Growth Disturbances and Morphologic Abnormalities of the Hip in Children

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Overview

• Radiographic techniques
• Normal anatomy
• Conditions characterized by growth disturbance
  – Acetabular dysplasia
  – FAI
  – Acetabular protrusio
  – Acetabular rim syndrome
Imaging the Painful Hip

• Plain radiographs of pelvis and bilateral hips
  – 2 orthogonal views (AP and lateral)
    • Frog-leg
    • Cross-table
    • Dunn
    • False Profile
Lateral Hip Radiographs

Frog-leg

Dunn

False Profile

Cross-table
Lateral Hip Radiographs

- **Frog-leg**: SCFE, LCP, femoral head lesions, screening
- **False Profile**: DDH, Pincer impingement
- **Cross-table**: Femoral neck lesions and fractures
- **Dunn**: Cam-type femoroacetabular impingement (FAI)
Femoral Head Coverage

- **Deficient coverage**
  - Acetabular dysplasia
    - *Instability*

- **Excessive coverage**
  - Acetabular protrusio
  - Pincer type (FAI)
    - *Limited ROM*

Too little Too much
Femoral Head Coverage

Too Little

Dysplasia

Retroversion

Deep

Too Much

Protrusio

Anatomic Considerations
Proximal Femoral Physis

5 year old female

3 week old male
Femoral growth arrest lines
Femoral growth arrest lines

One year later
Acetabular Physes

- Multiple different growth centers/patterns
Acetabular Growth

- Os acetabuli (appears): ~ 8 years
- Acetabular epiphysis: ~ 8-9 years
- Ischial epiphysis: ~ 9-10 years
- Patient age at time of injury/insult is greatest predictor of acetabular growth
Intra-articular Anatomy

- Joint Capsule
- Ligamentum teres
- Cartilage/labral complex
- Synovial reflections/pectino-foveal fold, retinacula
Acetabular Physeal Cartilage
Developmental Dysplasia of the Hip

- Most common cause of osteoarthritis in young adults undergoing arthroplasty
- 3-6% of population
- 72% female, 28% male
- May develop in puberty due to delayed ossification of femoral head, and triradiate cartilage.
Adolescent DDH

• “...our results demonstrate limited reliability in radiographic diagnosis. To some, this may serve to emphasize the importance of history and physical examination in the workup of the patient...This also highlights the need to understand the pathomechanics of each individual case, especially in impingement surgery, rather than relying solely on static radiographic finding.”
Adolescent DDH

AP Pelvis

False Profile

Beltran et al. AJR 2013;200
Basic Hip Measurements
Basic Hip Measurements

- Lateral Center Edge Angle (LCEA)
- Acetabular Inclination Angle (AI)
- Anterior Center Edge Angle (ACEA)
- Alpha Angle

- **Measurements aren’t everything!**
Radiographic Evaluation DDH
Radiographic Measurements

- Lateral Center Edge Angle
- Acetabular Angle
- Anterior Center Edge Angle
Radiographic Measurements

- **Lateral** deficiency of acetabulum:
  - Lateral center edge angle (LCEA)
  - 25-40 degrees = “normal”
Radiographic Measurements

• **Anterior** deficiency of acetabulum:
  – Anterior center edge angle (ACEA)
  – 25-40 degrees = “normal”
Radiographic Measurements

• Increased inclination of weight-bearing surface:
  – Acetabular inclination (AI)
    • 0-10 degrees = normal
• Decreased surface area
Basic Rules to Remember

- LCE 25-40 degrees
- ACE 25-40 degrees
- AI 0-10 degrees
Developmental Dysplasia of the Hip

• Natural history:
  – OA in all hips by age 65 with LCEA < 17°
  – LCEA 18-25° controversial

• Surveillance of “borderline” patients:
  – physical exam by dedicated hip specialist
  – MRI to assess status of cartilage, labrum

dGEMRIC
Developmental Dysplasia of the Hip

- 14 year old female with right hip pain
- Decreased lateral coverage
  - LCEA 19 degrees
- Does patient need surgery?
Developmental Dysplasia of the Hip

