

Magnetic Resonance in Medicine Musculoskeletal MRI

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Introduction of Musculoskeletal (MSK) MRI

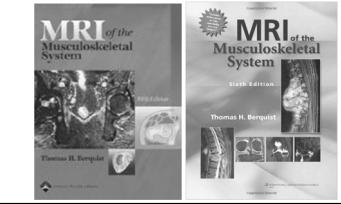
肌肉骨骼磁振造影簡介



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- Introduction of musculoskeletal (MSK) MRI

- MRI of the musculoskeletal system (5th/6th edition)
- Editor: Thomas H. Berquist MD



General Technical Considerations

- Patient screening
- Positioning
- Coil selection
- Pulse sequences
- Use of intravenous/intraarticular contrast agents



Patient Screening

- MRI safety issues
- Surgical/hemostasis clips
 - Mostly nonferromagnetic or contain minimal ferromagnetic material
 - Usually not a significant problem in imaging
- Cerebral aneurysm clips or pacemakers
 - Ferromagnetic and may twist or turn in a magnetic environment
 - Titanium and tantalum clips showed the least attractive force and minimal image distortion

Composition	Artifact	
Graphite	石墨	None-minimal
Titanium	鈦	Minimal
Tantalum	鉭	Minimal
Aluminum	鋁	Mild-moderate
Stainless steel	不鏽鋼	Moderate-severe

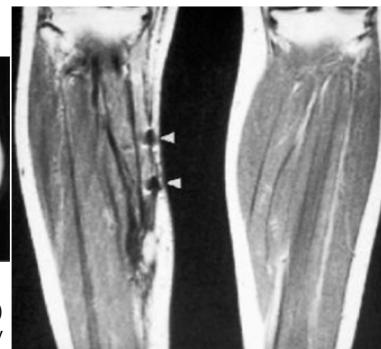
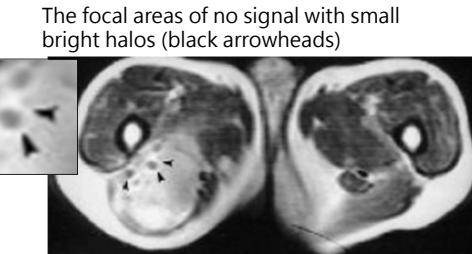
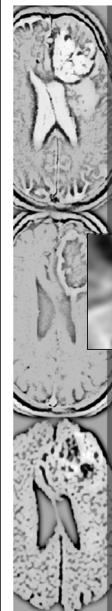
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5

MR artifacts of Hemostasis Clips

The focal areas of no signal with small bright halos (black arrowheads)



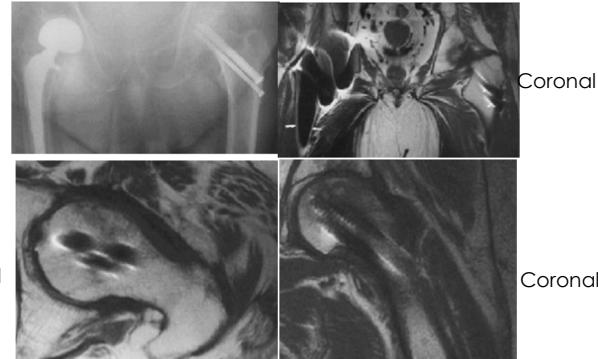
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6

Metal Artifacts

- bipolar implant on the right and three cannulated hip screws on the left



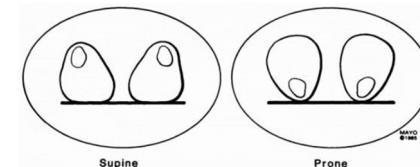
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Positioning & Coil Selection

- Positioning considerations
 - body part or anatomic region to be examined
 - expected examination time
 - Pathology is suspected in the posterior soft tissues → prone position; to prevent compression of soft tissues and anatomic distortion
- Coil Selection
 - closely coupled coil (the smallest coil that covers the anatomy)
 - to achieve the maximum SNR and the best spatial resolution



