Crash Course: Imaging of Lumbar Spine

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AOCPMR Midyear Meeting
Format

- First 20 minutes: Review of X-ray interpretation
- Second 20 minutes: MRI anatomy, slice by slice
- Last 10 minutes: Characterization of disc herniations

GOAL: Understand how to apply and recognize normal radiographic anatomy
Anatomy by Expectation (Bogduk, 2005)

- Radiologic images are projections of same anatomy
- Image simply confirms what you expect should be in particular position
AP vs. Lateral views

**AP View**
- Pedicles at each side of vertebral bodies
- Verify true AP by center position of spinous process and equal interpedicular distance
- Interpedicular distance estimates transverse width of spinal canal

**Lateral View**
- Demonstrates spinal curves
- Better delineates individual vertebral bodies and intervertebral spaces
- Distance between posterior vertebral body (anterior border) and spinolaminar line (posterior border) represents sagittal diameter
Normal AP Lumbar diameter 15 to 27mm
Stenosis < 11.5mm (Slipman, 2007)
Mean AP diameter 25-30mm (Nirvan, 2005)
Vertebral Bodies

(Bogduk, 2003)
pedicles

(Bogduk, 2003)
Facet Joints

(Bogduk, 2003)
Facet joints

- Draw pair of lines in sagittal plan, across diameter of each circle
- Upper lumbar facet joints in the sagittal plane
- Lower lumbar facet joints in oblique plane

Difficult to visualize in AP view
spinous processes

(Bogduk, 2003)
posterior elements

(Bogduk, 2003)
Anatomic elements

- pedicles
- vertebral bodies
- articular facet joints
- margins of the laminae
- spinous processes
- transverse processes

www.depts.washington.edu
Anatomic elements

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Posterior Elements

L1

L2

L3

L4

L5
Posterior Elements

L5
L4
L3
L2
L1
Anterior Elements

L1
L2
L3
L4
L5
facet joint
transverse processes
spinous processes

L1
L2
L3
L4
L5
Anatomic elements

- vertebral bodies
- pedicles, laminae, superior and inferior articular processes
- transverse process
- spinous process
Anatomic elements

- **vertebral bodies**
- pedicles, laminae, superior and inferior articular processes
- transverse process
- spinous process
Anatomic elements

- vertebral bodies
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www.drgarymellick.com
Facet joints
Anatomic elements

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Anatomic elements

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Oblique Views

- Commonly used for interventional procedures
- "Hub" view
- Objects appear to move in direction OPPOSITE to the direction X-ray beam rotated
Oblique Views

PA View 30 degree right rotation (Bogduk, 2003)
“Squaring Off”

- AP view of a lumbar spine segment does not necessarily provide a perpendicular view
  - Lumbar lordosis varies the inter-segment angle
- Tilting the X-ray beam to reduce the elliptical margins of vertebral body into straight lines
  - Vertebrae take on a more square shape
Squaring Off
Vertebral Body

Pedicle

Spinous Process

Lamina

Superior and Inferior Articular Process

Transverse Process

(Bogduk, 2003)
45 degree Right Rotation

Vertebral Body
Pedicle
Spinous Process
Lamina
Superior and Inferior Articular Process
Transverse Process

(Bogduk, 2003)
Pedicles
Vertebral Bodies
Pedicles
MRI Basics

- **T1-weighted images** – radio receiver listens early during decay
  - Short TR, Short TE
  - Fat is white with excellent soft tissue discrimination

- **T2-weighted images** – radio receiver listens late during decay
  - Long TR, Long TE
  - Sensitive to increased water white, fat is gray

### Anatomical Information

### Pathology

<table>
<thead>
<tr>
<th>Sequence</th>
<th>TR</th>
<th>TE</th>
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<tr>
<td>T1WI</td>
<td>&lt;1,000 msec</td>
<td>&lt;45 msec</td>
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<tr>
<td>T2WI</td>
<td>&gt;2,000 msec</td>
<td>&gt;60 msec</td>
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TR = Repetition Time, TE = Echo Time

Erkonen, 2005
Sequences

- **STIR = Short T1 Inversion Recovery**
  - Pulse sequence with specific timing to suppress signal from fat

- **FLAIR = Fluid Attenuation Inversion Recovery**
  - Suppresses water signal

- **Proton Density Weighted Image**
  - Minimize T1 and T2
  - Excellent anatomical info
Saggital Views

Midline

Paramedian

Transpedicular
Midline Sagittal View

**Intersects:**
- Vertebral bodies and discs
- Vertebral canal
- Laminae and spinous processes posteriorly
- Conus medullaris at L1
- Cauda equina
- Dural sac at all segmental levels.

