MSK MRI
Knee: Cartilage and Bone

Joint Department of Medical Imaging
University Health Network, Mount Sinai and Women's College Hospitals

University of Toronto
MRI knee: Cartilage and Bone

Cartilage
- Imaging
- Lesions

Osteochondral lesions

Cartilage “repair”

Bone
- Contusions, Avulsions
- Stress/Insufficiency fractures
Articular Cartilage

Highly specialized tissue
Complex ultrastructure

Biomechanically - essential
- Load distribution
- Low friction wt bearing surface
Numerous Pulse Sequences Advocated
- Clinical MR imaging assessment of cartilage

- Spin Echo (T1, PD, T2)
- GRE (2D, 3D)
- MR Arthrography (MRA)
- Magnetization Transfer Contrast (MTC)
- Fast (Turbo) Spin Echo
- Fat Suppression T1 Weighted Spoiled GRE
Fat Suppressed T1W SPGR

High spatial resolution – 3D

Excellent contrast
  Cartilage(bright) + lesions
    • Low signal intensity
    • Contour defects

Min internal tissue contrast

Long imaging sequences
Rapid Isotropic Imaging Techniques

GRE, FSE/TSE (SPACE, CUBE)

- Acquisition 3D isotropic imaging

3D DESS
0.6mm isotropic resolution, 5min scan time
MACI Cartilage Repair

Multiplanar recons - 3D data set
Fast (Turbo) Spin-Echo

High spatial resolution

- Fast imaging times
  (512x256, 4-5 min)

Good contrast characteristics

Lesions, internal structure
- Intermediate/T2 W signal
- MT effect collagen

Lesions ↑ signal intensity
### MR Imaging Evaluation Cartilage

<table>
<thead>
<tr>
<th></th>
<th>SENSITIVITY</th>
<th>SPECIFICITY</th>
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<tbody>
<tr>
<td>SPGR</td>
<td>75-93 %</td>
<td>93-99 %</td>
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<tr>
<td>FSE</td>
<td>87-94 %</td>
<td>94-99 %</td>
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- Disler et al. AJR 1996;167:127-132
- Potter et al. JBJS 1998;80-A:1279-1287
- Bradella et al AJR 1999;172:1073-1080
1.5T

3T

FSE, 4000/15, ETL 8, +32kHz, FOV14cm, 3mm, 512x384, Fat Sat
Articular Cartilage Damage

Degenerative
  • Aging/Osteoarthritis

Traumatic
  • Chondral/Osteochondral injury
Degenerative Osteoarthritis

• Most common form arthritis
  ~10% of the general population

• Insidious, slowly progressive condition

• Major - disability worldwide
  ↑ incidence - aging population

   Economic perspective $65 billion in US
   (CDC, 1999)

Major advances OA - early detection/diagnosis disease - MR Imaging
MR imaging features OA

- Obtusely marginated lesions
- Diffuse cartilage thinning
- Multiple kissing defects - varying size and depth

- Typical locations
  - Medial TibioFemoral
  - Patellofemoral
- Abnormal biomechanical stress/trauma
Mensicectomy - etiologic factor osteoarthritis
Amount OA ↔ Amount meniscus removed

Major principle meniscal surgery

- Preservation as much meniscal tissue as possible

Baseline exam: 1 year postop
Follow-up exam: 2 years postop
Follow-up exam: 2 years postop
Defects often solitary

Can be variable in size

Acutely angled margins

Partial vs Full Thickness
purely chondral or osteochondral
Traumatic Chondral Injury

Adults

- Tidemark zone (cart/bone)
- Weak link – wt bearing cart

Rotary / Shearing forces

- Fissures
- Flap Tears
- Delamination
- Focal Defects
Partial Thickness – Chondral Injuries
Full Thickness – Acute Chondral Injuries
* Underlying Marrow Edema
Full Thickness – Acute Chondral Injury
Displaced Chondral Fragment
Full Thickness – Acute Chondral Injury
Displaced Chondral Fragment
Complete ACL Tear – Repeated Pivot Injuries
Complete ACL Tear – Repeated Pivot Injuries – Cartilage and Meniscal
Description of lesions

type of lesion
location and severity
reproducible and acceptable to referring surgeons
Numerous classification systems proposed

