Objective
To review how to optimize MRI to --
• produce high quality images of the musculoskeletal system
• provide clinically relevant diagnostic information.

Outline
• Goals of musculoskeletal MRI
• Quality image production
• Roles of various MR pulse sequences and techniques.
• Common problems in musculoskeletal MRI
Imaging goals for MSK MRI

*Answer the clinical question*
1. Demonstrate and characterize pathology.
2. Define extent of disease.
3. Provide information to direct management and treatment.

Objectives

Anatomic detail
Signal characteristics and abnormalities

Factors

- Scanner
- Coil
- Sequences, parameters and planes.
- Contrast agent

1. Demonstrate and characterize pathology.

History: “Rule out shoulder effusion”

Joint effusion
“Rule out Stener lesion”

1. Demonstrate and properly characterize pathology.
   - Objectives
     - Anatomic detail
     - Signal characteristics and abnormalities

History: “Arm mass”

Benign intramuscular lipoma
History: “Leg mass.”

Not lipoma.

“Rule out rotator cuff tear”

Which tendons are torn?

Signal abnormality

Which tendons are torn?
2. Define extent of disease.

- Appropriate coverage
  - Important anatomic sites
  - Joints
  - Bone

History: “trip and fall”

Diagnosis: Quadriceps tendon tear.
Quadriceps tendon tear

History: “Osteosarcoma of femur”
3. Provide imaging information to direct management and treatment.

- Diagnosis or differential diagnosis
- Size, location, involvement, extent
- Surgical mapping
- Changes from prior studies
  - Stable, growth, shrinkage, necrosis, recurrence, healing
- Complications

Quality Image Production

- Signal to noise ratio
- Image contrast
- Spatial resolution
- Coverage
Signal to Noise

- More signal (and less noise) is better
  - Better perceive low contrast objects.
  - Better perceive smaller objects.

100% noise
SNR affects our ability to perceive low contrast structures.

SNR affects our ability to see small objects.
  - High spatial resolution does not guarantee visibility.

Take home?

- SNR affects our ability to perceive low contrast structures.
- SNR affects our ability to see small objects.
  - High spatial resolution does not guarantee visibility.

Increasing SNR

- Increase magnetic field strength.
Increasing SNR

1.5 T  3 T

Smaller or better coil

Coil Selection

signal \propto r^3

head (30 cm d)  knee (18 cm d)
Signal to Noise

- Increase SNR
  - Increase Field strength
  - Use better coil

- No time or spatial resolution penalty

Importance of Bandwidth

Narrow Setting

\[
\text{SNR} \propto \frac{1}{\sqrt{\text{BW}}}
\]
### Importance of Bandwidth

<table>
<thead>
<tr>
<th>COR PD Fatsat, 1.5T</th>
<th>BW=780 Hz/pixel</th>
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<tbody>
<tr>
<td>COR PD Fatsat, 1.5T</td>
<td>BW=80 Hz/pixel</td>
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</table>

### Narrower Bandwidth
- Increased chemical shift artifact
- Chemical shift $\alpha$ Tesla
  - ~ twice chemical shift at 1.5T than 0.7T, 4 X at 3.0T
- Workaround
  - Swap phase and frequency encoding directions
  - Get rid of the fat signal!
    - chemical saturation (fatsat)
    - STIR

### Pulse sequences and techniques
- Anatomy sequences
  - T1, PD
- Pathology sequences
  - T2, T2 FS, IR/STIR, post contrast
- 3 planes
  - Axial, coronal, sagittal
### Sequence Use

<table>
<thead>
<tr>
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<tr>
<td>T1 fatsat</td>
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### Tumor Imaging

Neurovascular Bundle
Solid!

Abscess!

MR Arthrography

Normal hip labrum

Torn hip labrum
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Case 2

Tear!

Case 3

Tear!
### Shoulder Labrum

![Image of shoulder labrum MRI]

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81 y/o f, right hip prosthesis

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Gradient echo
Magnetic Susceptibility

- “Blooming” artifact
- Worst with gradient echo sequences
- Increased with higher field strengths
- In MSK
  - Metal
  - Trabecular bone
- Foe or friend?

Magnetic Susceptibility

Post-surgical change
“blooming” artifact

1.5 T

2D FLASH: TE=19, 20 flip

Black trabeculae, dephasing secondary to susceptibility.

Metastatic focus, destroyed trabeculae, increased specificity.

56 y/o F with left shoulder pain and lung cancer
**Common problems**

- **Metal/hardware**
- **Coil selection/positioning**
- **Patient positioning**
  - Coverage
  - FOV
  - Wrap
  - Frequency and phase directions
  - Motion

**Artifact Depends on Hardware Composition**

*Susceptibility of metals*

**Bad Metals**
- Stainless steel
  - Large artifacts
  - Plates, screws
- Cobalt chrome
  - Moderate artifacts
  - Older hips
  - Bipolar hips
  - Knees

**Good Metals**
- Titanium
  - Minimal artifacts
  - Newer hips
  - IM nails
- Oxidized Zirconium
  - Oxinium
  - Modest artifacts
  - Knees
Metal and MRI Sequences

Bad Sequences
- Gradient echo
- Fatsat anything (spin echo)

Good Sequences
- Fast spin echo (FSE)
- STIR (FSE IR)

Optimal Scanning
- Metal friendly pulse sequence
- Longer echo train
- Wide bandwidth
- High matrix
- Frequency encode axis away from the ROI
Good position of coil

Poor coil Positioning

Correct knee orientation
Correct knee orientation

MEDIAL OR LATERAL???
Phase and frequency

What did we learn?

- Reviewed imaging goals for MSK MRI.
- Discussed quality image production.
- Highlighted value of different pulse sequences.
- Elevated awareness of common MSK imaging problems.