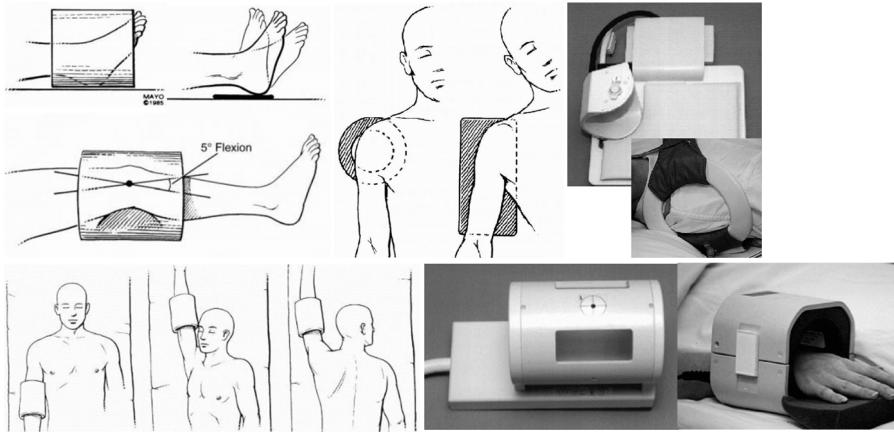
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8

Positioning & Coil Selection

<https://mrismaster.com/>

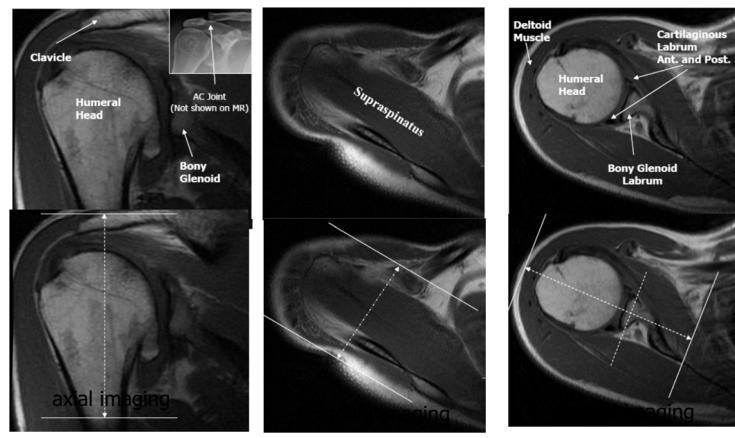


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9

Positioning & slicing - Shoulder



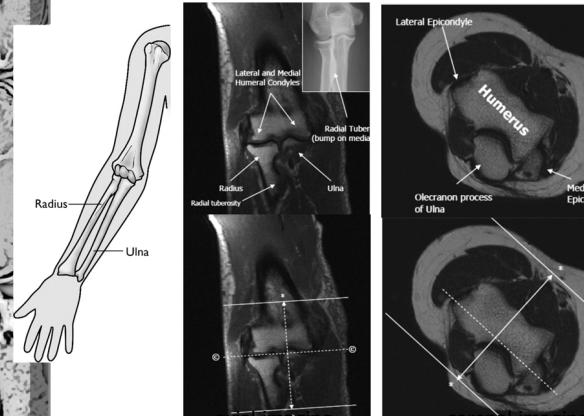
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10

Positioning & slicing - Elbow



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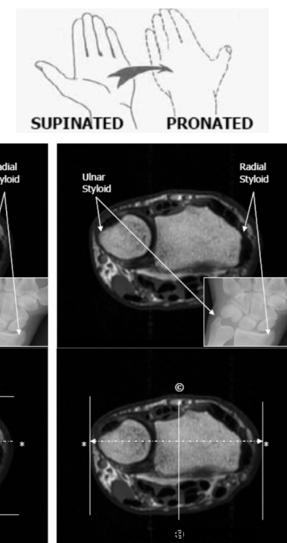
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11

Positioning & slicing - Wrist

Remember to pronate the wrist!

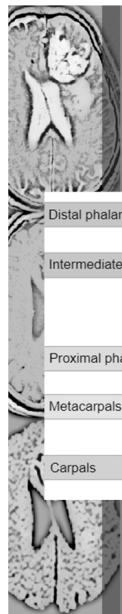


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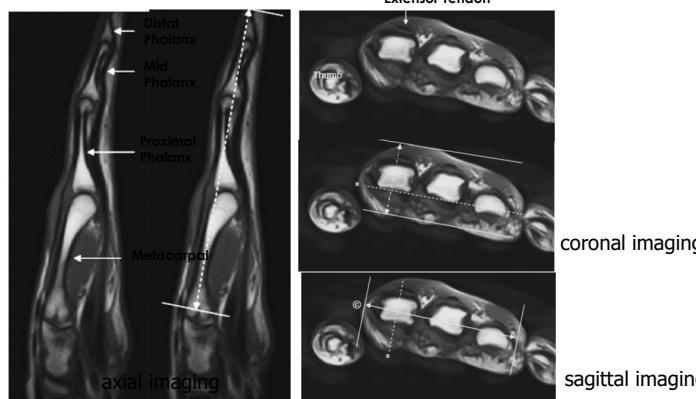
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Positioning & slicing - Finger

