Spondylolysis – Update on Diagnosis & Management

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Spondylolysis - Update

GOALS & OBJECTIVES

1. Review of Prevalence & Anatomy
2. Review/Update controversial aspects of spondylolysis:
   – Diagnostic Imaging
   – Bracing
3. Review goals of rehabilitation
4. Review return to play decision-making
Introduction \((1,2,9,13,14,19)\)

- Unilateral or Bilateral Defect – Pars Interarticularis
- Pars Interarticularis – junction of pedicle, articular facets, lamina
- Defect at L5 in 95% of cases
- Prevalence
  - General Population: 3-10%
  - Athletic Population: 23-63%
    - Gymnastics, Football, Weight Lifting, Rowing, Volleyball
- Adolescent Athletes:
  - Most common cause of back pain \((13,19)\)
Anatomy of a Pars Defect

- PARS INTERARTICULARIS
- LAMINA

[www.eorthopod.com] [Netter Photos]
Pathophysiology$^{(1,3,9,13)}$

• Multifactorial
  – +/- Pre-existing Dysplasia
  – Repetitive Microtrauma
    • Hyperextension, Rotation, Hyperlordosis

• Predisposing factors:
  – Hyperlordosis, Thoracic kyphosis
  – Iliopsoas inflexibility, Thoracolumbar fascial tightness
  – Abdominal weakness
  – Female athlete triad

• Bony Impingement – Pars of L5 sheared by Inferior articular process L4 and superior articular process S1
Pathophysiology

• Other predisposing factors:
  – Hyperlordosis
  – Iliopsoas inflexibility
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  – Thoracic kyphosis
  – Female athlete triad

• Bony Impingement – Pars of L5 sheared by Inferior articular process L4 and superior articular process S1
Anatomy of Bony Impingement
Clinical Presentation\textsuperscript{(12,13,14,19,20,25)}

- Three Classic Patient Types:\textsuperscript{(13,25)}
  1. Female, Hyperlordotic, Hypermobile
  2. Male, Hypomobile/Inflexible, Tight paraspinal
  3. New to a sport, deconditioned, poor core
Clinical Presentation

• Examination:
  – Hyperlordosis
  – Hamstring inflexibility
  – Pain on extension (add side-bending to affected side - Kemp Test)
  – Lumbosacral tenderness and muscle spasm
  – Stork test: low specificity\(^{(14,20)}\), low sensitivity\(^{(19)}\)
  – Various other functional/provocative tests\(^{(19)}\)
Clinical Exam

• Prospective Case Series – Ability of clinical tests to distinguish between causes of back pain

• Subjects:
  – 25 in Case group: >3 weeks LBP, 13-20yo, 56% Male
  – 13 in Control group

• Methods:
  – Both groups:
    • Clinical exam protocol
    • All underwent MRI L-spine
  – Case group: CT of L4/L5

• Clinical Exam Protocol:
  – Gait pattern
  – Inspection – scoliosis, lordosis, LLD, etc.
  – Palpation
  – Neurological examination
  – Functional testing
  – Multiple provocative tests (Stork, Percussion, Spring, Coin, Hook/Rocking tests)

• Results:
  – No clinical test, alone or in combination, could distinguish between spondy and other etiologies
Spondylolysis - Imaging

Leone *Skeletal Radiol* 2011
Imaging Controversy

• Despite spondylolysis being a well recognized and published condition for decades...we still don’t have a consensus on imaging...due to the pros and cons for each modality, radiation exposure in adolescent spines, and growing technology helping MRI to potentially become a more sensitive option.
Imaging – Radiography\(^{(1,5,9)}\)

- A/P and Lateral – Eval DDX & Listhesis
- Oblique – Observe radiolucent pars defect:
  - Acute: Narrow, irregular
  - Chronic: Smooth, Rounded
- Appreciable on Lateral view if listhesis present