**DOES NOT intersect:**
- facet joints
- pedicles
- transverse processes
Paramedian View

- **Intersects:**
  - Vertebral bodies & discs
  - Vertebral canal
  - Laminae posteriorly
  - Cauda equina

- **DOES NOT intersect:**
  - Facet joints
  - Pedicles
  - Transverse processes
  - Spinous processes

- **MAY intersect**
  - Lateral conus medullaris
Vertebral bodies and discs appear to have narrower AP diameters with paramedian view compared to midline scan.
Right Paramedian

Left Paramedian
Transpedicular View

- **Intersects:**
  - Lateral vertebral body
  - Pedicles
  - Intervertebral foramen
  - Spinal Nerves
  - Facet joint

- **DOES NOT intersect:**
  - Spinous Process
  - Transverse Process
  - Nucleus Pulposus
  - Cauda Equina
Far Lateral View

- Intersects:
  - Transverse Processes

- DOES NOT intersect:
  - Everything else
Interpretation of Axial View

- Vertebral canal of the lumbar spine contains:
  - Conus medullaris - terminates at L1-2
  - Cauda equina
  - Dural sac - terminates at S2
  - Lumbar spinal nerves, passing to the intervertebral foramina

http://www.chirogeek.com
Anatomy: Spinal Nerve

- **Spinal Nerve**
  - Nerves about to leave at next level lie ventral and lateral
  - Nerves leaving at lower levels lie dorsally and medially
  - Exiting spinal nerve lies
    - Below pedicle
    - Behind inferior border vertebral body
    - ABOVE the disc, not behind it.

- **Intervertebral foramen contains:**
  - spinal nerve
  - terminal dorsal and ventral roots

- Distal to intervertebral foramen spinal nerves divides into larger ventral ramus and smaller dorsal ramus
AP lumbar spine
Conus medullaris

L1-L2
Dural Sac
dural sac

Bogduk, 2003
Determining axial slice level
Anatomy: Quadratus Lumborum

- Anterior to lateral 2/3 of transverse processes
- Extends laterally beyond transverse process
- Extends from 12th rib to iliac crest and iliolumbar
- NOT PRESENT BELOW L5 TRANSVERSE PROCESS
Anatomy: Psoas Major

- Anterior to medial 1/2 of transverse processes
- Extends in front of anterolateral vertebral bodies and discs
- Narrow at upper lumbar levels
- Increasingly wider at lower levels
  - Fibers from lower levels are added to muscles

http://www.scipion.hr/
Anatomy: Diaphragm Crura

- Arise at upper lumbar levels
- Left crus descends to L3
- Right crus descends to L2

http://www.scipion.hr/
Anatomy: IVC

- Travels to right of vertebral bodies
- **Formed at L5 level** via two common iliac veins
- May be displaced forward by the right Crus

http://www.scipion.hr/
Anatomy: Aorta

- Travels to left of vertebral bodies
- Bifurcates at L4 into 2 common iliac arteries
- Right renal artery arises at L2 level, passes to right behind IVC

http://www.scipion.hr/
Quadratus lumborum

- Lies laterally, anterior to transverse process
Psoas Major
- Lateral to the vertebral body, anterior to quadratus lumborum
**Crura**

- Anterolateral corners of the vertebral body
Aorta lies to left of vertebral body
IVC to right of vertebral body
Anatomic Relations

- Below L5, 4 vessels anterior to spine
  - 2 common iliac arteries
  - 2 common iliac veins

- Between L4 and L5, 3 vessels
  - 2 common iliac arteries
  - Inferior vena cava
Anatomic Relations

- Aorta at levels L1 to L4
  - Below L4 aorta is replaced by common iliac arteries
- IVC at levels L1 to L5
  - Below L5 replaced by common iliac veins
- Both crura at L1
  - Left crus to L2, right crus to L3
- Psoas at all levels
  - Small at L1, growing to maximum size at L5
- Quadratus Lumborum starts at L1, absent below transverse process of L5
L1-L2

Will the left crus be present? yes no
Will the right crus be present? yes no
Will the aorta be present? yes no
If not, will the common iliac arteries be present? yes no
Will the inferior vena cava be present? yes no
If present will it be displaced by the right crus? yes no
Will the quadratus lumborum be present? yes no
Will psoas be present? yes no
Will psoas be large? yes no
Will iliac crests be present? yes no
Will the left crus be present?  yes  no
Will the right crus be present?  yes  no
Will the aorta be present?  yes  no
If not, will the common iliac arteries be present?  yes  no
Will the inferior vena cava be present?  yes  no
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L4-L5

Will the left crus be present? yes no
Will the right crus be present? yes no
Will the aorta be present? yes no
If not, will the common iliac arteries be present? yes no
Will the inferior vena cava be present? yes no
If present will it be displaced by the right crus? yes no
Will the quadratus lumborum be present? yes no
Will psoas be present? yes no
Will psoas be large? yes no
Will iliac crests be present? yes no
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Neural Relations

