MR Imaging of the Degenerative Lumbar Spine

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MRI

• Pros
  – Exquisite bone and soft tissue detail (including disks, ligaments, nerves)
  – Very sensitive for subtle and early abnormalities (e.g., occult fracture, early stress injury, tumor, infection)
  – IV gadolinium assists in evaluating soft tissue and osseous pathology
  – Multiplanar
  – Can directly evaluate disk and ligament pathology

• Cons
  – Expensive, not readily available
  – Sensitive but sometimes not specific
  – Operator and equipment dependent
  – Time consuming (not for acute trauma or large body parts)
  – Important contraindications (PPM, neurostimulators, cochlear implants, CLAUSTROPHOBIA)
  – Degraded by minimal patient motion, susceptible to artifact (gas, metal—newer metal-reducing protocols), gadolinium cannot be used as widely as previously thought (NSF, allergies)
**MRI Fundamentals**

- **T1**: Anatomic weighting
  - Fat is bright
- **T2**: Pathology weighting
  - Water is bright
- **PD**: Combination

**TR**
- Low $\leq$ 1000
- High $\geq$ 2000

**TE**
- High $\geq$ 60
- Low $\leq$ 30

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TR = Time to repetition
TE = Time to excitation
Magnetic Resonance Imaging
Basic Protocols

- Lumbar spine
  - Sagittal and axial T1
    - Marrow evaluation
    - Neural foramina
      - Fat around nerve roots
    - Ligamentum flavum
    - Facets
  - Sagittal and axial T2
    - Myelographic effect - thecal sac
    - Central nerve roots
    - Marrow edema
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Magnetic Resonance Imaging
Special Considerations

• Axial Images
  – Stacked
    • Angled to disc spaces
  – Continuous
    • Pick up small discs and fragments

• Fat Saturation
  – Accentuate fluid signal
  – Particularly useful for compression fractures, trauma & demyelinating disease

• Coronal Images
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• Coronal Images
Normal Disc Anatomy

- Nucleus Pulposus: composed centrally of collagen and hydrophilic proteoglycans
- Annulus fibrosis: collagenous ring that maintains the NP within the confines of the edges of the adjacent vertebral bodies. Peripheral fibers (Sharpey’s) attach to adjacent endplates and anterior and posterior longitudinal ligaments. Fissures/tears in the AF allow escape of the NP.

Normal MRI Anatomy

- Discs
  - Amphiarthodial (symphyseal) joint
  - Nucleus
    - Water + Proteoglycans
    - T1 < vertebral body
    - T2 > vertebral body
  - Annulus
    - Concentric lamellae
    - Inner fibers
      - Type II collagen (cartilage)
      - Signal = nucleus
    - Outer fibers
      - Type I collagen (ligaments)
      - Low signal
    - Sharpey’s fibers
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- **Vertebra**
  - Venous plexus
    - Basivertebral vein

- **Facet Joints**
  - True synovial or diarthrodial joint
  - Normal orientation
  - Articular surfaces lined by hyaline cartilage (high signal T2)
  - Innervated by medial branch of dorsal ramus

- **Posterior contour**
  - Concave above L4/5
  - Flat at L4/5
  - Convex L5/S1
Normal MRI Anatomy

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L5/S1
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The Aging Disc

- Water and proteoglycans replaced by collagen
  - Earliest sign = fibrous intranuclear cleft
  - Disc dessication
- Loss of disc height
  - Bulging annulus
- Vacuum disc
  - Nitrogen from extracellular fluid in cracks and fissures
  - If supine, may accumulate fluid with ↑ T2 signal

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Role of Imaging

- Location and type of disk (or other) pathology
- Compression of Nerves
  - Location – assist in surgical planning
  - Mechanism of compression
    - Disc, osteophyte, ligament or other
- Instability/Listhesis
  - Dynamic
  - Isthmic or degenerative
- Discogenic disease
  - Disc degeneration and associated changes

Terminology

- Spondylosis: generic term for degenerative disk disease with osteophytes
- Annular fissure: disruption of fibers of outer portion of disk (preferred over tear)
- High intensity zone: increased T2 signal in outer annulus, may or may not reflect a tear, although HIZ and annular tear often used interchangeably
Terminology, continued

Multidisciplinary joint task force
North American Spine Society (NASS) American Society of Spine Radiology (ASSR)
American Society of Neuroradiology (ASNR)

