Fundamentals of Spine MRI and Essential Protocols

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Outline

A. Typical sequences on Spine MRI
1. Sagittal and Axial T1
2. Sagittal and Axial T2
3. Sagittal STIR
4. Ax 3D vol GRE
5. Fat suppressed
6. 3-D space

B. Medical reason for each sequence
1. Degenerative disease
   • Sag T1, T2, STIR
   • 3-D space
2. Infection/Cancer
   • Sag T1, T2, STIR
   • Contrast
   • Fat sat
   • Clinical examples

C. Indications for CONTRAST
1. Infections
2. Inflammatory/Autoimmune
3. Neoplasm
4. Post surgery

D. Trauma
1. GRE
2. Ax Fat sat T1

E. Special circumstances
   • Metal hardware

Typical sequences Spine MRI

- Lumbar Spine
  - Sag T1, T2, STIR
  - AX T1, T2 through disc spaces

- Thoracic
  - Sag T1, T2, STIR
  - Ax T2 survey

- Cervical
  - Sag T1, T2, STIR
  - Ax 3D vol GRE
  - Ax T2

Must Answer Questions for each case:

- Is the Bone Marrow signal normal?
- Is the alignment anatomic?
- Are the bony elements intact?
- Are the discs normal?
- What is the signal in the spinal cord?
- Is there cord compression?
- At each level is there
  - spinal canal stenosis?
  - neural foraminal stenosis?
  - nerve root impingement?
  - What is the cause?
- Are the surrounding tissues normal?
**Essential Elements: Sagittal T1**

- Bone marrow signal
- Anemia
- Cancer
- Size of neural foramen
- Alignment
- Facet Degenerative disease
- Subacute blood

**Essential Elements: T2/ STIR**

<table>
<thead>
<tr>
<th>T1</th>
<th>SAG T2</th>
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<tbody>
<tr>
<td>T1</td>
<td>SAG STIR</td>
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- Disc annular tear
- Hydration
- Cortex of bone fracture
- Bone bruise
- Size of spinal canal
- STIR cord signal
- MS muscle abnormality
- Ax disc herniation
- Nerve root impingement

**Normal Disc**

- At each level is there:
  - Spinal canal stenosis?
  - Neural foraminal stenosis?
  - Nerve root impingement?
  - What is the cause?

**Degenerative Spine disease**

Type 1: bone marrow edema

- Acute or sub-acute inflammatory changes

Is it degenerative disease or infection discitis/osteomyelitis?

**Disc Herniations:**

- Extrusion
  - Sequestration

**Disc Herniations: Morphology**

- Protrusion
  - Focal
    - Base is <25% periphery of disc
  - Broad-based
Spine MRI Cancer / Infection Protocol

- **Lumbar Spine**
  - Sag T1, T2, STIR
  - Ax T1, T2 through disc spaces

- **Thoracic**
  - Sag T1, T2, STIR
  - Ax T2 survey

- **Cervical**
  - Sag T1, T2, STIR
  - Ax 3D vol GRE
  - Ax T2

- **Gadolinium**
  - Fat-suppressed Sag T1
  - Ax T1
  - Cor T1

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Mets with pathologic fracture and cord compression

Is the Marrow signal normal?
Pathologic fracture
Cord compression
Intraspinal
Extraspinhal enhancement

On the T2 the abnormality is centered in the bone rather than the disc thus discitis is less likely.
DDX discitis osteomyelitis epidural abscess but note no disc enhancement normal endplate and dark signal of disc on T2.

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Spine MRI Cancer / Infection Evaluation

- **Leptomeningeal metastasis**
  - Pre contrast T1
  - Post contrast fat sat T1

- **Paraspinanal muscle abnormality**

Are the surrounding tissues normal?

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Leptomeningeal metastasis

- Clumping of nerve roots
- Abnormal enhancement

- Axial T2
- Axial T1

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Intramedullary neoplasm

- Sag T2
- T1
- Post Gad T1

- Signal in the spinal cord?
- Cord compression?

