MRI EVALUATION OF CARTILAGE

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INTRODUCTION

• Anatomic imaging not sufficient
• Current techniques detect established cartilage defects and subchondral change (BME & cyst)
• Early intervention of cartilage imaging & novel treatments
  – demand for functional/biochemical imaging
  – need to image early cartilage breakdown
RECENT INNOVATIONS

- T2 Mapping
- T1 rho imaging
- DWI
- DTI
- dGEMRIC (delayed gadolinium MRI of cartilage) → currently only technique proven to be predictive for future joint degeneration
CARTILAGE

- **CHONDROCYTES**: (1-2%)

**EXTRACELLULAR MATRIX**:

- **Solid**
  - Proteoglycans (5-10%)
  - Collagens-Type II (15-20%)

- **Fluid**
  - Water (70-80%)
COLLAGEN NETWORK

- **Proteoglycan:**
  - draws water & maintains osmotic pressure
  - counteracts swelling pressures
  - provides force in tension & shear
  - resists compression
GLYCOSAMINOGLYCANS (GAG)

- Extensive polysaccharide chains
- Form large complexes of negatively charged proteoglycans
- maintain:
  - osmotic pressure
  - fluid within the cartilage matrix
  - compressive stiffness
GLYCOSAMINOGLYCANS (GAG)

- Cartilage behaves as a stiff elastic polymer to sudden impact
- Slow viscoelastic deformation to sustained loading
- GAG loss is a known early event in the progression of OA
- ? early breakdown reversible
dGEMRIC

• assesses early cartilage damage as **GAG loss** prior to development of macroscopic cartilage defects

• **negatively** charged MRI contrast (Gadolinium; Gd), (IV or intra-articular) is repelled by **negatively** charged GAG
dGEMRIC

= GAG

= Gadolinium
dGEMRIC

• Less GAG in cartilage $\rightarrow$ less negative charge relative to normal cartilage $\rightarrow$ the more the negatively charged contrast will penetrate GAG deplete cartilage (1)

• Gd penetrates normal cartilage, high [GAG], in a reciprocal manner
dGEMRIC

• $\uparrow$ Gd $\rightarrow$ $\downarrow$ T1 value (MRI property of Gd)
• Double negative:
  
  $\downarrow[GAG] = \uparrow$Gd = $\downarrow$ T1
  $\uparrow[GAG] = \downarrow$Gd = $\uparrow$T1

• [GAG] is directly proportional to T1 value
• T1 value = T1 relaxation time = dGEMRIC index
TECHNIQUE

\[ [\text{GAG}] = \text{dGEMRIC index} \]
TECHNIQUE

• IV Gd – double dose

• Exercise

• Wait 30-90min for penetration (2)

• IA better than IV (3, 4)

• T1 maps of cartilage generated/manually plotted

• No difference between 1.5T & 3T (5)
VALIDATION

• Reproducible (6)

• Excellent *in vitro* correlation (7)

• Higher dGEMRIC index (less Gd, higher [GAG]) = higher resistance to mechanical compression (8, 9)
INTERPRETATION

- Proton density
- T1 weighted (dGEMRIC)
- GAG stain

Bone Cartilage

5 mm
SHOULDER ARTHROGRAM

HUMERAL HEAD  dGEMRIC INDEX  GLENOID dGEMRIC INDEX
DYSPLASIA

• 9/52 Periacetabular Osteotomy (PAO) failed

• dGEMRIC index:
  – useful measure of early OA
  – best predictor of failure (P<0.02)
  – identified poor candidates for PAO

• Poor dGEMRIC index (<400msec) → for conservative management (injection, physio, debridement)
• Good dGEMRIC index (>400msec) → PAO
• Eliminated the need to rely solely on radiographs (changes occur too late) [10]
DYSPLASIA
DYSPLASIA

- N=96 dysplastic hips OA defined as 2SD < average, i.e. dGEMRIC < 390 msec
- Mean dGEMRIC 473 cf normal hips of 570 [11]
SUCFE

- 16 patients SUCFE followed up for 14.5 years
  - T1 values lower laterally than centrally
  - Good correlation between dGEMRIC index, pain and alpha angles (degree of offset) [12]

- Perthe’s disease:
  - loss of GAG medially [13]
• Significant correlation between:
  – dGEMRIC index
  – pain
  – alpha angle

• correlation of dGEMRIC with alpha angle suggests that hips with more femoral deformity show features of early OA [14]

• Cam FAI  → lower dGEMRIC values anterosuperiorly
• Pincer FAI  → generalized circumferential loss [15]
ACL INJURED KNEE

• dGEMRIC evaluation of the ACL injured knee shows 13% lower dGEMRIC index in the medial compartment when compared with the normal contralateral side [16]
PCL INJURY

Pre PCL injury

4 wks post injury

3 mo post injury

6 mo post injury

![Graph showing dGEMRIC values over time](image)

- Pre
- 1 month
- 3 months
- 6 months

*Note: Image and data are illustrative and for educational purposes.*
# KNEE DISLOCATION

<table>
<thead>
<tr>
<th></th>
<th>Medial Facet</th>
<th>Lateral Facet</th>
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<tbody>
<tr>
<td>Bilateral Patellar Dislocation</td>
<td>411</td>
<td>426</td>
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<tr>
<td>Unilat Dislocation – non dislocated side</td>
<td>465</td>
<td>466</td>
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<tr>
<td>Normal</td>
<td>490</td>
<td>510</td>
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</table>
CARTILAGE Rx

- Higher GAG in following MACI than MFX [19]
KNEE OA

• All low dGEMRIC index areas show abnormality on knee arthroscopy (N=16) [23]

• Knee pain in patients without OA but low dGEMRIC index are more likely to develop radiographically evident OA in 6 yrs [24]

• Valgus malaligned knee lower dGEMRIC index laterally and varus knee medially [25]
KNEE OA

• dGEMRIC index correlates strongly with knee flexor and extensor strength, suggesting that strong coordinated muscles may play a role in preventing OA

• overweight & meniscetomy are RF for OA – dGEMRIC index 14% lower $\rightarrow$ 374 vs 437 [26]

• Moderate increase in dGEMRIC index of cartilage in patients with moderate OA & who exercise [27]
OTHER JOINTS

• Matrix Associated Autologous Chondrocyte Implantation (MACI) of the ankle [28]

• 1st CMC of the thumb [29]
AFL APPLICATIONS

• Known injury/congenital/developmental issue in potential draft candidate → will FAI stand up to the rigors of AFL?

• Assists in diagnosis → no cartilage defect, but is that cam lesion significant? Does the low dGEMRIC index account for pain? Pubic symphysis?

• Explains prolonged pain despite no apparent cause → Post PCL injury
AFL APPLICATIONS

• Timing of return to competition → Post bone bruising. Is waiting for BME to resolve insufficient?

• Informed consent regarding risks of playing vs retirement → Are there early but permanent changes in dGEMRIC index post meniscectomy?

• More realistic expectations from player, club & medical staff following injury →? Decreases future risk of litigation

• Retired AFL players & incidence of OA

melbourne radiology clinic
CONCLUSION

• dGMERIC imaging validated technique in early GAG loss

• GAG loss:
  – precedes OA, ? reversible
  – detected by Gd penetration & T1WI

• Best imaging predictor of OA
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