

Musculoskeletal MR Protocols

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Technical note: minimum matrix numbers for any sequences should in general be around 256 (avoid matrices of 192 or less in square FOV's).

MSK 1: Shoulder MRI

Indications: shoulder pain, internal derangement, rotator cuff tears.

Sequences: shoulder in *external* rotation.

- *Oblique coronal T2 FSE with fat saturation* [3.0 mm thick, 0.6 mm gap]
- Oblique sagittal T1 SE
- Oblique sagittal T2 FSE with fat saturation
- Axial T1 SE
- Axial T2 FSE with fat saturation

For pre- and post-contrast exams, add the following:

- *Non-contrast* oblique coronal T1 SE with fat saturation.
- *Post-contrast:* oblique coronal, oblique sagittal, axial T1 SE with fat saturation.

Comments:

- Good for diagnosing rotator cuff tears; less effective for labral pathology.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 1A: Shoulder MR arthrogram

Indications: postoperative patients, rotator cuff tears, labral pathology.

Sequences: shoulder in *external* rotation

- Axial T1 SE with fat saturation
- Oblique coronal T1 SE with fat saturation
- *Oblique coronal T2 FSE with fat saturation* [3.0 mm thick, 0.6 mm gap]
- Oblique sagittal T1 SE with fat saturation
- Oblique sagittal T1 SE
- Oblique sagittal T2 FSE with fat saturation

Comments:

- Good for both rotator cuff and labral pathology.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 1AB: Shoulder MR arthrogram (instability protocol)

Indications: antero-inferior labral pathology, shoulder dislocation/instability.

Sequences: shoulder in *external* rotation

- Axial T1 SE with fat saturation
- Oblique coronal T1 SE with fat saturation
- *Oblique coronal T2 FSE with fat saturation* [3.0 mm thick, 0.6 mm gap]
- Oblique sagittal T1 SE with fat saturation
- Oblique sagittal T1 SE
- Oblique sagittal T2 FSE with fat saturation
- ABER T1 SE with fat saturation

Comments:

- Added sequence with shoulder in **Abduction External Rotation** puts traction on the anteroinferior labrum and inferior glenohumeral ligament, diagnosing pathology resulting from anterior shoulder dislocations.
- Added benefit of assessing articular-surface rotator cuff tendon tears.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 2: Elbow MRI

Indications: pain, internal derangement.

Sequences: elbow supinated at side (preferred) or overhead while prone.

- Coronal PD FSE
- *Coronal T2 FSE with fat saturation* [384 x 269 matrix, 3.0 mm thickness, 0.6 mm gap]
- Axial T1 SE
- Axial T2 FSE with fat saturation
- Sagittal T1 SE
- Sagittal T2 FSE with fat saturation

For pre- and post-contrast exams, add the following:

- *Non-contrast* coronal T1 SE with fat saturation.
- *Post-contrast:* coronal, sagittal, axial T1 SE with fat saturation.

Comments:

- Make sure that axial sequences go distally enough to encompass the biceps tendon insertion onto the radius.
- To evaluate for intra-articular bodies, recommend CT air arthrogram instead of MR arthrogram.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 2A: Elbow MR arthrogram

Indications: pain, internal derangement.

Sequences: elbow supinated at side (preferred) or overhead while prone.

- Coronal T1 SE with fat saturation
- *Coronal T2 FSE with fat saturation* [384 x 269 matrix, 3.0 mm thickness, 0.6 mm gap]
- Axial T1 SE
- Axial T2 FSE with fat saturation
- Sagittal T1 SE with fat saturation
- Sagittal T2 FSE with fat saturation

Comments:

- Make sure that axial sequences go distally enough to encompass the biceps tendon insertion onto the radius.
- To evaluate for intra-articular bodies, recommend CT air arthrogram instead of MR arthrogram.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 3: Wrist MRI

Indications: pain, occult scaphoid fractures.

Sequences: wrist neutral at side or overhead while prone.

- Coronal PD FSE
- *Coronal T2 FSE with fat saturation* [384 x 210 matrix, 3.0 mm thickness, 0.3 mm gap]
- Axial T1 SE
- Axial T2 FSE with fat saturation
- Coronal 3-D GRE
- Sagittal T1 SE

For pre- and post-contrast exams, add the following:

- *Non-contrast* coronal T1 SE with fat saturation.
- *Post-contrast:* coronal, sagittal, axial T1 SE with fat saturation.