Leone _Skeletal Radiol_ 2011
Imaging - Radiography

• Utilization of **Oblique** Images
  
  – Pro:
    • Potential for quick confirmation of clinical suspicion
    • If seen – characterize chronicity
  
  – Con:
    • Low sensitivity
      – Miss occult and early stress lesions
    • Additional radiation
    • Most practitioners likely to utilize secondary imaging regardless
Radiation Exposure\textsuperscript{9} 
(mSv = milisievert, measurement of radiation dose)

- U.S. Natural Background Exposure: 3 mSv/year
- Chest X-ray: 0.1 mSv
- L-Spine X-ray, 6 View: 1.5 mSv
- SPECT: 5 mSv
- CT: 10-20 mSv
Imaging - SPECT\(^{(1,5,6,9,12,16)}\)

• Pros:
  – High Sensitivity and can localize lesion
  – Early diagnosis of active lesions
  – Differentiate between Acute & Chronic Non-Union:
    • Increased Signal: Osseous activity/Healing Potential
    • Absence of Signal: Nonunion/Low Healing Potential
  – Correlates with pain etiology (improved treatment outcomes\(^{16}\))
Imaging - SPECT

• Cons:
  – Poor Specificity - potential for false positives
    • Positive SPECT shown in asymptomatic athletes
    • DDx for Positive Bone Uptake – Infection, Tumor, Arthritis
  – Radiation exposure, intravenous injection, increased time for completion
  – Cannot detect chronic non-union
  – Cannot distinguish if incomplete fx is in healing (osteoblastic) or developing (osteoclastic) phase
Imaging - SPECT\(^{(9)}\)

→ Due to low specificity, a positive SPECT needs to be followed up with targeted CT imaging.

→ Because of increasingly reliable MR sequencing and the amount of radiation exposure from combo SPECT & CT scanning, there are increasing recommendations to abandon SPECT screening.

Leone *Skeletal Radiol* 2011
Imaging – Computed Tomography (1,2,5,6,9,14)

- Pros: Identify anatomical details of a pars defect
  - Complete or Incomplete Pars Fracture:
    - Most Sensitive & Specific independent imaging modality
  - Can help stage the chronicity of the lesion:
    - Wide/Sclerotic – Chronic
    - Narrow/Non-corticated margins - Acute
  - Evaluate bony healing, surgical planning
  - More specific than SPECT
Imaging – Computed Tomography

• Cons:
  – Radiation exposure
  – Not good at:
    • Active vs. Inactive fracture
    • Early Stress Reaction – No Cortical Defect
  – Limited evaluation of associated conditions and other differential diagnosis
Imaging - CT Options\(^{(2,9)}\)

- Reverse-Angle Gantry CT:
  - Perpendicular to Pars Lesion\(^{(2)}\)
  - Decreasing use due to advances in CT technology

- Newer Technology:
  - Rapid, Thin-Slice
  - Increased anatomical coverage
  - Higher spatial resolution
  - Sagittal Reconstructions
  → Results in: High resolution 2D reformations, 3D Rendering

Leone Skeletal Radiol 2011
Imaging - SPECT + CT\(^{(9,13)}\)

- Combination
  - SPECT: highest sensitivity for bone activity
  - CT: highest anatomical specificity

- Neg CT + Pos SPECT:
  - Stress response, Pre-lysis
  - Early incomplete
  → Good prognosis for healing and bony union

- Pos CT + Neg SPECT:
  - Non-union chronic lesion
Imaging - MRI \((1,5,9,10,11,13,14,24)\)

- **Pros:**
  - Sensitive for early active lesions
  - Reliable for:
    - Early/Stress lesions
    - Acute complete lesions
    - Chronic lesions
  - Absence of radiation
  - Visualization of other spinal disorders

Leone *Skeletal Radiol* 2011
Imaging - MRI

• Cons:
  – Lower Sensitivity – Mostly involving Incomplete Fractures\(^{(9,24)}\)
  – Lacks ability to grade the lesion, detect bony healing
  – Dunn, *Skeletal Radiol, 2008*\(^{(11)}\)
    • Comparative study of incomplete fxs – MRI vs. CT
    • MRI: Limited ability to fully depict cortical integrity
Imaging - MRI