**Staging / Grading cartilage lesions**

Histology, Surgical, Imaging - Radiographs, MRI

- **WORMS** *(Whole Organ MR Scoring 2003)*
- **ICRS** *(Surgical 2000)*
- **Noyes** *(Surgical 1989)*
- **Outerbridge** *(Surgical 1961, Modified 1985)*
Grading/Severity: Outerbridge classification

- Softening and swelling
- Less than half thickness
- Full thickness
- Erosion to subchondral bone
Grade I: softening and swelling

“abnormal cartilage without obvious erosion or fissure”
Grade II: partial thickness

“fissure or erosion involving less than ½ thickness”
Outerbridge classification
Grade 2 medial femoral condyle
Grade III: full thickness fissure

“full thickness defect or fissure”
Grade IV

“chondral defect with subchondral changes”
Outerbridge classification
Grade 4 apex and medial facet patella
Osteochondral Injury / OCD

Injury cartilage + underlying subchondral bone

- In situ
  - Overlying cartilage intact
- Partially detached
  - Cartilage partially disrupted
- Completely detached
  - Cartilage completely disrupted

- MRI - NB information; lesion size, status of overlying cartilage and subchondral bone, edema or cysts, possible loose bodies

- Osteochondritis Dissecans - common young adults and children. Repetitive microtraumatic impact loading
Osteochondritis Dissecans

- **2 discrete forms** – clinical outcome / instability

**Juvenile OCD** (open growth plates)
- high rate healing - spontaneous healing >50% of cases

**Adult OCD** (closed physis)
- greater propensity for instability → intervention

**Instability**
- adults – rim ↑T2, or interface cysts
- children – inner ↑T2 + outer ↓T2, breaks subchondral plate, cysts - multiple / large (>5mm)
The presence of:

- a high T2 signal intensity rim
- cysts surrounding an OCD lesion
- a high T2 signal intensity fracture line extending through the articular cartilage overlying an OCD lesion
- a fluid-filled osteochondral defect

are signs of instability in patients with adult OCD of the knee.
Osteochondral Injury / OCD

The most useful secondary MR imaging findings for distinguishing between stable and unstable juvenile OCD lesions with a high T2 signal intensity rim are:

- a rim of fluid signal intensity
- multiple breaks in the subchondral bone plate on T2-weighted MR images
- a second outer rim of low T2 signal intensity
A high T2 signal intensity rim surrounding a juvenile OCD lesion indicates instability only if:

- it has the same signal intensity as adjacent joint fluid
- is surrounded by a second outer rim of low T2 signal intensity or
- is accompanied by multiple breaks in the subchondral bone plate on T2-weighted MR images.

Cysts surrounding a juvenile OCD lesion indicate instability only if they are multiple or large in size.
Osteochondral Injuries – Overlying Cartilage Intact
“In Situ” - Stable
Osteochondral Injury – Partial disruption Cartilage
“Partially Detached” - Loose In-Situ
Osteochondral Injury – Complete Disruption Cartilage
“Completely Detached” - Loose
Osteochondral Injuries – Complete Disruption Cartilage
“Completely Detached” - Displaced
Chondral / Osteochondral Lesions

What can be done

Unstable osteochondral lesion (acute/subacute)
- Surgical fixation

Chondral Lesions - ?
Surgical Repair Procedures - Cartilage

Marrow Stimulation Techniques
- Abrasion, Drilling, Microfracture

Osteochondral Transplantation
- Autologous transplants (OAT, Mosiacplasty)
- Allograft transplantation