Comments:

- Reduced sensitivity for triangular fibrocartilage tears and ligamentous injury.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 3A: Wrist MR arthrogram

Indications: pain, internal derangement.

Sequences: wrist neutral at side or overhead while prone.

- Coronal T1 SE with fat saturation
- *Coronal T2 FSE with fat saturation* [384 x 210 matrix, 3.0 mm thickness, 0.3 mm gap]
- Axial T1 SE with fat saturation
- Axial T2 FSE with fat saturation
- Sagittal T1 SE with fat saturation
- Sagittal T1 SE

Comments:

- More effective for evaluating the triangular fibrocartilage, as well as extrinsic and intrinsic carpal ligaments.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 4: Hand/finger MRI

Indications: pain, internal derangement.

Sequences: hand prone at side or overhead.

- Coronal T1 SE
- Coronal T2 FSE with fat saturation
- Axial PD FSE
- *Axial T2 FSE with fat saturation* [384 x 250 matrix, 3.0 mm thickness, 0.3 mm gap]
- Sagittal T1 SE
- Sagittal 'gray' STIR

For pre- and post-contrast exams, add the following:

- *Non-contrast* axial T1 SE with fat saturation.
- *Post-contrast:* coronal, sagittal, axial T1 SE with fat saturation.

Comments:

- Coronal and axial sequences should encompass adjacent digits for comparison
- Sagittal images can be done through the symptomatic finger(s) only.
- Slice thickness: 2-2.5 mm with minimal interslice gap.
- Axial T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

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MSK 4G: Finger MRI without contrast (thumb injury protocol)

Indications: assess for ulnar collateral ligament injury/Stener lesion.

Sequences:

- Oblique coronal T1 SE
- *Oblique coronal T2 FSE with fat saturation* [384 x 250 matrix, 2.0 mm thickness]
- Axial T2 FSE with fat saturation
- Sagittal T2 FSE with fat saturation

Comments:

- Limited study geared towards assessing the ulnar collateral ligament.
- Slice thickness: 2-2.5 mm with minimal interslice gap.
- T2 FSE with fat saturation: adjust 40 msec (+/-5 msec).

MSK 5: Pelvis and hip MRI

Indications: pain, internal derangement, avascular necrosis.

Sequences:

- Coronal T1 spin echo of bony pelvis
- Coronal STIR of bony pelvis
- *Coronal T2 FSE with fat saturation of affected hip* [3.5 mm thick, 0.35 mm gap]
- Axial T2 FSE with fat saturation of affected hip
- Sagittal T1 SE of affected hip
- Oblique axial T2 FSE with fat saturation of affected hip

For pre- and post-contrast exams, add the following:

- *Non-contrast* axial T1 SE with fat saturation.
- *Post-contrast:* coronal, sagittal, axial T1 SE with fat saturation.

Comments:

- Oblique axial sequence is done parallel to the femoral neck, and is useful for diagnosing cam-type femoroacetabular impingement (FAI).
- Alpha angles are measured from the oblique axial images. Values are 74 +/- 5 degrees in patients with FAI, and 42 +/- 2 degrees in controls. Notzli et al. J Bone Joint Surg Br 2002; 84: 556-560.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 5A: Hip MR arthrogram

Indications: pain, labral pathology.

Sequences:

- Coronal STIR of bony pelvis
- *Coronal T1 SE with fat saturation of hip* [3.5 mm thick, 0.35 mm gap]
- Sagittal T1 SE with fat saturation of hip
- Sagittal T1 SE of hip
- Axial T2 FSE of hip with fat saturation of hip
- Oblique axial T1 SE with fat saturation of hip

Comments:

- Oblique axial sequence is done parallel to the femoral neck, and is useful for diagnosing cam-type femoroacetabular impingement (FAI).
- Alpha angles are measured from the oblique axial images. Values are 74 +/- 5 degrees in patients with FAI, and 42 +/- 2 degrees in controls. Notzli et al. J Bone Joint Surg Br 2002; 84: 556-560.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

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MSK 5SI: Sacro-iliac joint MRI

Indications: sacroiliitis, joint infection.

Sequences:

- Oblique coronal T1 SE through SI joints
- Oblique coronal STIR through SI joints
- Axial T1 SE
- Axial STIR
- Oblique coronal 3D FLASH through SI joints
- *Opt:* post-Gd oblique coronal T1 SE with fat saturation
- *Opt:* post-Gd axial T1 SE with fat saturation

Comments:

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MSK 5T: Pelvis MRI without contrast (trauma protocol)

Indications: assess for pelvic ring, sacral, or hip fractures.