• Highly dependent on sequencing...some of the poor sensitivity documented in the literature potentially due to inadequate sequencing:
  – Sequencing best suited for other dx (disc)
  – Slice thickness inadequate
  – Not multiplanar
  – Limited edema sensitive sequencing
Imaging - MRI Sequencing

• Ideal Sequencing:
  1. Edema Sensitive – STIR Images (T2 Fat Sat)
     • Visualize bony edema: Active & Early lesions
  2. Cortex (Marrow) Sensitive – T1 (or T2) Non Fat Sat
     • Visualize fracture
     • Good for anatomy – Seeing cortical bone, high contrast between marrow and signal void of disrupted cortex
  3. Multiplanar – Axial, Sagittal, Coronal Oblique
  4. Thin Slice – ≤ 3mm
MRI – Complete Fracture

Leone *Skeletal Radiol* 2011

T2 – Fat Sat: Edematous Change

T1 Sequencing: Complete Fx Cleft
MRI - Incomplete Fracture

- **STIR Sequence:** Edematous Change
- **T1 Sequence:** Defect Inferior Cortex
- **CT Imaging:** Incomplete Cleft Pedicle

Leone *Skeletal Radiol* 2011
Hollenberg, *Spine*, 2002\(^{10}\)

- Proposed Classification System:
  - Grade 0: Normal Pars
  - Grade 1: Stress Reaction – Marrow Edema, Intact Cortex
  - Grade 2: Incomplete Stress Fx – Marrow Edema, Incomplete Cortex Fx
  - Grade 3: Acute Complete Fx – Marrow Edema, Complete Pars Fx
  - Grade 4: Chronic Fx – No Marrow Edema, Complete Pars Fx

- Distinguishes:
  - Stress Rxn vs. Active Fracture vs. Inactive Fracture
MRI – Early Acute Lesions
Kobayashi, AJSM, 2013(14)

• Prospective study to assess the use of MRI for detection of early active spondy lesions
• Document MRI diagnosis in those cases occult on x-ray
• 200 athletes with LBP, Ages 10-18, 72% Male:
  – Unclear or No findings on X-ray
    • 96% No Findings, 6% Unclear Findings
  – MRI performed on all 200 athletes
    • Sag T2, Sag STIR, Axial T1, Axial T2, Axial STIR, 4-5mm slices
  – CT performed as follow-up to MRI if edema present
Kobayashi, *AJSM*, 2013\(^{(14)}\)

- **Results:**
  - MRI – Noted spondy in 97 of 200 athletes (48.5%)
  - Follow-up CT – 92 of 97 positive MRI cases:
    - Nonlysis Lesions: 43%
    - Early Stage: 49%
    - Progressive Stage: 8%
    - Terminal Stage: 0%

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Leone *Skeletal Radiol* 2011
Kobayashi, AJSM, 2013\textsuperscript{(14)}

• Discussion:
  – MRI useful in recognition of early active spondy
  – Recommend:
    • Use of MRI for initial screening after negative x-ray
    • For positive MRI - Should have localized CT for staging
  – No comparison to SPECT regarding sensitivity for early active lesions
  – For the 51.1% with negative MR:
    • No follow up CT
      → No MRI vs. CT sensitivity comparison
Additional MRI Comparative Studies

• **Campbell, et al. Skeletal Radiol, 2005**\(^{(24)}\)
  – Compared MRI to SPECT+CT
    • Concluded Effective & Reliable first-line imaging modality
    • Concluded MRI can replace SPECT
    • Not adequate for grading incomplete defects (3-4mm Slices)

