resolution increases, so does the number of visible details. A high-resolution 7T MRI study that we conducted at Balgrist Campus, for example, demonstrated substantial variability in the meniscal root anatomy of the knee [2]. Such knowledge can deepen anatomical understanding and help prevent normal variants from being mistaken for tears. It also illustrates why seeing more must be accompanied by an understanding of what these additional findings mean.

Assessments of image quality and reader preference remain valuable, but a broader evaluation should also consider lesion detection, classification, interreader agreement, diagnostic confidence, and agreement with an appropriate reference standard. Whenever feasible, studies should also examine whether the information changes the radiologist's conclusion or the clinician's management plan. The most convincing innovation is not the one that produces the most impressive side-by-side images. It is the one that resolves a real diagnostic uncertainty.

Faster MRI: Time as a clinical resource

Acceleration is among the most visible developments in current MRI. Parallel imaging, simultaneous multislice acquisition, compressed sensing, and deep-learning reconstruction can substantially shorten acquisitions. Faster examinations can reduce discomfort, motion, and the likelihood that a patient cannot complete the study. They can facilitate imaging of children, patients in pain, and individuals who struggle to remain still. At a system level, shorter protocols improve access and allow scarce MRI capacity to serve more patients.

Nevertheless, speed should not become an isolated performance target. Reconstruction can alter image texture, suppress noise, and change the appearance of subtle structures. A fast sequence that looks smooth may still obscure a low-contrast lesion; conversely, an unfamiliar texture may be judged negatively despite preserved diagnostic information. Validation must therefore include the abnormalities and clinical decisions for which the sequence will be used, rather than relying solely on perceived quality in healthy volunteers.

Our work on deep-learning-reconstructed, high-resolution knee MRI at 7T illustrates both the opportunity and the necessary discipline [3]. Higher parallel-imaging acceleration could be achieved with useful image quality within feasible acquisition times, but performance depended on

the degree of acceleration. The broader lesson applies at every field strength: Acceleration is a trade-off, not free time. The dividend can be taken as a shorter examination, or reinvested in spatial resolution, three-dimensional coverage, more robust fat suppression, or an additional contrast. The correct choice depends on the patient and the clinical question.

For a routine follow-up examination, a shorter protocol may provide everything required. For suspected subtle cartilage injury, peripheral nerve pathology, or a postoperative complication, it may be better to invest the time saved in image detail. Protocol design should therefore become more adaptive. The goal is not the shortest possible MSK MRI, but rather the shortest examination that answers the specific question reliably.

When higher resolution changes the question

Ultra-high-field MRI makes the relationship between technical capability and clinical value especially clear. The increased signal available at 7T can be converted into exceptional spatial resolution. This has enabled visualization of structures such as cervical nerve rootlets, dorsal root ganglia, lumbar nerve fascicles, fine cartilage morphology, and small meniscal insertions. Such images expand our understanding of anatomy. However, their strongest justification arises when they change how disease is assessed.

In patients with cervical radiculopathy, high-resolution 7T double-echo steady-state (DESS) imaging enabled direct assessment of nerve-root compression and improved diagnostic confidence and prediction of sensory or motor dysfunction compared with standard clinical MRI [4]. Here, the advance is not simply that the nerve root appears sharper. This approach allows the radiologist to assess the affected neural structure more directly, rather than relying primarily on foraminal narrowing as an indirect sign of neural compromise. That represents a meaningful change in the diagnostic approach. In this issue, Abel et al. show that combining compressed sensing and CAIPIRINHA with deep-learning reconstruction can retain clear visualization of cervical nerve structures in highly accelerated 7T DESS neurography, even at acceleration factors where CAIPIRINHA alone becomes increasingly limited by artifacts [5]. This is a useful example of acceleration being used to make high spatial resolution more clinically practical.

Similarly, 7T MR neurography of the lumbosacral plexus improved visualization of nerve roots, dorsal root ganglia, and fascicles compared with acquisition-time-matched 3T imaging [6]. However, some artifacts were more pronounced at 7T. This balanced finding is instructive: Higher field strength does not improve every aspect of every examination, and technical superiority should never be assumed from field strength alone. The relevant

endpoint is whether the additional anatomical information is robust enough to improve diagnosis in the patients who need it.

From quantitative measurements to clinical value

Quantitative muscle MRI provides another example of how imaging has improved clinical decision-making. In patients with rotator cuff tears, two-point Dixon MRI enables volumetric measurement of muscle fat fraction, replacing a broad visual category with a continuous quantitative value. In one of our studies, preoperative fat fractions of the supraspinatus, infraspinatus, and subscapularis muscles provided muscle-specific cutoff values for predicting retear after arthroscopic repair [7]. These measurements transform fatty infiltration from a descriptive imaging finding into a clinically actionable risk marker that can inform patient selection, surgical planning, and counseling about the likelihood of durable tendon healing.