Sequences: include entire bony pelvis

- Coronal T1 SE
- Coronal STIR
- Axial T1 SE
- Axial STIR

Comments:

- Limited survey to assess for occult fractures; best reserved for ER add-ons during the day.

MSK 6: Knee MRI

Indications: pain, internal derangement.

Sequences:

- Oblique sagittal PD FSE
- Oblique sagittal T2 FSE with fat saturation
- Oblique sagittal 3-D FLASH with fat saturation
- Axial PD FSE with fat saturation
- Coronal T1 SE
- Coronal PD FSE with fat saturation

For pre- and post-contrast exams, add the following:

- *Non-contrast* axial T1 SE with fat saturation.
- *Post-contrast:* coronal, sagittal, axial T1 SE with fat saturation.

Comments:

- 3-D FLASH with fat saturation is dedicated to cartilage evaluation.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).
- Optional for Smith-Nephew hardware scans only: substitute 1st sequence for sagittal T2 FSE (no fat saturation) with 2 mm slice thickness, 0mm interslice gap, 512 x 256 matrix, 22 cm FOV, ETL 7, Bw 200, 1 NEX.

MSK 6A: Knee MR arthrogram

Indications: evaluating for meniscal rears in a postoperative knee.

Sequences:

- Oblique sagittal T1 SE with fat saturation
- Oblique sagittal PD FSE with fat saturation
- Coronal T1 SE
- Coronal T1 SE with fat saturation
- Coronal T2 FSE with fat saturation
- Axial PD FSE with fat saturation

Comments:

- Keep ACE wrap around knee during scan, to direct intra-articular contrast into regions around the menisci.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

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MSK 6C: ConforMIS knee MRI (arthroplasty planning)

Indications: evaluating for knee implant design by ConforMIS

Sequences:

- Sagittal PD FSE with fat saturation
- Coronal PD FSE with fat saturation
- Sagittal 3D FLASH with fat saturation
- Coronal 3D FLASH with fat saturation

Comments:

- Per manufacturer's guidelines, first 2 sequences are required, and the next 2 sequences are recommended.

MSK 6Z: Zimmer knee MRI (arthroplasty planning)

Indications: evaluating for knee implant design by Zimmer

Sequences:

- Axial T1 SE of ankle without fat saturation (TR 400-5000 msec, TE 2.0-100 msec)
- Sagittal 3D FLASH with fat saturation of knee
- Add: sagittal T2 FSE of knee (Smith-Nephew sequence, see notes).
- Coronal T1 SE of knee
- Axial T1 SE of hip (TR 20-5000 msec, TE 2.0-100 msec)

Comments:

- See manufacturer's publication for more sequence parameters.
- Smith-Nephew planning sequence: perform sagittal T2 FSE (no fat saturation) with 2 mm slice thickness and 0mm interslice gap, 512 x 256 matrix, 22 cm FOV, ETL 7, Bw 200, 1 NEX.

MSK 7: Ankle MRI

Indications: pain, internal derangement.

Sequences: place fiducial over symptomatic site

- Sagittal T1 SE
- Sagittal T2 FSE with fat sat
- Axial PD FSE
- *Axial T2 FSE with fat saturation* [448 x 223 matrix, 3.0 mm thick, 0.3 mm gap]
- Coronal T2 FSE with fat saturation
- Coronal T1 SE

For pre- and post-contrast exams, add the following:

- *Non-contrast* axial T1 SE with fat saturation.
- *Post-contrast:* coronal, sagittal, axial T1 SE with fat saturation.

For plantar fascia evaluation (and whole foot imaging requested), add the following:

- Sagittal T2 FSE with fat saturation of forefoot.
- Axial T2 FSE with fat saturation of forefoot.

Comments:

- If region of interest is localized to the midfoot, extend field of view more anteriorly as needed.
- When whole foot imaging is requested (and region of clinical concern cannot be localized to either hindfoot or forefoot): perform MSK 7 and 8 concurrently but with separate sequences. Do not use larger FOV to encompass whole foot and ankle.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 7A: Ankle MR arthrogram

Indications: assess for intra-articular bodies, ligamentous injuries.

Sequences: place fiducial over symptomatic site

- Sagittal T1 SE
- Sagittal T1 SE with fat saturation
- Axial T1 FSE with fat saturation
- *Axial T2 FSE with fat saturation* [448 x 223 matrix, 3.0 mm thick, 0.3 mm gap]
- Coronal T1 SE with fat saturation
- Coronal T2 FSE with fat saturation

Comments:

- Contrast injection into the tibiotalar joint capsule.
- T2 fast spin echo with fat saturation: adjust TE to 40 msec (+/-5 msec).