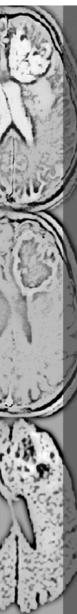


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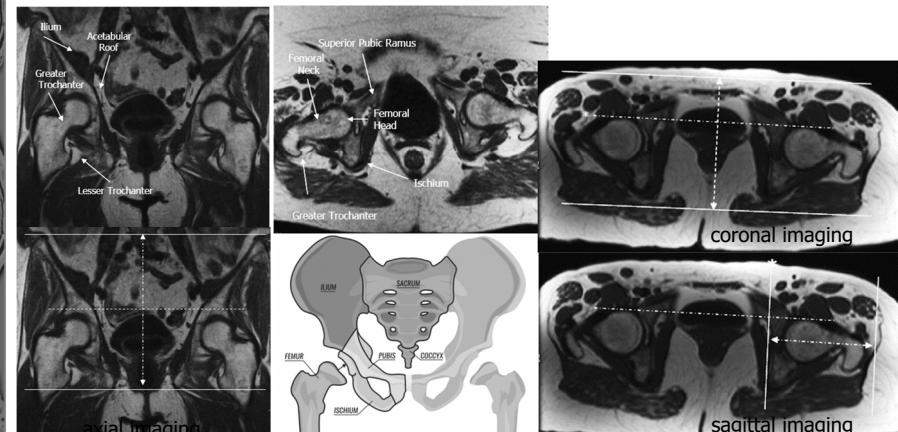
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Positioning & slicing – Hip joint



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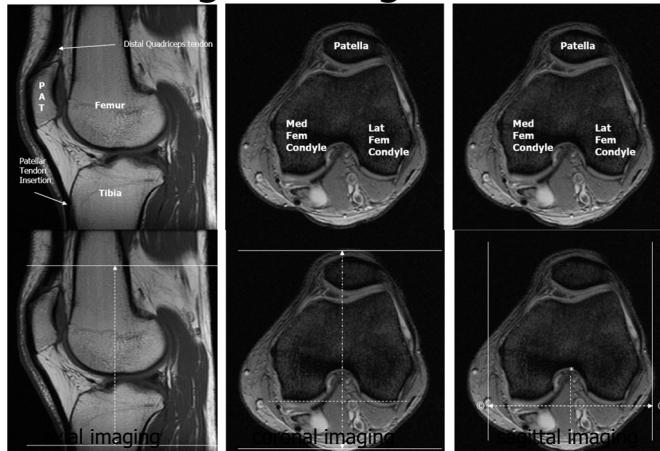
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14



Positioning & slicing – Knee

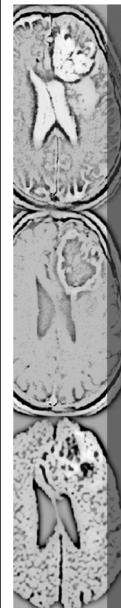


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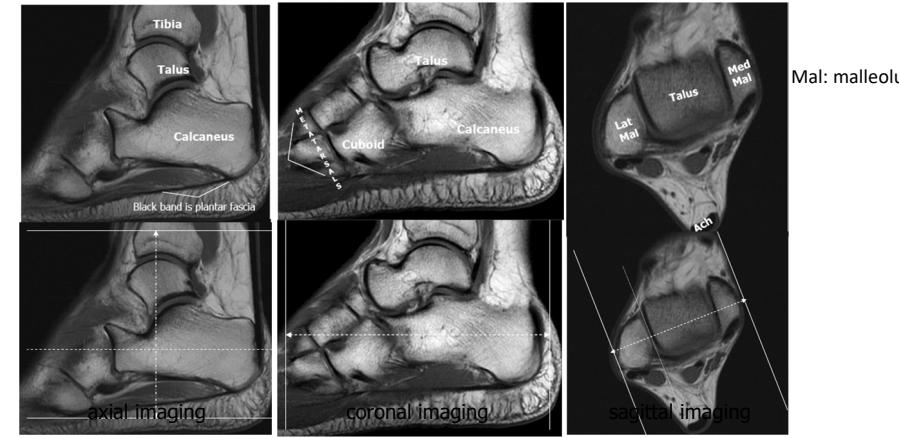
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15



