Orthopedic Hardware Imaging
Part II: MRI v. Metal

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Recap: Imaging Techniques

Radiography
– Standard for initial and surveillance imaging
  Hardware integrity
  Bones
  (Soft tissues)

CT
– Advanced form of XR
  Direct visualization of hardware and bone
  Poor visualization of soft tissues

Recap: Imaging Goals

• Surveillance and symptom investigation
  – Start with radiographs → may need more information

• Potential complications
  – Hardware
    • Breakage, loosening, migration
  – Bone
    • Malunion, fracture, osteonecrosis, osteolysis
  – Joint
    • Infection, degeneration
  – Soft tissue
    • Hardware debris, heterotopic bone, fluid collection, mass
  – Vessels
    • Vascular injury

What next?

MRI

• Poor visualization of implant integrity
• Fair assessment of immediately adjacent bone
• EXCELLENT visualization of soft tissue detail — if imaged well!

MR Physics Basics

Bear with me.
(It’s actually important.)

MR Physics Basics

• MRI signal: is based on protons in the body
  Protons become little individual magnets & line up in the direction of the magnetic field
**MR Physics Basics**

- **MRI signal**
  When energy (radiofrequency) pulses are applied, the protons change directions.

- **MRI signal**
  After the energy pulse, protons move back to their original position and release energy (MRI signal).

- **MRI signals can then make pictures**
  Different protons (fat, fluid, etc.) return to their original position and release energy (echoes) at different times, which is mapped to its location in the image slice to make a picture.

- **MRI signal**
  The signal is predictable when the magnetic field is as uniform (homogeneous) as possible.

- **MRI signal**
  Metal disrupts the magnetic field (inhomogeneity):
  - Bends magnetic field
  - Affects readout of signal (mismaps the signal)

**Real Life Examples**

**Scenario 1:**
63 y/o female with history of posterior knee dislocation and tibial plateau fracture, status post open reduction. Evaluate ACL, PCL, meniscus, and for a posterolateral corner injury.
Real Life Examples

Scenario 1:

Uh oh.

Factors affecting metal artifact

- Hardware
- Technical / Image Parameters
- Sequence Types

Factors affecting metal artifact

Things we can't change
- Hardware
  - Composition
- Technical parameters
  - Magnet strength
  - Receiver Bandwidth (rBW)
  - Matrix size
  - Slice thickness
  - Frequency encoding direction
- Sequences

Factors affecting metal artifact

Things we CAN change
- Hardware
  - Position inside magnet
- Technical parameters
  - Magnet strength
  - Receiver Bandwidth (rBW)
  - Matrix size
  - Slice thickness
  - Frequency encoding direction
- Sequences

Factors affecting metal artifact

- Hardware Composition
  - Good metal (non-ferromagnetic)
  - Bad metal (ferromagnetic)

Factors affecting metal artifact

- Hardware Composition
  - Good metal
  - Bad metal

Oxidized Zirconium
Fe / stainless steel
Cobalt (cobalt-chrome)
Factors affecting metal artifact

**Things we CAN change**

- **Hardware**
  - Position inside magnet
- **Technical parameters**
  - Magnet strength
  - Receiver Bandwidth (rBW)
  - Matrix size
  - Slice thickness
  - Frequency encoding direction
- **Sequences**

**Factors affecting metal artifact**

- **Hardware Position**
  - Hardware long axis parallel to the magnetic field (if possible)

**Factors affecting metal artifact**

- **Hardware Position (in the scanner)**

  GOOD: Parallel  
  BAD: Perpendicular


**Factors affecting metal artifact**

- **Imaging Parameters**

  Magnetic field strength:
  Higher strength magnet = MORE susceptibility artifact

**Factors affecting metal artifact**

- **Imaging Parameters: Magnetic field strength**

  GOOD: 1.5T  
  BAD: 3.0T

Same patient, same image parameters
DIFFERENT MAGNET STRENGTH
Factors affecting metal artifact

**Things we CAN change**

- Hardware
  - Position inside magnet
- Technical parameters
  - Magnet strength
  - Receiver Bandwidth (rBW)
  - Matrix size
  - Slice thickness
  - Frequency encoding direction
- Sequences

### Factors affecting metal artifact

**Imaging Parameters**

**Receiver Bandwidth:**

Increases the range of frequencies in a given pixel, so compresses the appearance of artifact into fewer pixels

\[ \uparrow \text{rBW} = \downarrow \text{artifact} \]

*One of the easiest & most important ways to decrease metal artifact!*

**Trade-off:**

\[ \uparrow \text{rBW} = \downarrow \text{SNR} \]

### Imaging Parameters

**Receiver Bandwidth:**

Increases the range of frequencies in a given pixel, so compresses the appearance of artifact into fewer pixels

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>rBW range (kHz)</td>
</tr>
<tr>
<td>Philips</td>
<td>Water-fat shift (pixels)</td>
</tr>
<tr>
<td>Siemens</td>
<td>rBW-per-pixel (Hz/pixel)</td>
</tr>
</tbody>
</table>

**Normal (1.5T)**

- GE: 16-20 kHz
- Philips: 1-2.5 pixels
- Siemens: 80-150 Hz/pix

**Adjusted!**

- GE: 100-125 kHz
- Philips: 0.5 pixels
- Siemens: 350–600 Hz/pix
Factors affecting metal artifact