• **Masci, et al. BJSM, 2006**\(^{(20)}\)
  – Compared MRI to SPECT only, CT only, & SPECT+CT
    • MRI equal to CT in detection of defect (did not specify complete vs. incomplete)
    • MRI decreased sensitivity compared to SPECT for stress lesion
    • Concluded MRI inferior to SPECT+CT for general detection of all types of lesions
    • High rate in this study of MRI false negatives
    • MRI sequencing – larger slice thickness, limited planes

- Prospective Case Series
- Methods:
  - Case & Control groups:
    - MRI L-spine
    - Sag T1, Sag T2, Cor STIR
    - Slice thickness not mentioned, No Axial Views
  - Case group: Also received CT of L4/L5, thin-slice
- Results:
  - 22/25 case athletes had positive MRI findings
  - 13/25 case athletes: +MRI Active Spondy
  - Personal communication with author:
    - Athletes in case group with (–)MRI for Spondy also had (–)CT
MRI – Ancillary Findings\(^{(9)}\)

- Aid in diagnosis:
  - Widened sagittal diameter of spinal canal
  - Posterior vertebral body wedging – Lumbar Height Index
    - Effect of spondylolisthesis vs. predisposing factor
    - Present in cases of spondy without listhesis
  - Reactive edema in pedicle adjacent to pars defect
- Direct Findings + Ancillary Findings \(\rightarrow\) MRI approaches a similar Sensitivity as CT.
Synopsis of Imaging Debate

• Positives and Negatives for all
• Important to know the limitations of your imaging options
• Important to know the imaging techniques and sequences utilized by your imaging centers - MRI
Synopsis of Imaging Debate$^{(9,13)}$

- **Reasons for SPECT/CT:**
  - Confidence in the combination of:
    - Sensitivity (SPECT) and specificity (CT)
  - MRI negative & athlete not responding to current plan of care
  - MRI contraindicated
  - Ideal MRI sequencing not available
- **Follow-up CT:** Grading necessary, assess bony healing
Synopsis of Imaging Debate

• MRI as first-line?:
  – Visualize stress reactions, Acute and Chronic lesions
  – No radiation in pediatric population
  – Rule out other pathology
  – Know capabilities of your imaging center

• MRI’s downside: Lower sensitivity for incomplete fractures, can’t assess bony healing or grade of the lesion
Potential Imaging Protocol

• Clinical Exam + Lumbar X-ray (AP & Lat)

• Initial screen with MRI:
  – Sensitive for early active lesions
  – Identify active vs. inactive lesions
  – Localize pathology
  – Rule out other differential diagnosis
  – Minimize Radiation

• Localized CT - for positive Spondy on MRI:
  – Staging of lesion
  – Baseline for follow up imaging – bony healing
Spondylolysis - Management
Conservative Management

• Overall:
  – Rest from sport – stop repetitive extension/rotation
  – Achieve pain-free status
    • Rest period with or without bracing
  – Rehabilitation
  – Return to Play transition

• Debate:
  – Initial length of time restricted from sport
  – Bracing:
    • Decision to utilize bracing
    • Type of brace
  – Time course for full return to sport
Spondylolysis - Bracing\(^{(1,5,6,7,8,9,12,17,18)}\)

- **Types of Braces:**
  - Thoraco-lumbar-sacral orthosis (TLSO) – antilordotic
  - Lumbo-sacral orthosis (LSO)
  - Corset/Soft Brace

- **Controversy:**
  - Lack of controlled studies – question efficacy
  - Similar outcomes despite type of brace
    - Maintain lordosis vs. Antilordotic
    - Soft corset vs. Hard Shell Orthotic
  - Bony healing with and without bracing
  - Is it the immobilization or the forced compliance with activity restriction?
Spondylolysis - Bracing

Controversy:

- Lack of controlled studies – question efficacy
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Spondylolysis - Bracing

• Historical Perspective:
  – Steiner/Micheli, 1985\(^{(7)}\): documented success with bracing protocol
  • 6 months, 23 hrs/day
  • 6 months wean from brace
  – Jackson/Wiltse, 1981\(^{(18)}\): documented success with activity restriction only, no bracing
Referenced Bracing Strategy\(^{(13,22,23)}\)
d’Hemecourt, *Orthopaedics*, 2000\(^{(23)}\)
Micheli, *Clin Sports Med*, 2006\(^{(22)}\)

