UTE Quantitative MRI:

Clinical applications

Michael Im

January 17, 2013

Background and Significance

Osteoarthritis

More than 20 million in US

80-90% > 65 yo

Major cause of:

- Work disability
- Reduced quality of life

U.S. Centers for Disease and Control Prevention, www.cdc.gov

Osteoarthritis costs U.S. $185B a year

Posted 12/4/2009 1:57 PM | Comment | Recommend

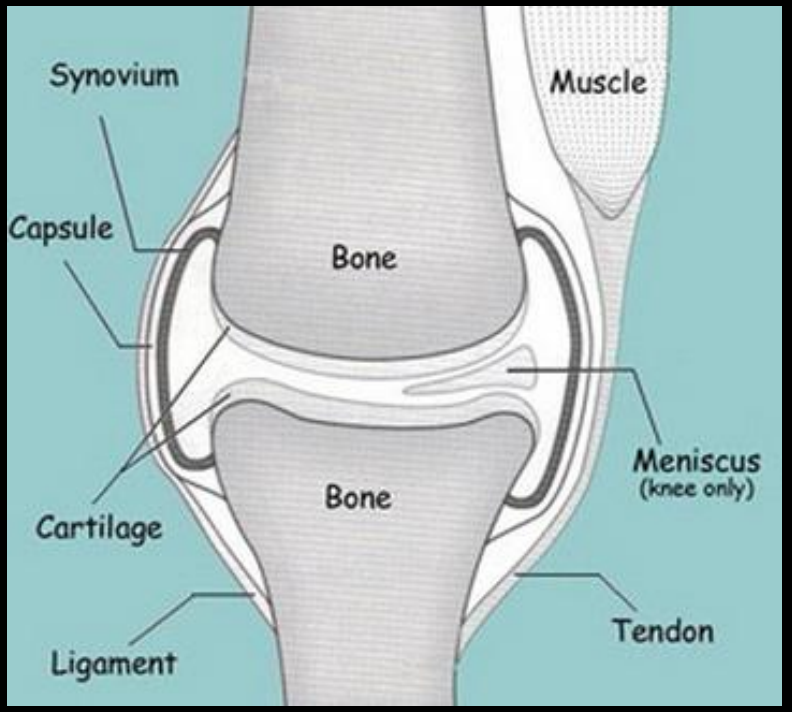
By Robert Preidt, HealthDay News

The study authors said increased awareness and better screening to identify patients with osteoarthritis may help delay disease progression and resulting disability, thus reducing medical costs.