Accepted definitions

- Annular tear
- Disc bulge
  - symmetric
  - asymmetric
- Disc herniation
  - disc protrusion
  - disc extrusion
  - disc sequestration

Disc Bulge

- Generalized displacement of disc material in the axial plane beyond the limits of the intervertebral disc space – which is defined as greater than 25% (90 degrees) of the periphery of the disc
- Not considered a form of herniation
- Can be symmetric (circumferential) or asymmetric (still has to be greater than 25%)
Disc Herniation

- Defined as a localized displacement of disc material beyond the limits of the intervertebral disc space
- Localized displacement in the axial plane can be focal (less than 25% of the disc circumference or 90 degrees)

Description of a disc herniation

- Morphology – protrusion or extrusion
- Continuity/Containment/Relationship to the posterior longitudinal ligament
- Location – axial and sagittal plane
- Volume
- Composition

Disc herniations classified on the basis of the shape of the displaced material

- Protrusion is present if the greatest distance between the edges of the disc material beyond the disc space is less than the distance between the edges of the base
- Extrusion is present when, in at least one plane, any one distance between the edges of the disc material beyond the disc space is greater than the distance between the edges of the base
Location of disc herniation in axial plane

- Central
- Right (or left) paracentral if extends laterally
- Right (or left) subarticular – lateral recess
- Right (or left) foraminal
- Right or left extraforaminal – far lateral
- Anterior

Location of Herniation

Location of disc herniation in the sagittal plane

- Disc level
- Infra-pedicular level usually from disc level below and extruded superiorly
- Supra-pedicular level usually from the disc level above and extruded inferiorly
Schmorl’s node

• Also known as intervertebral osteochondrosis
• Herniated disc in the cranio-caudal (vertical) direction through a weak region in the vertebral body endplate – referred to as an intravertebral herniation

Canal compromise – axial images

• Less than 1/3 = mild
• Between 1/3 and 2/3 = moderate
• Greater than 2/3 = severe
• Use similar grading scheme for describing neural foraminal stenosis

Disc Contour

• Annular fissures
  – May be symptomatic
  – Radial and concentric
  – High intensity zone (HIIZ)
  – Not all fissures radiographically apparent

http://www.asnr.org/spine_nomenclature/
Disc Contour

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Disc Contour

- Disc bulge
  - Concentric
  - >25% (90° -360°)
  - <3mm beyond margins
  - Clinical
    - Up to 39% of adults have asymptomatic bulge
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  - Type
    - Protrusion
    - Extrusion
  - Degree
    - Focal
      - <25% or 90° (greater than 25% now considered bulge)

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- Protrusion
  - Wider at base than apex
  - Some of outer annular fibers intact – contained disc
  - May be asymptomatic

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Disc Contour

• Extrusion
  – Wider at apex than base
  – Disruption of outer annular fibers
  – Migration in continuity with parent disc
  – May have surrounding inflammatory reaction
  – Pain mechanically and chemically
  – Rarely asymptomatic

Disc Contour

• Sequestered disc
  – No attachment to parent disc
  – May see low signal line between parent disc and fragment
  – Can migrate
    • Usually within 5 mm
  – Epidural location
    • Anterior>>Posterior
    – Rarely intradural
Disc Contour

- Location
  - Level
    - 90% at L4/5 or L5/S1
  - Short axis
    - Central
    - Right and left lateral
    - Subarticular zone
    - Foraminal zone (L3/4 and L4/5)
    - Extraforaminal zone (far lateral)
  - Long axis
    - Suprapedicular
    - Pedicular
    - Infrapedicular
    - Disc level

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Disc Contour

- Confounders
  - Epidural hematoma
    - Lenticular
    - Complex signal
  - High signal discs on T2
    - May be more apparent on T1
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Endplates

• Osteophytes
  – Spondylosis deformans
  – Traction at Sharpey’s fibers
Endplates

- Modic 1
  - ↓T1, ↑T2
    - Edematous change
    - Granulation tissue
- Modic 2
  - ↑T1, ↑T2
    - Fatty change
- Modic 3
  - ↓T1, ↓T2
    - Sclerotic change
Endplates