- **Imaging Parameters**
  - **Matrix size**
    - $\uparrow$ matrix $\Rightarrow$ ↓ voxel size & conspicuous of artifact
  - **Slice thickness**
    - $\downarrow$ slice thickness $\Rightarrow$ ↓ distortion

**Trade-off:** $\uparrow$ matrix $\downarrow$ slice thickness $\downarrow$ SNR

Factors affecting metal artifact

- **Imaging Parameters**
  - **Slice thickness**
    - $\downarrow$ slice thickness $\Rightarrow$ ↓ distortion

Factors affecting metal artifact

- **Imaging Parameters**
  - Frequency encoding gradient
    - Artifact is greatest in the direction of the frequency encoding direction

Factors affecting metal artifact

- **Imaging Parameters**
  - **Matrix size**
    - $\uparrow$ matrix $\Rightarrow$ ↓ voxel size & conspicuous of artifact

Factors affecting metal artifact

- **Imaging Parameters**
  - **Magnet strength**
  - **Receiver Bandwidth (rBW)**
  - **Matrix size**
  - **Slice thickness**
  - **Frequency encoding direction**

**Things we CAN change**

- Hardware
  - Position inside magnet
- Technical parameters
  - Magnet strength
  - Receiver Bandwidth (rBW)
  - Matrix size
  - Slice thickness
  - Frequency encoding direction
- Sequences
Factors affecting metal artifact

• Sequences
  - Good sequences
    - Fast or turbo spin echo (FSE or TSE): for anatomy
    - Inversion recovery (STIR, ModIR): for fluid & pathology
  - Bad sequences
    - Gradient echo (GRE)
    - Fat-suppressed images

Factors affecting metal artifact

- What to do!
  - Hardware
    - Position patient with hardware parallel to magnetic field (if possible)
  - Technical parameters
    - Magnet strength
      - Change patient to a 1.5T scanner
    - Receiver Bandwidth
      - INCREASE
    - Matrix size
      - INCREASE
    - Slice thickness
      - Thinner slices
    - Freq enc direction
      - Direct AWAY from the area to visualize
  - Sequences
    - Use FSE & STIR
    - AVOID: GRE, Fat Sat

Why is all of this important?

Real life patients.

Patients have hardware, but there is something in or around that hardware that needs evaluated with imaging.

How do we help our patients and their doctors get to a diagnosis so that they can be treated and get better?

Real Life Examples

Scenario 1:

63 y/o female with history of posterior knee dislocation and tibial plateau fracture, status post open reduction. Evaluate ACL, PCL, meniscus, and for a posterolateral corner injury.
Real Life Examples

Scenario 1:
Scout (GRE)

Dx we stop the exam?

Udo oh.

What can we do?

Real Life Examples

Technical parameters
- Magnet strength
- Receiver Bandwidth
- Matrix size
- Slice thickness
- Freq enc direction

- 1.5T scanner
- ↑ to 520 Hz/pixel (normal: 100)
- 384 x 269
- 3 mm
- Direct AWAY from the area to visualize
  Coronal plane (R – L)
  Sagittal plane (A – P)

Sequences
- TSE sequences (PD & T2)
- NO Fat-suppressed images

Real Life Examples

Scenario 1:

63 y/o female ... Evaluate
- ACL
- PCL
- Meniscus
- Posterolateral corner injury

Answers to each clinical question were possible since good metal artifact reduction was used!

Real Life Examples

Scenario 1:

16 y/o female with remote history of slipped capital femoral epiphysis and placement of femoral neck screws four years ago. She now has pain with soccer. Evaluate for hip pathology, including labral tear.
Scenario 2:

Uh oh.

Not again!

Why is that artifact so bad for such a little screw? Stainless steel!

What do we do?

Scenario 2:

Consider converting to a CT arthrogram? Too much time has passed!

Scenario 2:

Routine Sagittal T1 Fat Sat

Cannot visualize necessary structures to answer the clinical question!

Scenario 2:

• Consider converting to a CT arthrogram? Too much time has passed!

• Sequences T1 & T2 WITHOUT fat suppression *a key detail for arthrograms!
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Real Life Examples

Scenario 2:

Sagittal T1 (without FS)
Sagittal T1 Fat Sat

Real Life Examples

Scenario 2:

• Consider converting to a CT arthrogram? Too much time has passed!
• Sequences T1 & T2 WITHOUT fat suppression *a key detail for arthrograms!
• Technical parameters
  – Magnet strength 1.5T scanner
  – Receiver Bandwidth ↑ to 500 Hz/pixel (normal: 100)
  – Matrix size 256 x 192
  – Slice thickness 4 mm
  – Freq enc direction Direct AWAY from the area to visualize

Real Life Examples

Scenario 1:

16 y/o female ... Evaluate for labral tear.

✓ Crisis averted.
✓ Clinical question answered!

Real Life Examples

Scenario 2:

Coronal T1 (without FS)
Oblique axial T1 (without FS)

Summary

- Radiography: Standard for initial and surveillance imaging
- CT: Evaluate symptoms or radiographic abnormalities
  Techniques: ↑ kVp & mAs
  ↓ pitch
  Monoenergy?
  Recon: Thicker slices, Smoother filter
- MR: Evaluate symptoms and potential soft tissue complications
  Techniques: ↓ magnet strength
  ↑ Bandwidth
  ↑ Matrix size / ↓ slice thickness
  Freq enc direction AWAY from ROI
  FSE/TSE & STIR sequences

Thank you!

Questions?

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