Muscle and Skeletal MRI

Principles of Musculoskeletal (MSK) MRI

General Technical Considerations

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

MRI of the musculoskeletal system
(5th/6th edition)

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http://www.ym.edu.tw/~cflu

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• 肌肉骨骼磁振造影簡介
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

<table>
<thead>
<tr>
<th>Composition</th>
<th>Artifact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphite</td>
<td>None</td>
</tr>
<tr>
<td>Titanium</td>
<td>Minimal</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Mild-moderate</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>Moderate-severe</td>
</tr>
</tbody>
</table>

MR artifacts of Hemostasis Clips

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

surgical clip artifacts (white arrowheads) in the right calf medially

Metal Artifacts

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

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 (smallest coil that covers the anatomy)
  - to achieve the maximum SNR and the best spatial resolution
Positioning & Coil Selection

Positioning & slicing - Shoulder
- Axial imaging
- Coronal imaging
- Sagittal imaging

Positioning & slicing - Elbow
- Axial imaging
- Coronal imaging
- Sagittal imaging

Remember to pronate the wrist!

Positioning & slicing - Wrist
- Axial imaging
- Coronal imaging
- Sagittal imaging

Remember to pronate the wrist!
Positioning & slicing – L-Spine

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)

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

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.

<table>
<thead>
<tr>
<th>Tissue</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle</td>
<td>Medium</td>
<td>Short</td>
</tr>
<tr>
<td>Adipose tissue</td>
<td>Short</td>
<td>Medium</td>
</tr>
<tr>
<td>Nerve</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Other soft tissue</td>
<td>Medium to long</td>
<td>Medium to long</td>
</tr>
<tr>
<td>Tendon, bone</td>
<td>—</td>
<td>Very short</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Disease Process</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflammation</td>
<td>Increased</td>
<td>Increased</td>
</tr>
<tr>
<td>Neoplasia</td>
<td>Increased</td>
<td>Increased</td>
</tr>
<tr>
<td>Fibrosis</td>
<td>—</td>
<td>Decreased</td>
</tr>
<tr>
<td>Fatty infiltration</td>
<td>Decreased</td>
<td>—</td>
</tr>
<tr>
<td>Interstitial hemorrage</td>
<td>Increased</td>
<td>Increased</td>
</tr>
</tbody>
</table>

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)

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

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).
Tissue Contrasts in Spin Echo

<table>
<thead>
<tr>
<th>Tissue Type</th>
<th>SE T1 (TR/TE)</th>
<th>SE PD (TR/TE)</th>
<th>SE T2 (TR/TE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>450-550/12-17</td>
<td>2000/20</td>
<td>2000/80</td>
</tr>
<tr>
<td>Marrow</td>
<td>High (white)</td>
<td>Intermediate</td>
<td>Low intensity</td>
</tr>
<tr>
<td>Hyaline cartilage</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>High</td>
</tr>
<tr>
<td>Muscle</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Nerves</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Low intensity</td>
</tr>
<tr>
<td>Fibrocartilage</td>
<td>Low (black)</td>
<td>Low (black)</td>
<td>Low (black)</td>
</tr>
<tr>
<td>Ligaments – tendons</td>
<td>Low (black)</td>
<td>Low (black)</td>
<td>Low (black)</td>
</tr>
<tr>
<td>Blood vessels</td>
<td>Low (black)</td>
<td>Low (black)</td>
<td>Low or high</td>
</tr>
</tbody>
</table>

Tissue Contrasts

- T1W, SE 500/20
- PD, SE 2000/20
- T2W, FSE 4900/98
- Fat sat T2W, SE 2500/80

Flow-related artifacts

- Linear artifact created, usually caused by arteries.

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

Intravenous Gd Injections

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

Pre- and post-gadolinium images

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.

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.
**MR Angiography**

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

**Common Artifacts**

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

**THE END**

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