Technical Innovation

Small-Field-of-View MRI of the Knee and Ankle

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Imaging of joints has developed appreciably since the introduction of MRI, and image quality continues to improve with new technical developments. Improved visibility can be achieved by increasing the contrast or spatial resolution of the area of interest.

Although small-field-of-view imaging in other areas such as the temporomandibular joints, fingers, and neck has been described, its use in MRI of large joints has not, to our knowledge, been reported. Through five illustrative cases, we present our experience with MRI of large joints—namely, the knee and ankle—using a small-field-of-view surface coil to provide high-resolution images of predetermined areas of interest.

Materials and Methods

Patients

Five patients with clinical suspicion of internal derangement were examined on MRI. Three patients underwent knee examination, and two underwent ankle examination.

Imaging Methods

All examinations were performed on the same 1.5-T whole-body MRI scanner (Magnetom Sonata, Siemens). For the standard knee or ankle examination, a 23-cm circularly polarized extremity no-tune transmit-receive coil was used. For the knee, the standard sequences were sagittal proton density (TR/TE, 3,500/45) and fat-saturated T2-weighted (2,220/83), coronal T1-weighted (450/14) and fat-saturated T2-weighted, and axial fat-saturated proton density images. For the ankle, the standard sequences for suspected osteochondral defects were sagittal proton density (3,500/45) and fat-saturated T2-weighted (2,220/83), coronal T1-weighted (450/14) and fat-saturated T2-weighted, and axial fat-saturated proton density images. The parameters were as follows: field of view, 13.3 × 16.0 cm; matrix, 256 × 512 (displayed at 512 × 512); slice thickness, 3 mm with a 0.3-mm interslice gap; and number of averages, 3.

Turbo spin-echo sequences were used for all acquisitions except the T1-weighted sequence, for which a spin-echo sequence was used.

The images were reviewed by the attending musculoskeletal radiologist, and if a subtle lesion or a suspicious area was identified, additional images were obtained using a surface coil provided the area of interest was superficial enough to be encompassed by the small-field-of-view surface coil. For additional targeted imaging, a commercially available 4-cm no-tune loop receive surface coil approved by the United States Food and Drug Administration was placed over the area of interest. The optimal site of placement, with the shortest depth from surface to lesion, was chosen using the standard images as a guide. Parameters for small-field-of-view imaging were as follows: field of view, 10.0 × 10.0 cm; matrix, 256 × 512 (displayed at 512 × 512); slice thickness, 3 mm with a 0.3-mm interslice gap; and number of averages, 3. Imaging planes and sequences for the examination with the small-field-of-view coil were selected on the basis of the planes and sequences that were most informative with the standard coil. The overall scanning time was increased by an amount dependent on the number of additional sequences used. On average, only two sequences were performed, adding less than 15 min of additional preparation and scanning time.

Image Evaluation

Spatial resolution. Because the scanning sequences were identical, direct comparison of the spatial resolution was possible using the field of view and pixel matrix (Appendix 1).

Contrast resolution. The signal-to-noise ratio was measured in patient 1 as a reference. The same area (in this patient, the lateral aspect of the knee centered on the lateral meniscus) was examined using an extremity coil with a 16-cm field of view, an extremity coil with a 10-cm field of view, and a superficial coil with a 10-cm field of view. An identical coronal proton density sequence was used. An identical area (i.e., region of interest) was chosen at the lateral tibial plateau on all three examinations, and the signal intensity was measured. To estimate the degree of background noise, we used an area in the scanning plane and outside the patient to assess the standard deviation of signal intensity. The ratio of the two values was used as an estimation of the signal-to-noise ratio (Appendix 1).

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**Results**

**Image Resolution**

*Spatial resolution.*—In-plane resolution for the superficial coil (10-cm field of view) was 0.076 mm² (pixel size) compared with 0.200 mm² (pixel size) for the standard knee coil (16-cm field of view) (Appendix 1), which is a 2.6-fold improvement.

*Contrast resolution.*—The signal-to-noise ratio for the superficial coil was approximately double that of the standard knee coil (Appendix 1). Although there was a decrease in signal intensity with the smaller superficial coil, this decrease was more than compensated for by the larger decrease in noise.

**Illustrative Examples**

*Patient 1.*—An 18-year-old man who underwent anterior cruciate ligament reconstruction 1 year earlier presented with lateral joint pain. Imaging with the superficial coil showed a thin line of high signal extending to the inferior meniscal surface consistent with an undisplaced tear (Fig. 1C). This finding was not apparent on MR images obtained using the standard extremity coil (Figs. 1A and B). These three images were used to calculate the change in the signal-to-noise ratio as discussed.