Background and Significance

Whole joint concept

Cartilage and meniscus pathology contribute to osteoarthritis



Hypothesis: Better visualization will lead to improved patient care

MRI

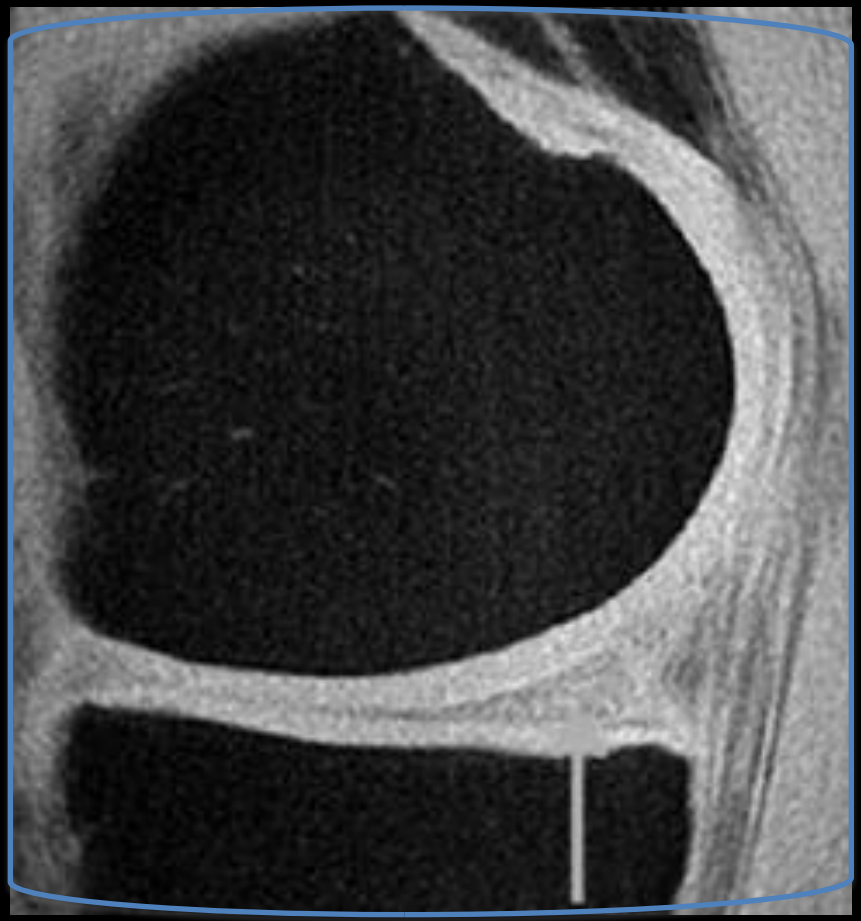
Visible
Long T2

Invisible
Short T2

Tissue or tissue component	Mean T_2
Deep layers of articular cartilage	5–10 ms
Knee menisci	5–8 ms
Achilles tendon	0.25 and 0.7 ms, 1.2 ± 0.2 ms, 0.53 ms (88%) and 4.8 ms (12%), 7 ms
Cortical bone	0.4–0.5 ms
Dentine	0.15 ms
Dental enamel	70 μs
Protons in water tightly bound to proteins	10 μs
Protons in proteins	10 μs
Protons in solids, e.g. calcium hydroxyapatite	1 μs or less

Robson, Bydder. NMR Biomed. 2006.