- **Initial:**
  - Removed from sport, Boston brace 23hrs/day
  - Begin physical therapy

- **4 to 6 weeks:**
  - If pain-free & progressing well in PT
    - Return to sport in brace

- **4 months:**
  - If bony healing or pain-free nonunion: wean brace
  - If pain and no healing: consider bone stim

- **9-12 months:**
  - If persistent pain and nonunion: surgical fixation
Additional Brace Parameters$^{(5,7,8,9)}$

- If acute, (+)SPECT/MRI & (-)CT:
  - 3-6 months
  - Rest from aggravating activity
  - Attempt bony healing
  - Most recommend brace for acute lesions: multiple proposed strategies

- Chronic Lesions:
  - Rest until pain-free, no brace, then start other conservative measures
  - Brace if can’t become pain-free
Bracing Literature Update
Sairyo K, J Neurosurg Spine, 2012\(^{(15)}\)

* Examine which spondylolysis lesions will go on to bone healing with bracing and how long it takes
  - 63 pars defects, 37 patients, Ages 8-18
  - Followed for bony healing with bracing
  - CT & MRI performed:
    * Early, Progressive High Signal (MR edema), Progressive Low Signal (no MR edema), Terminal
  - Brace: molded plastic TLSO
  - Repeat CT at 3mo and 6mo

- **Results:**
  - Early – 94%, 3.2 mo
  - Progressive/High Signal – 64%, 5.4 mo
  - Progressive/Low Signal – 27%, 5.7mo
  - Terminal – 0%

- **Supports early (CT stage) and active (MR edema) lesions have best prognosis for bone healing**

- **Limitations:**
  - No non-braced control group
  - Study looking at bone healing, not pain relief or return to sport
Spondylolysis Rehabilitation$^{(5,12,13)}$

- General Principles:
  - Start early
  - In conjunction with pain reducing stage
  - Progress through generalized range of motion and spine stabilization
  - Kinetic chain assessment & resistance training
  - Sport-specific retraining
Rehabilitation of the Gymnast

(Courtesy of Dr. Larry Nassar - USAG Medical Director)

• Phase 1: Initiate at time of Dx
  – Neutral Spine - Correct Imbalances/Core Stability

• Phase 2: Starts when pain-free
  – Start into extension, strengthening in extension

• Phase 3: Once tolerating extension in PT
  – Start sport-specific extension work in the gym

• Phase 4: Final progression
  – Gymnastics-specific progression, finish correction of baseline imbalances/mechanical deficiencies
Rehabilitation of the Gymnast

• Common deficiencies in the gymnast:
  – Shoulder & Thoracic mobility restrictions
  – Lower Crossed Syndrome:
    • Hip flexor/quad/IT band/erector spinae flexibility
    • Gluteus medius and core strength
  – Dyskinetic posterior chain firing patterns
    • Hamstring, Gluteus, Erector spinae
Rehabilitation of the Gymnast

(Courtesy of Dr. Larry Nassar - USAG Medical Director)
Natural Progression Spondylolisthesis\(^{(1,4,5,13)}\)

- **Bilateral Pars Defect**
  - 70% associated listhesis
  - Cases of low-grade slippage have 5% risk of progression
- **Fortunately low documented risk of progression in athletes**
- **Highest Risk for Progression**
  - >50% slippage at diagnosis
  - Skeletally immature or <16yo
  - Significant decreased risk with increased age
- **Follow-Up – Skeletally Immature**
  - Lateral Radiographs Q6-12mo
Return To Play\textsuperscript{(21)}

- Successful completion of a comprehensive physical therapy program
- Can accomplish full and pain-free range of motion
- Return of sport-specific strength and aerobic fitness
- Able to perform sport-specific skills without pain
References


References


References


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