MSK 8: Forefoot MRI

Indications: pain, internal derangement.

Sequences: place fiducial over symptomatic site

- Sagittal T1 SE
- *Sagittal T2 FSE with fat saturation* [320 x 192 matrix, 2.5 mm thick, 0.25 mm gap]
- Long-axis T1 SE
- Long-axis STIR
- Short-axis T1 SE
- Short-axis T2 FSE with fat saturation

For pre- and post-contrast exams, add the following:

- *Non-contrast* short-axis T1 SE with fat saturation.
- *Post-contrast:* short axis, long-axis, sagittal T1 SE with fat saturation.

Comments:

- Long-axis sequences are performed parallel to the metatarsal shafts. Short-axis images are done perpendicular to the metatarsals.
- When whole foot imaging is requested (and region of clinical concern cannot be localized to either hindfoot or forefoot): perform MSK 7 and 8 concurrently but with separate sequences. Do not use larger FOV to encompass whole foot and ankle.
- T2 FSE with fat saturation: adjust TE to 40 msec (+/-5 msec).

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MSK 8M: Forefoot MRI pre- and post-contrast (Morton's neuroma protocol)

Indications: assess for Morton's neuroma.

Sequences: place fiducial over symptomatic site

- Long-axis T1 SE
- Long-axis T2 FSE with fat saturation
- Short-axis T1 SE
- Short-axis T2 FSE with fat saturation
- Short-axis T1 SE with fat saturation
- *Post-Gd short-axis T1 SE with fat saturation* [320 x 192 matrix, 2.5 mm thick, 0.25 mm gap]

Comments:

- Long-axis sequences are performed parallel to the metatarsal shafts. Short-axis images are done perpendicular to the metatarsals.
- Perform scan with patients prone; flip short-axis images when sending to PACS.

MSK 9: Pre- and post-contrast long bone MRI (tumor/mass, or infection protocol)

Indications: osseous or soft tissue lesion, palpable or seen on other studies.

Sequences: place fiducial over mass if palpable

- Coronal T1 SE
- Coronal STIR
- Axial T1 SE
- Axial T2 FSE with fat saturation
- ~~Sagittal T1 SE with fat saturation~~
- Sagittal STIR
- Axial 2D FLASH in- and out-of-phase
- Axial Diffusion and ADC (b = 50, 400, 800)
- Coronal pre-Gd 3D VIBE with fat saturation.
- Coronal post-Gd 3D VIBE with fat saturation (axial, sag reformats)

Comments:

- On coronal and sagittal images, include entire long bone of concern. May include contralateral leg/thigh on coronal for comparison.
- On axial images, restrict slices to the actual lesion or site of concern. For T2 FSE with fat saturation: adjust TE to 40-50 msec.
- In- and out-of-phase imaging, DWI/ADC: restrict usage to examinations performed for characterization of intra-osseous lesion.
- For studies attempting to diagnose a bone lesion, check PACS to see if there is a diagnostic quality plain film of the lesion in question. If not, consult with interpreting radiologist about sending the patient to obtain plain films in department following MRI scan.

MSK10: MR neurography

Indications: evaluation of peripheral nerve disease.

Sequences:

- Axial T1 SE (4 mm thick)
- Axial T2 SPAIR (2 mm thick)
- Coronal T1 SE (4 mm thick)
- Coronal T2 or STIR 3D SPACE (1-2 mm thick)
- Coronal T2 fast spin echo with fat saturation (3 mm thick)
- Sagittal T2 fast spin echo with fat saturation (3 mm thick)

Comments:

- Field of view: ranges from 10-12 cm (wrist) up to 14-16 cm for knee or thigh).
- Matrix ranges from 256 x 256 for smaller FOV, up to 512 x 512 for larger FOV.
- For small FOV, no interslice gap. For larger FOV such as sciatic nerves, can have interslice gap for improved coverage of axial scans.

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MSK11: Upper or lower extremity MRI without contrast (long bone evaluation)

Indications: non-specific pain; tibial stress fractures.

Sequences: place fiducial over site of concern

- Coronal T1 SE
- Coronal STIR
- Sagittal T1 SE
- Sagittal STIR
- Axial T1 SE
- Axial T2 FSE with fat saturation

Comments:

- On coronal and sagittal images, include entire long bone of concern. May include contralateral leg/thigh on coronal for comparison.
- On axial images, restrict the slices to the actual lesion or site of concern. May include contralateral leg/thigh at tech's or rad's discretion.
- Typically done for humerus, femur, leg, or forearm.