Positioning & slicing – Ankle



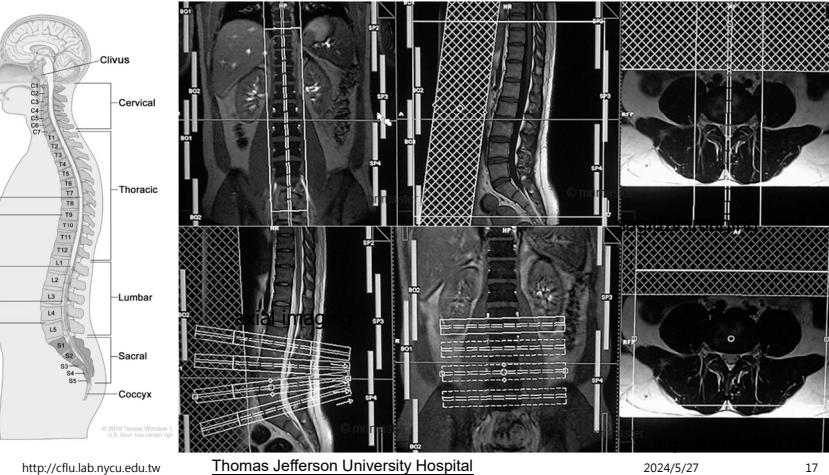
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16

Positioning & slicing – L-Spine



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Pulse Sequences

- Common sequences
 - Spin echo (SE)
 - Fast spin echo (FSE)
 - Inversion recovery (IR)
 - Short tau inversion recovery (STIR)
 - gradient-recalled echo (GRE) sequences
- Additional parameters
 - Fat suppression or water excitation
- Other sequences
 - Diffusion imaging (for fracture)

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18

Routine Protocols

- For diagnostic purpose
 - T1-weighted images (bone marrow/fat)
 - T2-weighted images (lesions with long T2 relaxation time)
 - STIR sequence/ fat suppression (bone metastasis/post Gd)
- Additional considerations
 - Intravenous/ intraarticular gadolinium injection
 - MR angiography

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Relaxation Times of MSK Tissues

- Fat has a bright signal on T1W images e.g. (yellow) bone marrow.
- Tissues with little fat or water e.g. cortical bone, tendons, ligaments are dark in both T1W & T2W.

Tissue	T1	T2
Muscle	Medium	Short
Adipose tissue	Short	Medium
Nerve	Medium	Medium
Other soft tissue	Medium to long	Medium to long
Tendon, bone	—	Very short

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30



Effects of pathology on MSK

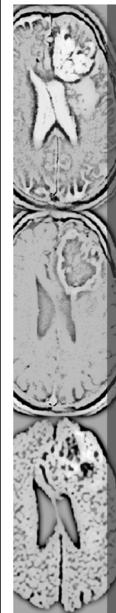
- **Fibrosis:** The mobile spin density of predominantly fibrous tissue is low → providing little MR signal.
- **Fatty Infiltration:** little exchange between the protons in fat and those in the host tissue → biexponential nature.
- **Hematoma:** prolongation of both T1 and T2 relaxation times, probably due to the presence of inflammation and edema.

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Disease Process	T1	T2
Inflammation	Increased	Increased
Neoplasia	Increased	Increased
Fibrosis	—	Decreased
Fatty infiltration	Decreased	—
Interstitial hemorrhage	Increased	Increased

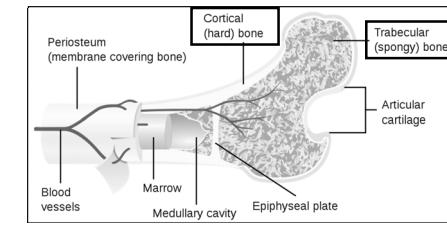
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21