Studies have shown that a small proportion of arthroscopically apparent meniscal tears were not seen not to extend to articular surface on MRI [1, 2]. This is particularly common in the lateral meniscus, either peripheral or posterior when an associated anterior cruciate liga-

ment injury is present [3]. The improved spatial resolution and signal-to-noise ratio achieved using a superficial coil may improve one’s diagnostic accuracy in this situation.

*Patient 2.*—A 27-year-old man presented with persistent pain from an ankle injury that occurred 3 years earlier that had been treated conservatively. Standard MRI revealed an osteochondral lesion of the talus dome laterally (Fig. 2A). We were not able to delineate the tibial or talar articular cartilage contour despite magnification. Images obtained using the superficial coil showed a flap of cartilage was separated from the subchondral bone in the region of the deep radial zone, depression of the subchondral bone (Figs. 2B and 2C), and subchondral cysts (Fig. 2B). The configuration and thickness of this lesion were confirmed at arthroscopy.

This case indicated separation at the deep layer of the articular cartilage, probably representing a “tidemark” separation. The tidemark, the junction between the calcified and noncalcified cartilage, is a vulnerable zone for cartilage, subject to injury caused by shearing forces [4].

Using a superficial coil allows improvement in spatial resolution. This alternative method could be used to complement efforts to improve contrast resolution with sequences such as driven equilibrium Fourier transformation, refocused steady-state free precession, or diffusion imaging.

*Patient 3.*—An 18-year-old male squash player presented with an 18-month history of ankle pain aggravated by exercise. The contour of the cartilage surface of an osteochondral lesion in the medial aspect of the talus dome was difficult to discern on standard MRI (Fig. 3A). The lesion—a focal bulge suggesting hypertrophic reparative fibrocartilage (Fig. 3B)—was better delineated with the superficial coil. High-signal foci within this bulge suggested that the lesion was not simply a flap of displaced hyaline cartilage.

Cartilage surface contour is difficult to visualize when little joint fluid is present [5]. The contour of the talus dome cartilage is particularly difficult to visualize in the absence of sufficient joint fluid because the cartilage is relatively thin and is closely applied to the distal tibial cartilage. The thin cartilage is also prone to MRI artifacts (namely truncation, chemical shift, and partial volume). The use of a surface coil improved contrast and spatial resolution because it allowed a small amount of joint fluid to delineate clearly the contour of the cartilage that was not seen on images obtained using a standard extremity coil. Signal differences within the cartilage are also easier to detect using the surface coil.

*Patient 4.*—A 36-year-old woman presented with anterior knee pain from a tennis injury that occurred 6 months earlier. MRI with a superficial coil revealed a cartilage abnormality in the lateral facet of the patella with subchondral bone change (Fig. 4). An area of slightly thickened articular cartilage was visible at the medial aspect of the lateral patellar facet. The thickened cartilage shows loss of the trilaminar pattern.
Fig. 2.— MR images of 27-year-old man who injured ankle 3 years earlier presented with persistent pain despite conservative treatment. 

A, Coronal proton density image (TR/TE, 3,500/42) obtained using standard extremity coil shows mildly displaced osteochondral lesion (arrow) involving lateral corner of talar dome. Contour of articular cartilage of distal tibia and talar dome is difficult to discern. Tibial and talar articular surfaces cannot be differentiated.

B, Coronal proton density image (3,500/39) of lesion shown in A obtained using 4-cm surface coil positioned over lateral malleolus shows separation of talar cartilage (straight arrow) in deep radial zone. Cartilage surface contour of distal tibia and of talar dome is more easily discerned. Small cystlike lesions (curved arrow) are present in underlying bone.

C, Sagittal proton density image (3,500/39) of lesion shown in A obtained using 4-cm surface coil positioned over lateral malleolus shows 1-cm (anterior to posterior) flap of cartilage separation in deep radial zone. This finding is at "tidemark" zone (arrow), boundary between calcified and noncalcified cartilage that is a relatively weak plane subject to shearing injuries.

Fig. 3.— MR images of ankle in 18-year-old male squash player with 18-month history of ankle pain aggravated by exercise.

A, Sagittal proton density image (TR/TE, 3,500/42) obtained using standard extremity coil shows osteochondral lesion (arrow) of medial corner of talar dome. Cartilage surface contour is difficult to discern.