MSK12: Thoracic spine, lumbar spine, and pelvis MRI (bone marrow survey)

Indications: assess extent of bone marrow metastases, typically for multiple myeloma.

Sequences: place skin marker over upper T-spine for determining levels.

- Large FOV sagittal T1 SE through C-, T-, and L-spine
- Large FOV sagittal STIR through C-, T-, and L-spine
- Large FOV coronal T1 SE through entire thorax
- Large FOV coronal STIR through entire thorax
- Coronal T1 SE through bony pelvis and femurs
- Coronal STIR through bony pelvis and femurs

Comments:

- On sagittal spine sequences, divide spine into 2 scans if needed.
- Can recommend whole body PET-CT as an alternative means of assessing myelomatous involvement. Bredella et al. AJR 2005; 184: 1199-1204.

MSK13: Pre- and post-contrast hand MRI (arthritis protocol)

Indications: characterize and follow-up inflammatory arthritides in the hands and wrists.

Sequences: if doing both hands/wrists, position hands and wrists together in prayer position, with skin marker over the dorsum of the right hand as reference. Patient should be in lateral decubitus position. Use knee or extremity coil.

- Axial T1 spin echo
- Axial T2 FSE with fat sat (TE 40 msec +/- 5 msec)
- Coronal T1 spin echo
- Coronal T2 FSE with fat sat (TE 40 msec +/- 5 msec)
- Post-Gadolinium axial T1 spin echo with fat saturation
- Post-Gadolinium coronal T1 spin echo with fat saturation

Comments:

- Use 3 mm slice thickness for all sequences.
- Rectangular FOV of around 130-140 mm: adjust as necessary to include entire carpal region; fingertips can be excluded if necessary.
- Reference: Schoellnast et al. AJR 2006; 187: 351-357. David Rubin, personal communication.

MSK14: Non-contrast chest MRI (pectoralis protocol)

Indications: characterize pectoralis major muscle/tendon injuries.

Sequences: use coronal localizer to set axial scan landmarks.

- Axial T1 spin echo
- Axial T2 FSE with fat sat (TE 40 msec +/- 5 msec)
- Oblique coronal T1 spin echo
- Oblique coronal STIR
- Axial T2 FSE with fat sat (TE 40 msec +/- 5 msec)
- Oblique coronal T2 FSE with fat sat (TE 40 msec +/- 5 msec)
- Oblique sagittal T2 FSE with fat sat (TE 40 msec +/- 5 msec)

Comments:

- If possible, position patient supine to minimize respiratory motion.
- Axials: scan from lower edge of humeral head down to the deltoid tuberosity of the humeral shaft, using coronal localizers.
- Oblique coronal sequences: set parallel to course of pectoralis major tendon from axial images.
- Use 5-inch surface coil centered over the axilla.
- 32 x 42 cm FOV for initial 4 sequences, 5 mm slice thickness with 0.5 mm gap for axials, 3 mm slice thickness with 0.3 mm gap for oblique coronals.
- 18 x 21 cm FOV for last 3 sequences centered around pectoralis major tendon insertion on humeral shaft.
- Reference: Lee et al. AJR 2000; 174: 1371-1375. Lee et al. Radiographics 2017; 37: 176-189.

MSK15: Non-contrast pelvic MRI (athletic pubalgia/sports hernia protocol)

Indications: pubic symphysis region pain, osteitis pubis.

Sequences:

- Coronal T1 spin echo through bony pelvis.
- Coronal STIR through bony pelvis.
- Axial T2 FSE with fat sat through pelvis (TE 40 msec +/- 5 msec)
- Sagittal T2 FSE with fat sat (TE 40 msec +/- 5 msec): small FOV.
- Oblique axial PD FSE: small FOV.
- Oblique axial T2 FSE with fat sat (TE 40 msec +/- 5 msec): small FOV.

Comments:

- Patients should empty bladders immediately prior to scan.

For last 3 sequences only:

- Use 5-inch surface coil centered over symphysis.
- Oblique axial plane: use sagittal image near hip joint to set plane parallel to arcuate line.
- 4 mm slice thickness with 0 skip.
- 20 x 20 cm FOV, with 256 x 256 matrix.
- Reference: Omar et al. Radiographics 2008; 28: 1415-1438.