- LCEA: 20 degrees
- AI: 9 degrees
- Labral tear
- Paralabral cysts
- Peripheral acetabular cartilage loss
- Intraosseous cyst
14 month old with left DDH
14 month old with left DDH

s/p closed reduction and SPICA
14 month old with left DDH
14 month old with left DDH

One year later
DDH - Sequelae

Age 9

Age 11
DDH Sequelae – Severe Arthrosis

Age 9

Age 11
DDH - Sequelae
DDH Sequelae → AVN

C+ T1 fs in Spica
Developmental Dysplasia of the Hip

- Growth disturbance of proximal femoral physis (AVN) most frequent complication of treatment of DDH
- Occurs with every form of hip splintage
  - May affect contralateral hip in unilateral DDH
- Leads to early arthrosis and disability
- Requires additional surgery
Femoral head asphericity occurs even in the absence of treatment.

Children with DDH have variably shaped femoral heads, most of which are aspherical to some extent.

11 yo female with treated DDH -- AVN
Adolescent DDH

19 year old healthy female s/p “locking incident” in left hip
Adolescent DDH
Adolescent DDH

POST-PAO
Acetabular Dysplasia: Imaging

- **Plain Radiographs:**
  - AP Pelvis (neutral pelvic tilt)
  - False profile view of affected hip
  - +/- Dunn lateral (to assess associated femoral head deformity)

- **MRI**
  - High-resolution, cartilage sensitive sequences
  - Focus on hip in question (not entire pelvis)
  - dGEMRIC correlates with pain scores and surgical outcome s/p PAO


dGEMRIC

- Morphologic sequences:
  - 3D volumetric sequence
    - Thin section cartilage imaging
    - Multiplanar reformats

- Cartilage mapping sequences
  - T1 mapping
  - Coronal and sagittal planes
  - T1 index measured directly at PACS workstation
dGEMRIC in Practice

- Late walker (17 months)
- Never crawled
- Peculiar gait
- Treated with abduction brace

18 month old female
dGEMRIC in Practice

18 months
Gait abnormality

10 years
Asymptomatic

14 years
Right hip pain
dGEMRIC in Practice

Normal cartilage, normal labrum
“Although we cannot provide a specific threshold dGEMRIC value for the prediction of stress or failure, the figure shows the increased likelihood of early failure as the dGEMRIC index decreases.”

Cunningham et al. JBJS 2006;88:1540-8.
Clinical note: “Moderately severe acetabular dysplasia with acetabular rim syndrome and subluxation. T1 dGEMRIC index yields risk of failure post-PAO ~30%. She understands she has intra-articular issues.”
dGEMRIC risk?

- Hyperintensity in the dentate nucleus on T1W MRI images is associated with previous administration of linear but not macrocyclic GBCA


- **Magnevist** (Gd-DTPA\(^2\)) historically primary agent for dGEMRIC studies (linear agent); more recent studies have shown similar results with **Dotarem** (Gd-DOTA\(^-\))

Alternatives to dGEMRIC

- **T2 mapping**
  - Measures water content and collagen network in cartilage
  - sensitive to orientation of magnetic field
  - MSE sequence (TE 10.3-103 ms)
  - Normal topographic variation (based on orientation of $B_0$)

Cartilage Mapping FAI

<table>
<thead>
<tr>
<th>Modified Outerbridge Score (MRI)</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
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</tbody>
</table>
Cartilage Mapping FAI

- Retrospective review of 39 hips with cam or mixed impingement, comparing Outerbridge grades to T1 and T2 maps
Cartilage Mapping

- Detects biochemical changes in cartilage
  - dGEMRIC, T2, T1 $\rho$, T2*, gagCEST
- Limitations: Thin cartilage, curved surface, depth of joint, and normal zonal variation
- Planar maps
Cartilage Mapping FAI (3T)

- dGEMRIC reveals specific patterns of cartilage degeneration in FAI
- Cartilage damage in FAI focal
- Localized T1 ROI analysis required
  - Lengthy interpretation times
  - No clear advantage over high-resolution morphologic sequences.

