Clinical Musculoskeletal MRI

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Objectives
At the end of this lecture, you will be able to:
• Learn the basic anatomy of the major joints of the body
• Discuss key elements to optimize the quality of MRI images by understanding the anatomy of these joints.
• Describe the type of diagnostic information referring clinicians need from MSK MRI.
• Address common problems in MSK MRI.

Outline
• Brief review of joint anatomy
• Review fundamental goals of musculoskeletal MRI
• Describe strategies to produce quality images
• Discuss the roles of various pulse sequences and techniques for the musculoskeletal system
• Address a few common problems in musculoskeletal MRI

Part 1

Brief Review of Joint Anatomy

• Shoulder

Shoulder Overview
Shoulder joint highly mobile, prone to instability
Rotator cuff and glenohumeral ligaments stabilize
Small contribution by glenoid labrum

Joint capsule
Extends from glenoid margin or scapular neck to anatomic neck of humerus
Normal joint recesses are visualized at arthrography
Auxillary, subscapularis, rotator interval, anterior and posterior recesses, biceps tendon sheath
Rotator cuff: 4 muscles arising on scapula and inserting on humerus

- **Supraspinatus**: From supraspinatus fossa of scapula to greater tuberosity
  - Abducts humerus, also depresses humeral head
- **Infraspinatus**: From posterior surface of scapula to greater tuberosity
  - Externally rotates humerus
- **Teres minor**: From lateral border of scapula to greater tuberosity
  - Externally rotates humerus
- **Subscapularis muscle**: From anterior surface of scapula to lesser tuberosity
  - Superficial fibers extend across to anterior margin of greater tuberosity as part of transverse ligament
  - Internally rotates, adducts humerus

Knee Overview

- Largest and most complex joint
- Hinge joint throughout its greatest range of motion
- In all positions, femur in contact with tibia, with large areas of contact
- In all positions, patella in contact with femur
- Bones do not interlock; stability maintained by ligaments, tendons, capsule, and menisci
Imaging goals for MSK MRI

*Answer the clinical question*
1. Demonstrate and characterize pathology.
2. Define location and extent of disease.

Demonstrate and characterize pathology

- Anatomic detail
- Signal characteristics
Demonstrate and characterize pathology

Factors
• Scanner
• Coil
• Sequences, parameters, and planes
• Contrast agent
• Patient

How much anatomic detail do you really need?

It depends.

“Rule out shoulder effusion”

Easy

Joint effusion

Easy
“Rule out Stener lesion”
Demonstrate and characterize pathology

- Anatomic detail
- Signal characteristics

Case 1: “Arm mass”
Case 1: “Arm mass”
Benign intramuscular lipoma

Case 2: “Leg mass.”

NOT lipoma.

Putting it together
• Anatomic detail
• Signal characteristics

“Rule out rotator cuff tear”

Which tendons are torn?
“Rule out rotator cuff tear”

Which tendons are torn?

Signal abnormality

Which tendons are torn?

Signal abnormality

Tendinopathy

Intrasubstance tear

Imaging goals for MSK MRI

*Answer the clinical question*
1. Demonstrate and characterize pathology.
2. Define location and extent of disease.

Define location and extent of disease.

- Appropriate coverage
  - Important anatomic sites
  - Joints
  - Bone

Define location and extent of disease.

- Appropriate coverage
  - Important anatomic sites
  - Joints
  - Bone

Flexible
History: “trip and fall”
Diagnosis: Quadriceps tendon tear.

History: “trip and fall”
Problem?

Quadriceps tendon tear

Quadriceps tendon tear

History: “Osteosarcoma of femur”

History: “Osteosarcoma of femur”
History: “Osteosarcoma of femur”

Imaging goals for MSK MRI
*Answer the clinical question*
1. Demonstrate and characterize pathology.
   - anatomic detail
   - signal characteristics
2. Define location and extent of disease.
   - appropriate coverage

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.

Proof?
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 of small structures.

Increasing SNR
Increasing SNR

• Increase magnetic field strength

Increasing SNR

• Increase magnetic field strength

1.5 T

3 T

Increasing SNR

• 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
Signal to Noise

- Increase SNR
  - Increase Field strength
  - Use better coil

*No time or spatial resolution penalty*
Importance of Bandwidth

Narrow Setting

\[ \frac{1}{\text{SNR}} \propto \sqrt{\text{BW}} \]

- COR PD Fatsat, 1.5T
  - BW = 780 Hz/pixel
- COR PD Fatsat, 1.5T
  - BW = 80 Hz/pixel

Narrower Bandwidth

- Increased chemical shift artifact
- Chemical shift \( \propto \) Tesla
  - \( \sim \) twice chemical shift at 1.5T than 0.7T, 4 \( \times \) at 3.0T

Workaround

- Swap phase and frequency encoding directions
- Get rid of the fat signal!
  - chemical saturation (fatsat)
  - STIR

Image matrix

- Matrix 512/384
- Matrix 320/240

Importance of Bandwidth

- COR PD Fatsat, 1.5T
  - BW = 780 Hz/pixel
- COR PD Fatsat, 1.5T
  - BW = 80 Hz/pixel
Part 3

Pulse sequences and techniques

- Anatomy sequences
  - T1, PD
- Pathology sequences
  - T2, T2 FS, IR/STIR, post contrast
- 3 planes
  - Axial, coronal, sagittal

<table>
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<tr>
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Tumor Imaging

Tumor Imaging

Neurovascular Bundle
Edema or Abscess?

Abscess!

Sequence | Use
--- | ---
T1 | Bone marrow, tumor imaging
T1 fatsat | Post contrast imaging
PD | Anatomy, menisci, ligaments, tendons
PD fatsat | 
T2 / T2 fatsat | 
STIR/ Mod IR | 
Gradient | 

MR Arthrography

Tear or no tear
Tear or no tear

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Shoulder labrum

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T2 fat sat

Patellar cartilage flap

81 y/o f, right hip prosthesis

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cor PSE T2 fatsat

cor PSE IR
### Magnetic Susceptibility

- **Foe or friend?**

### 56 y/o F with left shoulder pain and lung cancer

- Black trabeculae, dephasing secondary to susceptibility.
- Metastatic focus, destroyed trabeculae, increased specificity.

### 40 y/o man with right hip pain

- PVNS

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Part 4

Common Problems

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

Metal/hardware

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)
Metal and MRI Sequences

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

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

Optimal Scanning

- Lower magnet strength
- Metal friendly pulse sequence
- Longer echo train
- Wide bandwidth
- High matrix
- Frequency encode axis away from the ROI

Optimal Scanning

PD. BW 70 hz/pixel
PD. BW 600 hz/pixel

Positioning

Good position of coil

Poor coil Positioning
Phase and frequency

Wrong phase  Correct phase

What did we learn?

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

END