We applied a similar approach to chronic Achilles tendon disease, using two-point Dixon MRI to quantify calf-muscle fat content in patients with midportion or insertional disease [8]. The mean fat fraction of the triceps surae was approximately 11% and did not differ between the two disease locations, although their patterns of tendon damage and accompanying findings differed substantially. This result is also informative: Quantitative MRI can reveal meaningful differences, but it can also demonstrate when clinically distinct phenotypes share similar muscle composition. Such measurements add context to morphological findings and may provide a basis for future longitudinal and treatment-response studies.

Quantitative assessment is not limited to muscle. Ultrashort-echo-time (UTE) MRI extends this approach to tissues with short T2 relaxation times, including tendons, ligaments, and menisci, which are difficult to assess with conventional sequences. In a whole-knee 3T study, UTE T2* mapping demonstrated good scan–rescan repeatability, while also showing that knee position can influence measurements in some tissues [9]. UTE magnetization-transfer approaches offer measurements of tendon degeneration that are less sensitive to orientation effects than UTE T2* mapping [10]. Together, these studies show that technical capability is only one part of the path toward clinical value; quantitative measurements must also be reproducible, biologically interpretable, and relevant to diagnosis or patient management.

Restoring diagnostic value after surgery

Postoperative imaging offers perhaps the clearest example of technology solving an unmet clinical need. Orthopedic metal implants can cause signal loss, distortion, pile-up, and failure of fat suppression on MRI. Without appropriate

techniques, the tissues closest to the implant may be precisely those we cannot evaluate. Basic MRI protocol choices, including field strength, bandwidth, voxel size, pulse sequence, and fat suppression, remain important. Advanced methods such as compressed-sensing slice encoding for metal-artifact correction (CS-SEMAC) can further recover anatomy near hardware [11].

The clinical benefit is substantial because MRI can evaluate the implant environment and the surrounding soft tissues in one examination. Metal-artifact-reduced MRI has demonstrated diagnostic value in challenging settings such as suspected periprosthetic hip infection [12]. It can also depict synovitis, osteolysis, muscle injury, tendon failure, collections, and neurovascular abnormalities. In this context, artifact reduction does more than improve appearance; it gives the radiologist access to a previously diagnostically inaccessible region and may influence the decision between observation, aspiration, revision surgery, or another intervention.

Even here, however, better images require informed interpretation. Metal-artifact-reduction techniques can introduce characteristic blurring and ripple artifacts, although newer approaches have shown considerable success in reducing these artifacts [13]. The remaining artifact pattern is influenced by implant material and geometry, while interpretation also requires knowledge of the surgical approach and expected postoperative changes. Technology opens the diagnostic window; expertise determines what we see through it.

From validation to implementation

Moving from better images to better decisions requires a broader culture of validation. First, we need technical studies that define how a method behaves, including its failure modes. Second, diagnostic studies should use realistic patient populations, relevant pathology, multiple readers, and appropriate reference standards. Third, workflow studies should determine whether the method changes reporting time, confidence, recommendations, or communication with referring clinicians. Finally, outcome and health-system studies should examine whether the technique improves care, avoids unnecessary tests, reduces repeat imaging, or expands access.

Not every innovation needs a randomized trial before clinical use. The level of evidence should be proportional to the claim being made. If a reconstruction is proposed as a faster replacement for an established sequence, diagnostic noninferiority may be the central requirement. If a quantitative biomarker is claimed to guide therapy, longitudinal and outcome data become essential. If an automated tool influences interpretation, its performance must be assessed across institutions, scanners, patient groups, and uncommon but consequential findings.

Implementation also requires attention to generalizability. Many advances originate in highly specialized centers with expert technologists, optimized coils, and dedicated physicists. Their broader value depends on reproducibility in routine practice. A method that performs exceptionally under ideal conditions but fails unpredictably during a busy clinical day will not improve decisions. Robustness, ease of use, and education are therefore clinical performance characteristics, not secondary operational details.

The next step

As new MSK MRI techniques emerge, three questions can keep innovation clinically grounded. First, does the technique reveal relevant information that was previously unavailable or unreliable? Second, does it provide the necessary information faster, more safely, or with less burden on the patient? Third, does the result change the diagnostic thinking, management, or outcome? A technique need not satisfy all three, but its intended contribution should be explicit.

This framework also helps us choose wisely among competing possibilities. Sometimes the best decision will be to use ultra-high resolution; at other times it will be to accept less detail in exchange for speed and comfort. Sometimes a quantitative sequence will add important biological information; at other times a well-optimized conventional protocol will be the correct examination. Innovation should expand our options, not make every protocol more complicated.

This edition of MAGNETOM Flash accompanies the Annual Meeting of the International Skeletal Society. The advances presented in this ISS edition reflect how dynamic MSK MRI has become. Across the field, we can acquire images faster, reconstruct them more intelligently, visualize smaller structures, quantify tissue properties, and obtain diagnostic information closer to metal than was possible only a few years ago. The responsibility that accompanies these capabilities is to connect them to the decisions faced by patients and clinicians.

Better images will always inspire us. They reveal anatomy, stimulate new questions, and drive the field forward. But the enduring measure of progress is not how an image performs on the screen; it is whether the information helps the right patient receive the right diagnosis and the right care. The next step for musculoskeletal MRI is therefore clear: from better images to better decisions.



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