Does this T1 map add value?
Cartilage Mapping FAI (3T)

Which image is most useful?

PD fs

T1 fs
Do you need cartilage maps?

3D Steady State GRE
2D PD TSE
Do you need contrast OR maps?

Not if image resolution high enough
BCH Protocol: MR Hip for Cartilage

- dGEMRIC 1.5T
  - Older (20+) DDH patients contemplating PAO

- dGEMRIC 3T
  - FAI

- Noncontrast 3T
  - FAI
  - Athletes/adolescents with nonspecific hip/groin pain
Dangers of dGEMRIC

15 year old male with left hip pain c/w FAI
Dangers of dGEMRIC

15 year old male with left hip pain c/w FAI
Dangers of dGEMRIC

Prior outside study: MRI arthrogram

15 year old male with left hip pain c/w FAI
Dangers of dGEMRIC

Patient went to surgery for head/neck arthroscopy
Dangers of dGEMRIC

Patient went to surgery for head/neck arthroscopy

Osteoid osteoma
Developmental Dysplasia of the Hip

• Controversial approach to “mild” acetabular dysplasia
Case Example
To Treat or not to Treat?

14 year old female with 2 years of right hip pain
Dx: snapping hip

MRA: “normal”

Treated with arthroscopy and labral repair at outside hospital
To Treat or not to Treat?

- Recurrent right hip pain similar to pre-op
Case Example
To Treat or not to Treat?

Important to note morphologic features of DDH at imaging, as outcomes s/p scope are POOR in patients with DDH.
Normal or Abnormal?

- Normal variant Supra-acetabular fossa (10.5% of arthrograms)

Dietrich et al. Radiology 2012;263:484-491
Supra-acetabular fossa

Dietrich et al. Radiology 2012;263:484-491

14 year old male
Supra-acetabular fossa

15 year old female with right hip pain

What is going on at weight-bearing zone?
Supra-acetabular fossa

Normal Supra-acetabular fossa
DDH Mimics

Left DDH?

Bilateral DDH
Mimic 1: Epiphyseal Separation

Normal side

Abnormal side
Mimic 1: Epiphyseal Separation

19 day old male with multiple fractures c/w abuse
Epiphyseal Separation

22 day old with limited ROM
Mimic 1: Epiphyseal Separation

Follow-up: healing at fracture site
Mimic 2: Neuromuscular Disease
Mimic 3: Inflammatory arthropathy

13 year old male with right hip pain and ? DDH
Mimic 3: Inflammatory arthropathy
Normal Variant:
Tubular acetabular channels

* Normal finding in ~15% of population

Lien et al. AJR 2006;187(3)
Variant versus Disease?

14 year old male with left hip pain

T1 map: FH 566 ms, Acetab 397 ms
14 year old male with left hip pain: unspecified connective tissue disease
Variant versus Disease?

11 yo female with Marfans

- Chronic impingement with contre-coup destruction of posterior cartilage

Leunig M et al. CORR 2009;467:2241-2250.
Acetabular Overcoverage

- **Coxa profunda**
  - Floor of acetabula fossa at or medial to ilioischial line

- **Protrusio acetabuli**
  - Medial aspect of femoral head medial to ilioischial line
Coxa Profunda

- Considered a normal radiographic finding (in females)
- Not associated with overcoverage
- Relationship to pincer FAI should be abandoned

Nepple JJ et al. JBJS Am 2013;95:417-23

Anderson LA. CORR 2012;470(12):3375-82
Acetabular Protrusio

- 27% of patients with Marfans
- Prevalence increases with age until 20 years
- Serial radiographic examinations and well-documented family history required to rule out progression
Acetabular Protrusio

Female with Marfan’s syndrome: what is the expected outcome?
5 year old male with osteomyelitis at right tri-radiate cartilage
5 year old male with osteomyelitis at right tri-radiate cartilage

3 years later
Acetabular Physes

- Multiple different growth centers/patterns
Triradiate cartilage fusion

- Premature closure of tri-radiate cartilage leads to lateralization of femoral head and secondary dysplasia
- Medial wall thickened
- Enlarged teardrop