Autologous Chondrocyte Transplantation
- Autologous chondrocyte implantation (ACI)
- Matrix assisted chondrocyte implantation (MACI)
Marrow stimulation techniques

Abrasion arthroplasty
Subchondral drilling
Microfracture

Small lesions < 4cm²

- Penetration - subchondral bone
- Defect fill with fibrocartilaginous repair tissue
Microfracture
Most widespread of repair techniques

Debridement defect

Use Pick or Awl - multiple penetrations (3-4 per cm²) subchondral bone

Promote subchondral bleeding
- Formation Fibrin Clot
18 mos postop

Traumatic OCD - Microfracture
MR Imaging - Microfracture

Initial (< 6-12 mos)
- SI heterogeneous repair tissue thinner adjacent cartilage
- Marrow (edema) signal Δs

Maturation repair tissue (1-2 yrs)
- ↑ thickness repair tissue
Compared to other repair techniques

Microfracture

Technically uncomplicated
Single stage procedure
Basic arthroscopic equipment

• Equivalent clinical results - ACI

• Similar histology repair tissue
  - outcome $\neq$ quality tissue

Osteochondral Autograft Transplantation

OAT
Mosaicplasty

Small lesions < 4 cm²

- Autologous transplantation
  Osteochondral plug(s)
- Resurfacing – defects
Osteochondral Autograft Transplantation

OAT
Mosaicplasty

Small lesions < 4 cm$^2$

• Autologous transplantation
  Osteochondral plug(s)

• Resurfacing – defects
Graft congruity – primary goal/challenge

positioning graft cartilage - flush surrounding articular surface

• Predetermine procedural success

• Incongruity
  - Technical difficulties
  - Graft subsidence / motion
Defect fill/ articular congruence
Osteochondral Allograft Transplantation

Transplantation fresh allograft
Treatment - large defects
  > 3cm², > 1cm depth

- Open surgical procedure
- Treatment/Transplantation
  - Focal defects
  - Entire articular surface
MR Imaging - Assessment

Position graft

Congruence • cartilage
  • subchondral bone

Complications
  • Collapse
  • Fragmentation
  • Displacement

6 weeks postop
Autologous Chondrocyte Transplantation

ACI – Autologous chondrocyte implantation

MACT – Matrix assisted chondrocyte Transplantation

Repair “Large defects” 2-12 cm²

2 stage procedures
  Biopsy/culture - cartilage
  Implantation
MR Imaging - Assessment

ACI, MACI

Defect fill

Integration • cartilage
  • subchondral bone

Complications
  • Delamination
  • Degeneration

MACI 24M - Courtesy S. Trattnig
MACI 6M - Courtesy S. Trattnig
Osseous Injuries – General Principles

Impaction/Contusion fractures

Pivot shift – ACL (lat fem condyle, lat tib plateau)
• Bone bruising, trabecular impaction, +/- Fx line

Avulsive fractures

Segond, ACL footplate fracture
• Fracture line (T1, T2), relatively less “bone bruising”
Unique Osseous Injuries: Knee

Fatigue fracture
   summation of microfractures caused by repeated trauma
   (frequently seen in athletes)
   *normal bone abnormal load*

Insufficiency fracture
   osteoporotic / osteomalacic bone fractured by normal stress
   *abnormal bone normal load*

SONK – Spontaneous Osteonecrosis Knee
Bilateral knee pain, recent running
Fatigue fractures proximal tibiae
Fatigue fractures proximal tibiae
Spontaneous osteonecrosis of the knee (SONK)

- Female
- >55
- Acute onset severe pain
- Usually without a history of trauma
- Aetiology debated
Subchondral Insufficiency Fracture of the Knee
Acute fracture occurs as a result of stress or minor trauma to a weakened subchondral bone plate.

Avascular areas in biopsy specimens appear to be a secondary phenomenon and not the primary cause.
Subchondral Insufficiency Fracture of the Knee

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