Lesion Characteristics

- Abnormal tissues (long T2 relaxation time)
 - Increased signal intensity in T2-weighted images
 - Differentiation from muscle, cortical bone, and fibrous structures (ligaments, tendon, and scar tissues)



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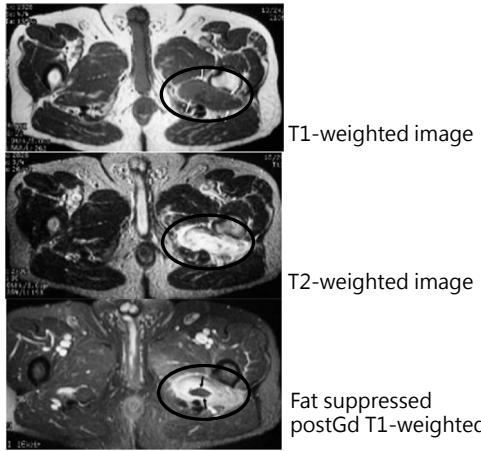
22



Soft Tissue Sarcoma

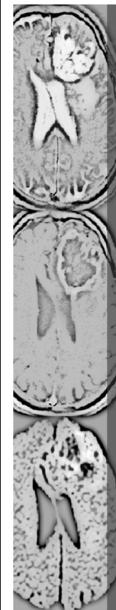
- ✓ SE 450/20 image shows excellent soft tissue anatomy, but the mass is isointense to muscle and only visible due to the differences in size (arrows).
- ✓ SE 2000/80 image clearly demonstrates the high signal intensity tumor.
- ✓ Postgadolinium, fat-suppressed T1-weighted image shows tumor enhancement except the central necrotic area (arrows).

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23



Interpretation of MRI

- Pathologic processes of the musculoskeletal system are identified at MRI by abnormal morphology, abnormal signal characteristics, or the combination of both.



acute disruption of the anterior cruciate ligament



chronic tear of a ligament

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24

Tissue Contrasts in Spin Echo

	SE T1 (TR/TE) 450-550/12-17	SE PD (TR/TE) 2000/20	SE T2 (TR/TE) 2000/80
Fat	High (white)	Intermediate	Low intensity
Marrow	High (white)	Intermediate/white	Low intensity
Hyaline cartilage	Intermediate	Intermediate	High
Muscle	Intermediate	Intermediate	Intermediate
Nerves	Intermediate (slightly<muscle)	Intermediate (slightly<muscle)	Intermediate (slightly<muscle)
Fibrocartilage	Low (black)	Low (black)	Low (black)
Ligaments – tendons	Low (black)	Low (black)	Low (black)
Blood vessels	Low (black)	Low (black)	Low or high

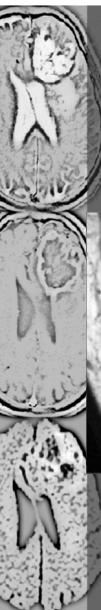
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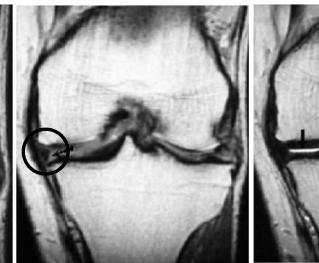
25

Tissue Contrasts

T1W, SE 500/20



PD, SE 2000/20



T2W, FSE 4900/98



Fat sat T2W, SE 2500/80



Joint fluid vs. meniscus

meniscal tear (arrow)
intercondylar erosions (arrowheads)

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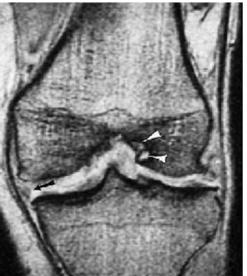
26

Tissue Contrasts

GRE 700/12, 25°



GRE 700/31, 25°



meniscal tear (arrow)
intercondylar erosions (arrowheads)

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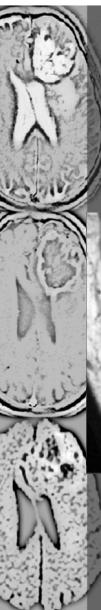
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27

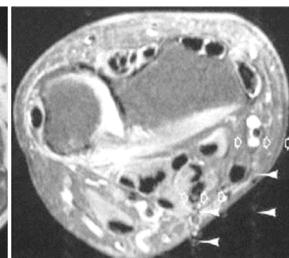
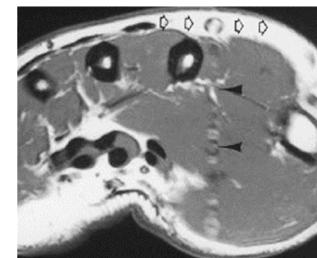
Flow-related artifacts

- Linear artifact created, usually caused by arteries.