- **Transpedicular**
  - through pedicle

- **Subpedicular**
  - below pedicle, above disc

- **Transdiscal**
  - through disc, below vertebra
L3 nerve roots about to emerge

L3 ventral ramus

facet joint

(Bogduk, 2003)
Transpedicular

Subpedicular

Transdiscal

(Bogduk, 2003)
L3-L4 Transdiscal

http://www.chirogeek.com
Central Region
- Directly behind disc
- PLL thickest
  - Herniations less common

Paracentral Zone
- Lateral to central
- PLL thinner
  - Herniations frequent

Subarticular Zone
- Between medial facet joint and medial pedicle

Foraminal Zone
- Within intervertebral foramen
- Between medial and lateral edges of pedicle
- 5-10% herniations
- Site of dorsal root ganglion

Schematic representation of the anatomical "zones" identified on axial images. The anterior zone (not illustrated) is delineated from the extraforaminal zone by an imaginary coronal line in the center of the vertebral body. (Adapted from Wiltse LL, Berger PE, McCulloch JA. A system for reporting the size and location of lesions of the spine. Spine 1997;22:1534-1537)
Coronal drawing illustrating the main anatomical "zones" and "levels". (From Wiltse LL, Berger PE, McCulloch JA. A system for reporting the size and location of lesions of the spine. Spine 1997;22:1534-37)
IVC displaced from vertebral column
Psoas small and thin
Quadratus Lumborum attenuated
Kidneys bilaterally
Bilateral Crura
L1 Subpedicular

- IVC
- Aorta
- Right Crus
- Left Crus
- Psoas
- QL
- L1 spinal nerve
- dural sac
- nerve roots
IVC close to vertebral column
Right Crus absent
Psoas narrow
Quadratus Lumborum flares laterally
L2 Subpedicular

- IVC
- Right Crus
- Aorta
- Psoas
- QL
- L2 exiting nerve
- L2 exiting nerve roots
- L3 nerve root
- L3 nerve root

Adjacent structures include:

- L3 nerve root (on the left side)
- L2 exiting nerve root (on the right side)
L2-3 Transdiscal

- IVC
- Aorta
- Psoas
- NP
- QL
- L3 sap
- L2-3 facet
- L2 iap
Psoas substantial with prominent anterior margin
IVC and Aorta present
Quadratus Lumborum present
Vertebral body and pedicles present
L3-4 Transdiscal

- IVC
- Aorta
- Psoas
- NP
- L3–4 Transdiscal
- L3 iap
- L4 sap
- L3-4 facet
- QL
Psoas large, bulges anterior and lateral
Aorta bifurcating into common iliacs
Quadratus Lumborum present
Vertebral body, pedicles, transverse processes present
L4 Transpedicular

- Psoas
- QL
- Transverse Process
- Pedicle
- IVC
- Common Iliac A.
L4-5 Transdiscal

- CIA
- CIV
- Psoas
- QL
- L4-5 facet
- L4 iap
- L5 sap
Psoas large
Absent Quadratus Lumborum
2 common iliac arteries
2 common iliac veins
Iliac crest present
L5-S1 Transdiscal

CIV

CIA

S1 iap

S1 sap

L5-S1 facet

S1 iap

Psoas

Iliacus

Psoas
Definitions

- **Herniated disc**: best general term to denote displacement of disc material beyond intervertebral disc space. The term includes discs that may properly be characterized by more specific terms, such as "protruded disc" or "extruded disc." Avoid using term herniated nucleus pulposus.

- **Disc Bulge**: Greater than 50% of the circumference of the disc and extends a relatively short distance, usually less than 3 mm, beyond the edges of the apophyses.

Degenerative disease or changes of maturity?

- 30% of 30 year olds have radial fissures
- 40% of 40 year olds have disc bulging
Definitions

- **Protruded Discs**: greatest distance, in any plane, between the edges of the disc material beyond the disc space is less than the distance between the edges of the base in the same plane.
  - **Focal**: Protrusions with a base less than 25% (90 degrees) of the circumference of the disc.
  - **Broad-based**: If disc material is herniated so that the protrusion encompasses 25% to 50% of the circumference of the disc.

Focal Herniation

Definitions

- **Extruded Discs:** 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 measured in the same plane.

- **Sequestrated:** subtype of "extruded disc" but, by definition, can never be a "protruded disc." No continuity between herniated disc material and parent disc. Disc material that is displaced away from the site of extrusion, regardless of continuity, may be called "migrated," a term which is useful for the interpretation of imaging studies because it is often impossible from images to know if continuity exists.

References

- www.stryker.com
- www.depts.washington.edu
- www.injuryupdate.com
- http://www.chirogeek.com