- Schmorl’s node
- Herniation of disc material through endplate
- May occur if bone weak
  - Osteoporosis, tumor, metabolic dz
- May be acute/traumatic
- Most asymptomatic
- Painful
  - Surrounding inflammation
  - T2, enhancement
- If chronic
  - Fatty or sclerotic change

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Facet Joints

- True synovial joint
  - Cartilage wear
  - Subchondral sclerosis
  - Osteophytes (mushroom)
  - Marrow changes in adjacent pedicles
  - Cysts
    - 90% in lumbar
    - 70-80% at L4/5
    - Small veins may mimic
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Facet Joints

- Pain
  - Mechanical compression of nerve
    - Osteophytes
    - Buckling of lig flavum
  - Pain from facets
    - Medial branch
    - Worse with extension
    - LS - buttock, thighs and hips – not below knees
Spinous Processes

- Baastrup Disease
  - Hyperlordosis or loss of height with apposition of spinous processes and damage to interspinous ligaments
  - Eburnation with osteophytes
  - Form bursa or synovial joints

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Pathology-Physiologic
Stenosis - Central Canal

- Acquired
- Congenital (Developmental)
  - Rarely symptomatic unless acquired component
- Symptoms
  - Back pain – neurogenic claudication relieved by sitting or flexion
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Stenosis - Central Canal

- Disc anteriorly
- Facets/Lig flavum posteriorly
- Other factors
  - Epidural lipomatosis
  - Post-surgical scar
  - OPLL
  - Degenerative listhesis

Stenosis - Central Canal

- Shape
  - Normal = round or nearly round
  - Stenosis = trephoil
- Relative size
  - Mild <1/3
  - Moderate 1/3 – 2/3
  - Severe >2/3
- AP diameter
  - <12mm – relative
  - <10mm – absolute

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Stenosis - Neural Foramen

- Radicular pain
- Disc anteroinferiorly
- Facet/lig flavum posterosuperiorly

Stenosis - Neural Foramen

- **Shape**
  - Normal = vertical oval
  - Stenosis = keyhole, lobulated, figure of 8, horizontal

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- Disc in inferior foramen not without consequence
- CT may help differentiate disc from bone
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Instability - Dynamic

- Plain radiographs
  - Flexion/extension
  - Dynamic assessment
    - Sagittal-plane translation of ≥ 3 mm
    - Sagittal-plane rotation of ≥ 9°
- MRI
  - Joint effusions
  - Edematous endplate changes

Flexion  Extension

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  - Flexion/extension
  - Dynamic assessment
    - Listhesis of
    - Change in angle of
- MRI
  - Joint effusions
  - Edematous endplate changes
  - Fluid in disk (sometimes can mimic infection)
Instability
Spondylolisthesis - Isthmic

- Pars defect (non-union)
- Chronic repetitive microtrauma
- L5/S1 most common with pars defects at L5(82%)
  - 10-15% unilateral
- Buildup of osseous, cartilaginous or fibrous material at defects with mass effect
- 80% asymptomatic
- Pain on hyperextension
- Hamstring tightness
Instability
Spondylolisthesis - Isthmic

- Imaging
  - Canal widened
  - Horizontally oriented neural foramina
  - Marrow changes in pedicles and articular processes
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Instability
Spondylolisthesis - Degenerative

- Degeneration of disc and facets with instability
- L4/5 most common
- Present clinically and managed similarly to central stenosis
- Imaging
  - Central canal stenosis
  - Intact pars
  - Horizontally oriented neural foramina

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Internal Disc Derangement
• Disruption of annulus
  – Can have pain from contained annular tear
• Over time → loss of disc height → overlap of facets and ligament laxity → instability → pain
Internal Disc Derangement

- Plain films
  - Instability
- MRI
  - Disc dessication or bulge
  - Radial tears = "High Intensity Zone" (HIZ)
- Discography
  - Can identify radial tears within central annulus
  - Reproduce pain
Internal Disc Derangement

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Imaging Special Situations

• The Post-Operative Spine
  – Gadolinium
    • Scar tissue enhances uniformly vs recurrent disk which peripherally enhances or does not enhance
  – Fast Spin Echo
    • Reduce metal artifact
    • Titanium< Stainless steel
  – CT +/- myelography
    • Pseudarthrosis
    • Hardware malposition
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EXTENSIVE HARDWARE ARTIFACT, MR >> CT
CT MYELOGRAM IN PATIENT WITH HARDWARE

THANK YOU

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