DDH
Acetabular Protrusio

8 year old female with Marfan’s syndrome → triradiate epiphysiodesis
Acetabular Protrusio

8 year old female with Marfan’s syndrome → triradiate epiphysiodesis
Acetabular Retroversion
Acetabular Retroversion

14 year old female with right hip pain and impingement symptoms
Acetabular Overcoverage

- 14 year old male with 22q minus (velocardiofacial) syndrome
- Protrusion noted on scoliosis radiographs
- Asymptomatic
Acetabular Overcoverage

- 1 year later
- Worsening left hip pain
- LCEA 56 degrees
Acetabular Overcoverage

Globally increased WB surface with focal superior acetabular fossa
Acetabular Overcoverage

Globally increased WB surface with focal superior acetabular fossa
Acetabular Overcoverage

s/p bilateral reverse periacetabular osteotomy
14 year old female
Symptoms of external
Snapping hip

Radiograph reveals
acetabular retroversion

Repeat radiograph with proper
technique
Femoroacetabular Impingement (FAI)

- FAI is a process rather than disease
  - Repetitive “collisions” between femur and acetabular rim
    - Morphologic alterations femur and/or acetabulum
    - Extremes of hip motion/activity

Background

Cam FAI
Alpha Angle

Abnormal values

- $> 50 ^\circ$

- $> 50.5 ^\circ$
  - Hack K et al. JBJS Am 2010;92:2436-2444.

- $> 60 ^\circ$

- $> 63 ^\circ$
  - Pollard TC. Acta Orthopaedica 2010;81:134-141

- $> 83 ^\circ$
  - Jung KA et al. JBJS Br 2011;93:1303-1307
Alpha Angle

Artwork courtesy of Andrew Phelps MD
Radial MRI Imaging

- Imaging planes rotate around a fixed central point
- Creates images orthogonal to points on the circumference of a circular surface
Radial MRI Imaging

- **Labrum:** Planes rotate around acetabulum

- Useful in MR arthrography
Radial MRI Imaging

- **Femoral head/neck morphology**: Reformatted along axis of femoral neck
Radial MRI Imaging

3D SPACE

3D True Fisp
Radial MRI

9 o’clock  10:30  12:00  1:30
Cam FAI
Cam FAI

- Etiology:
  - Developmental?
  - Traumatic?
  - Genetic?

10 year old male with abdominal pain
AP scout image from abdominal CT
Cam FAI

10 year old male with abdominal pain
AP scout image from abdominal CT

Same patient at age 18 years
AP scout image from abdominal CT
Cam FAI

- MRI for FAI:
  - Acetabular cartilage damage
  - Labral tear

1. Cartilage delamination
2. Labral tear
What do these patients have in common?

14 year old female with left hip pain

16 year old male with left hip pain
Acetabular “rim fracture”

- May be present in both DDH and FAI
- 3.6% of FAI patients have rim fracture
- Related to abnormal acetabular development and/or stress fractures of the acetabular rim
- Can be excised in their entirety, partially excised, or left in situ
- **Treatment dilemma:** rim fracture with intact articular cartilage that contributes to joint stability
Rim Fragment – Fracture vs. Ossicle?
Rim Fragment – Fracture vs. Ossicle?

Unfused ossicle

Different patient, asymptomatic
Rim Fragment - Healing

Healed “fracture” after correcting the dysplasia with PAO
Rim Fragment - DDH

Articular cartilage spans fragment

Healed “fracture” s/p PAO
Rim Fragment- FAI

- Os acetabuli/rim fractures described in 3.6% of patients with FAI
- May be excised in their entirety, partial resection, or internal fixation (versus left alone).
Rim Fracture - FAI

Corrected LCE angle <<< 20 degrees
Rim Fragments - FAI

- CE angles should be measured with and without rim fragment*
- Complete resection of fragments may lead to iatrogenic instability*
- Preoperative CT or MRI can help define the fragments and associated articular cartilage

18 year old male track athlete with right hip pain, “most likely FAI”
18 year old male track athlete with right hip pain, “most likely FAI”
Think Outside the Cam
Think Outside the Cam
Spondyloarthropathy