Proton density



T2 weighted



Flow artifact (arrowheads); swapping the phase direction (open arrows) would change the direction of the artifacts ; spatial presaturation may be an alternative.

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28



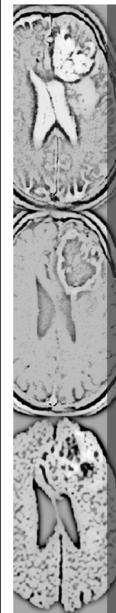
Scan Time

- SE T1-weighted sequences
 - TR/TE: 568/15, 256 × 256, one acquisition = 4 min, 55 s.
- FSE T1-weighted sequences
 - TR/TE: 663/12, ET 3, 256 × 256, one acquisition = 1 min, 57 s.
- SE Double echo (PD and T2) T2-weighted sequences
 - TR/TE: 2,000/20, 80, 256 × 256, 1 acquisition = 8 min, 53 s.
- FSE sequences using proton density or T2-weighting
 - with fat suppression – TR/TE: 4,000/92, ETL 8, 256 × 256, 1 acquisition = 3 min, 39 s.

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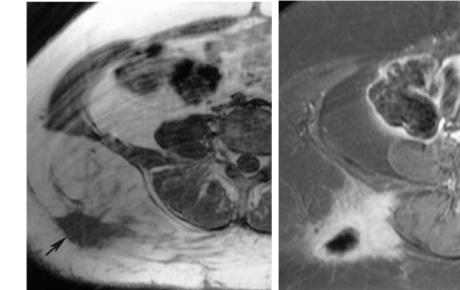
29



Intravenous Gd Injections

- Fat-suppression techniques are commonly employed when T1-weighted sequences are used after contrast injection.

Pre- and post-gadolinium images



Fat-sat TIW

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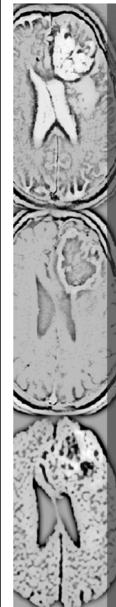
Intraarticular Gadolinium

- The technique is most commonly used for shoulder, elbow, wrist, hip, and knee MR arthrography.
- Normal saline, iodinated contrast, and lidocaine could be safely mixed with gadolinium without concern for dissociation that could result in free gadolinium.
- Intraarticular injection was safe and efficacious at a concentration of 2 mmol/L.

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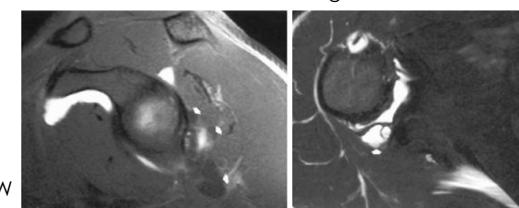
31



Intraarticular Gadolinium

- Images should be obtained within 30 minutes of injection to optimize contrast benefit.
- Fat-suppressed, T1-weighted images are optimal for intra-articular detail.

Shoulder arthrogram



Fat sat Axial T2W

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32

MR Angiography

- Two-dimensional TOF sequences maximize flow signal using flow-related enhancement combined with suppression of signal intensity from stationary tissue.



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Common Artifacts

- Motion Artifacts
- Chemical Shift (high field-strength magnets)
- Saturation Artifact (cross talk)
- Aliasing Artifacts (small FOV)
- Non-uniform Fat Suppression (field uniformity)



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34

Magic Angle Artifact

- Occurs on sequences with a short TE (less than 32ms; T1W sequences, PD sequences and gradient echo sequences)
- Regions of tightly bound collagen at 54.74° from the main magnetic field (B_0), and appears hyperintense, thus potentially being mistaken for tendinopathy.
- Normal: In tightly-bound collagen, water molecules are restricted usually causing very short T2 times, accounting for the lack of signal.



<https://radiopaedia.org/articles/magic-angle-effect-mri-artifact-1>

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35

THE END

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36