DDX
- Neoplasm primary
- Mets
- Infectious myelitis
- Multiple sclerosis
- Transverse myelitis
- Infarction
Spine MRI: Trauma Protocol

- Sagittal T1
- Sagittal T2
- Sagittal STIR
- Sagittal GRE
- Axial T1
- Axial T2
- No Contrast

Acute epidural hematoma

- C6-T1 acute epidural hematoma GRE

Metal Artifact

Factors that Influence Metallic Artifact Generation
- Hardware Related Factors
  - 1. Composition of the hardware
  - 2. Position of the hardware in the main magnetic field
  - 3. Geometry of the hardware

Factors that Influence Metallic Artifact Generation
- 1. Local eddy currents in the hardware
- 2. Strength of the magnetic field (B0)
- 3. Slice thickness/Spatial resolution
- 4. Receiver Bandwidth (rBW)
- 5. Frequency encoding direction
- 6. Echo Time (TE) / Echo spacing
- 7. Sequence selection

Practical Tips for minimizing Metal Artifacts:

- Hardware composed of titanium, parallel to B0, cylindrical, and small diameter produces less artifact.

- The frequency encoded direction should be changed such that it is NOT parallel to the anatomy of interest.

- Avoid GRE, or frequency selective fat suppression techniques, as they produce massive signal voids.

- Avoid imaging on 3T or greater scanners.

Practical Tips for minimizing Metal Artifacts:

- Optimization of TSE sequences may be achieved by
  - increasing the rBW, ETL, acquisition matrix and by
  - reducing the FOV, and slice thickness.

- 3-D SPACE pulse sequences with optimized parameters produce less artifact than TSE, or SE sequences.

- The 3-D SPACE data set can be re-processed after acquisition to ameliorate the extent of artifact for better evaluation of critical anatomy.
3-Dimensional Turbo Spin Echo (3-D TSE)

- 3-D TSE sequences employ a long train of multiple spin echoes which are generated by 180° refocusing RF pulse.

- This refocusing RF pulse coupled with short echo spacing reduce the amount of spin dephasing that occurs;

- consequently the magnetic field inhomogeneity is reduced and the susceptibility artifact is minimized.

- In addition, 3D sequences also allow smaller voxel size which reduces the intra-voxel dephasing.

- 3-D sequences are intrinsically more efficient than 2-D acquisitions of multiple slices. Therefore the loss of SNR can be compensated for by using smaller voxel size and higher bandwidth.

3-D SPACE (Sampling Perfection with Application optimized Contrast using different flip angle Evolutions)

- 3-D SPACE is a volumetric sequence in which the flip angle of the refocusing RF pulse is modified to optimize the image contrast and minimize the RF power deposition (specific absorption rate (SAR)).

- This sequence generates a single primary isotropic data set that allows for the reconstruction of high-resolution reformatted images in any desired plane.

- In addition, the optimized variable refocusing flip angles reduce blurring which further minimize the artifacts compared to conventional TSE sequences with constant flip angles.

Effect of Sequence on Susceptibility Artifact

3-D SPACE

Figure 8: Sagittal (a) and coronal (b) T2-weighted (Tr/Te 1500/146) sections from 3-D SPACE acquisition with rBW of voxel dimensions of 3.2 × 3.2 × 0.9 mm. The artifact (2) from the titanium plate is minimal and does not interfere with the evaluation of the spinal canal or adjacent bone. Note the excellent delineation of the spinal cord, CSF, and the disk/CSF interface. A central disk herniation (1) is noted at C4-5. SPACE results in markedly improved visualization of disk herniations in the axial plane as well, together with the possibility for assessment of the neural foramina in true cross section.

Effect of Sequence on Susceptibility Artifact

3-D SPACE

Figure 9: Demonstrates the difference in the appearance of susceptibility artifact using T2-weighted 2-D TSE T2 and 3-D SPACE sequences.

The images were obtained from a 54 year old female with titanium interpedicular screw at L4.

a. Sagittal TSE T2 weighted (Tr/Te 3000/105) images obtained with matrix of 320 x 380 x 0.3 shows 2

3-D SPACE: Re-processed with smaller section thickness

Sagittal 3-D SPACE T2 weighted images obtained from a 54 year old female with titanium interpedicular screw at L4 shows the difference in susceptibility artifact when the section thickness is 0.9mm (a) from the primary volumetric data compared to the reprocessed image with 0.3 mm (b). With the higher spatial resolution, the artifact is more defined and

Frequency encoded direction A–P  H–F