B, Sagittal proton density image (3,050/39) of lesion shown in A obtained using 4-cm surface coil positioned over medial malleolus more clearly reveals thickened articular cartilage resulting in bulging contour (arrow) than A. Signal intensity of this thickened articular tissue differs from normal articular hyaline cartilage, which suggests it may be fibrocartilage.
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Fig. 4.—MR image of patellar region in 36-year-old woman with anterior knee pain from tennis injury 6 months earlier. Axial fat-saturated proton density image (TR/TE, 3,500/39) obtained using 4-cm surface coil positioned over patella reveals abnormality in lateral facet articular cartilage of patella with subchondral bone changes. Mild focal swelling of articular cartilage (arrow) is visible. Swollen cartilage shows loss of trilaminar pattern (as seen on medial facet). Cartilage signal is heterogeneous with high signal in region of radial (deep) zone and loss of superficial dark line (truncation artifact). This detail was not apparent on standard extremity coil imaging (not shown).

Patient 5.—A 13-year-old female long-jump athlete presented with knee pain from a knee sprain that occurred during training 5 days earlier. A moderate-sized joint effusion helps outline the meniscofemoral ligament, which is avulsed from its femoral attachment (Fig. 5A). The tear extended to involve the overlying fat. The rest of the medial collateral ligament complex was intact. This detail was not apparent on similar sequences using a standard knee coil. This area is a blind spot for arthroscopy, making clear delineation of an MRI-detectable abnormality valuable.

Discussion

MRI of large joints has improved over the past decade with better examination technique and higher image resolution, thus increasing diagnostic accuracy. Various techniques have been developed to improve images, such as MR arthrography, tailored cartilage sequences, positional and kinematic imaging, and oblique imaging planes to better visualize particular structures. This study illustrates how the resolution of images of large joints can be further improved by applying a superficial coil on the area of interest identified on a standard examination.

In our experience over the past 18 months, a superficial coil can be used with good effect for examining superficial structures in large joints on imaging. The standard examination can be used to identify areas of abnormality, and a superficial coil can subsequently be used to provide better resolution when required. This is provided the area of interest is around the optimal signal depth encompassed by the smaller field of view of the surface coil, which is, as a rule, half the diameter of the coil. In practical terms, the 4-cm superficial coil described here is useful for examining structures at more peripheral areas of the knee and ankle joints but not in central areas. Changing coils during an examination is not part of standard MRI. In most clinical applications, applying a superficial coil helped clarify the final diagnosis and allowed clearer depiction of subtleties apparent on standard imaging in most cases. Changing coils during MRI examination is akin to using transducers of different frequencies during sonography to look at deeper or superficial structures. In a small or remote radiology practice, the attending radiologist may not be available to supervise the MRI examination during scanning. In such situations, patients could be called back at a later date for additional imaging with a superficial coil.

Fig. 5.—MR images of knee in 13-year-old female long-jump athlete who was injured during training 5 days earlier. A, Coronal proton density image (TR/TE, 3,500/39) using 4-cm surface coil positioned over medial joint line shows moderate-sized joint effusion outlines meniscofemoral ligament (straight arrow), which has been avulsed from its femoral attachment. Small blood clot (curved arrow) is present. Tear (arrowhead) extends to involve overlying fat. B, Coronal proton density image (3,500/39) of contralateral normal knee was obtained using 4-cm surface coil positioned over medial joint line for comparison with injured knee. Intact meniscofemoral ligament (arrow) is clearly visible.
APPENDIX 1. Spatial Resolution, Contrast Resolution, and Signal-to-Noise Ratio for MR Images Obtained Using a Superficial Coil Versus a Standard Extremity Coil

**Spatial Resolution**

A. Superficial coil with 10.0 × 10.0 cm field of view and 256 × 512 matrix: (100 mm / 256) × (100 mm / 512) = 0.076 mm²

B. Extremity coil with 13.3 × 16.0 cm field of view and 256 × 512 matrix: (133 mm / 256) × (160 mm / 512) = 0.200 mm²

**Contrast Resolution and Signal-to-Noise Ratio**

A. Superficial coil with 10.0 × 10.0 cm field of view: signal intensity (of lateral tibial plateau) = 711.2 H, standard deviation (SD) of background noise = 13.1

Approximate signal-to-noise ratio = signal intensity / SD = 54.3

B. Standard extremity coil

1. With 13.3 × 16.0 cm field of view: signal intensity = 895 H, SD = 36.2

   Approximate signal-to-noise ratio = 24.7

2. With 10.0 × 10.0 cm field of view: signal intensity = 1,753 H, SD = 84.7

   Approximate signal-to-noise ratio = 20.7

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