Articular Cartilage in Children
What We Know
What We Need to Know

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The Physis

• A columnar arrangement of chondrocytes with minimal matrix
AND SO ON

AND SO ON

AND SO ON

AND SO ON
The Challenge of the Future

- Pediatric MSK radiologists and orthopedic surgeons are the stewards of the skeletal future of our patients
We Must Predictly the Future
The Past
Remarkable

• The greatest shock absorber on the planet
• PS I needed new metal springs in my garage door after only 3 years in my life
Chondrocytes produce collagen fibers anchored in subchondral bone.

Chondrocytes produce large negatively charged structures that reside within the matrix.
Arcs cross each other to form two distinct zones of organization.
Radial Zone

- Closest to subchondral bone
- Structured regular configuration with parallel orientation of fibers
Transitional Zone

- More superficial collagen fibers
- Crossing points of arcades of collagen fibers
Cartilage Structure

- Superficial Zone
- Transitional Zone
- Radial Zone
- Tidemark
- Calcified Zone
- Subchondral Bone
- Cancellous Bone
Cartilage Structure

Klein+ Tiss Eng B 2009
Proteoglycan Structure

- Large negatively charged structures
- Multiple GAGs around a protein core
- Highly viscous and poorly compressible
Zonal Variation in T2 Relaxation Times

Deep Layer of Cartilage

40 msec
50 msec
.5 msec
Biomechanics Cartilage Injury

- **Compressive**
  - Only force that acts on the joint during normal function
  - Articular surface resistant to compressive force

- **Shear**
  - Results from twisting, joint dislocation
  - Articular surface vulnerable to splitting with shear force due to mechanical differences between different layers
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Biomechanics of Cartilage Injury
Compressive Effects

- Compression force
  - Cell death indicated (red stain) begins superficially and extends deeper with increasing compressive force

*Milentijevic, et al., J Orthop Trauma, 2005; 19(7): 466-73*
Biomechanics of Cartilage Injury
Shear Forces

- **Shear force**
  - High speed low energy force
    - Articular cartilage surface first to fail
    - At high speed, stiffens
  - Low speed low energy force
    - Deeper layers of cartilage first to fail
    - At low speeds, cartilage more flexible and distortable to a greater extent before failure

Biomechanics of Cartilage Injury
Shear Forces

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Articular cartilage needs a way to attach to bone.

Deep calcified layer and subchondral bone anchor cartilage to bone.
MRI Cartilage Imaging

- **Surface loss**
  - Standard sequences
    - PD Fat sat
    - LAVA
    - T1
    - SPGR fat sat

- **Matrix loss**
  - Novel sequences
    - dGEMRIC
    - T1 rho
    - T2 mapping
    - Ultrashort TE
3D Isotropic Imaging

- Arthrogram effect
- Contour irregularity
- Contrast
- Slice thickness
- Additional information

Bone marrow edema
Delayed gadolinium enhanced MRI of cartilage

Developed by Burstein et al

AKA T1 mapping

1. Inject Ionic Gadolinium intravenously
2. Walk patient around
3. Image
Gadopentate
dGEMRIC: Burstein et al

Ionic contrast

Non-ionic contrast
T1 Mapping

- Multiple T1 sequences with rising TR
- IV contrast and delayed imaging: dGEMRIC
Do You Need To Wait i.e. Why Wait?

NO!

No significant supply to articular cartilage from subchondral bone
Protrusio: Abnormal Signal on Both Sides of Joint
Multiple Images with Increasing TE’s
Patellar Trochlear Disease

- Patellar chondromalacia is a major source of morbidity and osteoarthritis
- Shape of trochlea and patella may predict future disease
Excessive Lateral Pressure Syndrome

- Thickening of lateral patellar retinaculum
- Articular cartilage damage lateral facet
- Could this be the precursor to OA
T2 Mapping

- Used to great advantage in the patella to reveal subtle cartilage change
- Can be used to show normal findings
• Can it predict future articular cartilage loss?
• Jury is out
Ultrashort TE Imaging

• Aim is to image ultrashort T2 components
• TE <100- 50 microseconds
Basis for Ultrashort TE Sequence
Transverse Magnetization Decay

- Total magnetization
  - Long T2 component
  - Short T2 Component

Ultrashort TE Imaging
Majority Short T2 Tissue: PCL
Ultrashort TE Imaging
Majority Short T2 Tissue : Meniscus
Ultrashort TE Imaging
Deep Layer of Cartilage
Bae, et al., Radiology 2010; 254(3): 837-845
Abnormal Deep Layer

- Transition of normal deep layer to abnormal on MR imaging
T1 Rho Imaging

- Looks at slow motion relaxation of macromolecules
- Macromolecules in articular cartilage is proteoglycan

Li, Majumdar., JMRI 2011; 29:324-334
Top row T1 rho
Bottom row T2 map
Articular Cartilage: Adult vs child

• Much is known about articular cartilage in adults

• LITTLE is known about articular cartilage in children
Structure

- Pediatric articular cartilage is
  - More cellular
  - Higher proteoglycan content
Fibrils

- Fibrils seem to arc down from the articular cartilage THRU the epiphyseal cartilage to the zone of provisional calcification of the epiphysis
- Cartilage bundles appear thicker
Structure of physis at epiphysis

- At the main growth plate the chondrocytes are arranged in continuous columns.
- At the spherical growth plate chondrocytes are arranged as nests or islands of cells:
  - Thin
  - Discontinuous
Maturation of Subchondral Bone Plate

- Layer of calcified cartilage at the deepest layer of articular cartilage
- Appears to mature from the hypertrophic zone of epiphyseal physis
Normal Imaging Values

• T2 Mapping
  – T2 values of articular cartilage are slightly higher to or similar to adult values (Dardzinski et al, Radiology 2002, Watrin et al Radiology 2001)

• T1ρ
  – Values in children are slightly longer than in adults (Cobb et al, JMRI 2013)
What We Don’t Know

• Exact way subchondral bone plate forms is unclear
• Repair mechanisms available in a child also unclear
Conclusions

- Morphologic changes predict future disease
- Pay close attention to articular cartilage since we are the stewards of the future