Conventional MRI vs UTE T1rho
Meniscus

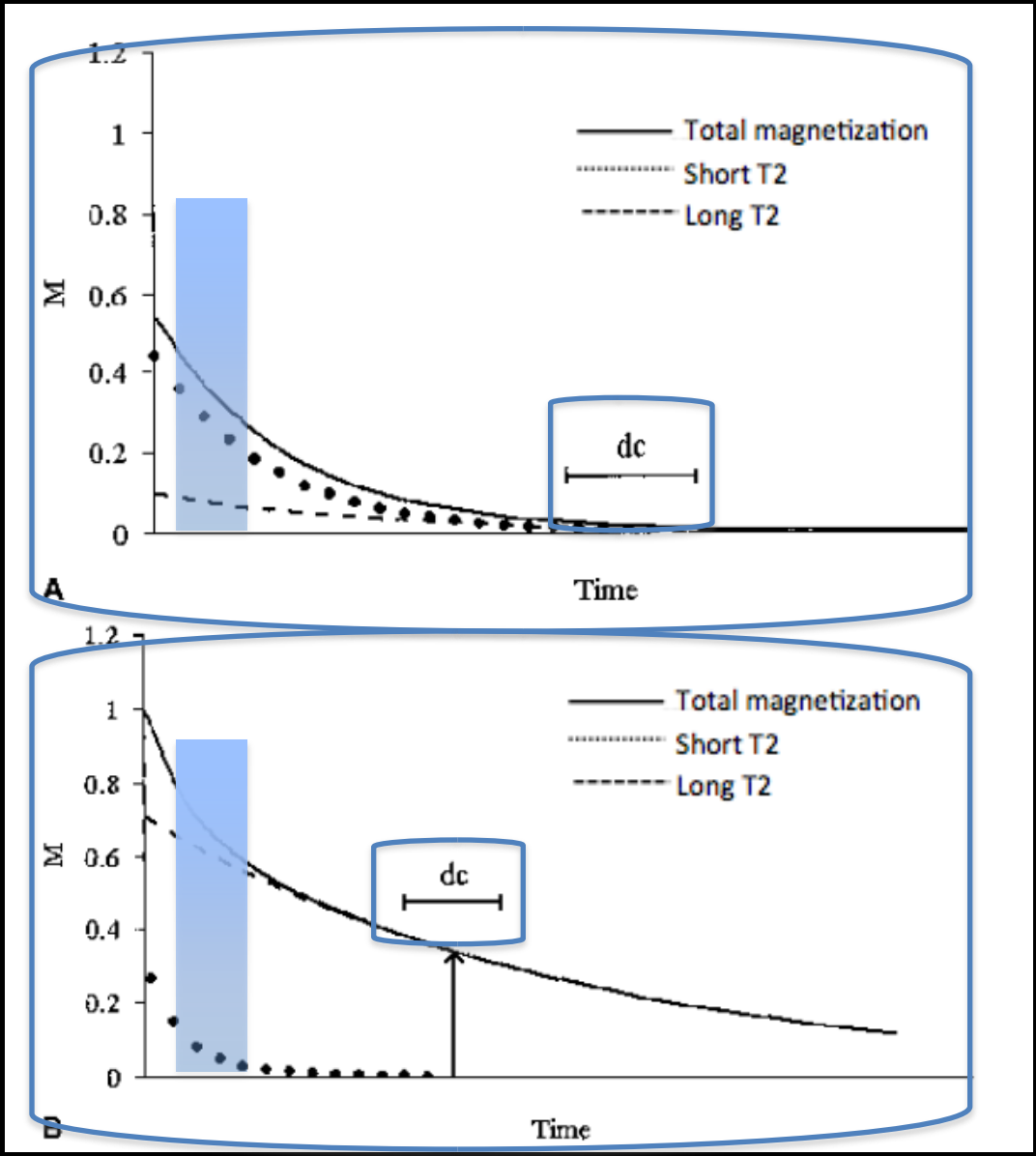


Du, Chung, Bydder, et al. MRM 2010.

Transverse magnetization decay

Majority of short T2 components

Minority of Short T2 components



Robson, Bydder. J Comput Assist Tomogr 2003

Musculoskeletal short T2 tissues

TABLE 3. Normal (Adult) Tissues with a Majority of Short T2 Components

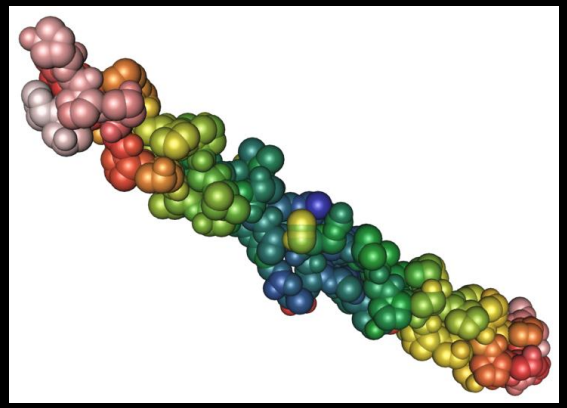
Meninges (dura)	Falx	Tentorium
Membranes	Capsules	Bands
Retinaculi	Septae	Fascae
Sheaths	Nails	Hair
Aponeuroses	Tendons	Ligaments
Menisci	Labrii	Periosteum
Bone	Dentine	Enamel

Robson, Bydder. J Comput Assist Tomogr 2003

Musculoskeletal short T2 tissues

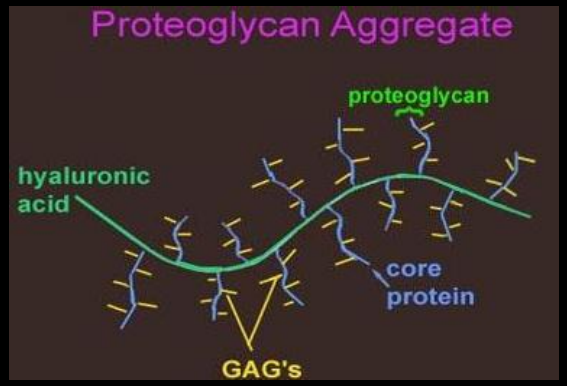
Musculoskeletal short T2 tissues

Collagen



T2

Proteoglycan



T1rho

dGEMRIC

Na

Purpose

Demonstrate clinical applications of UTE quantitative MRI

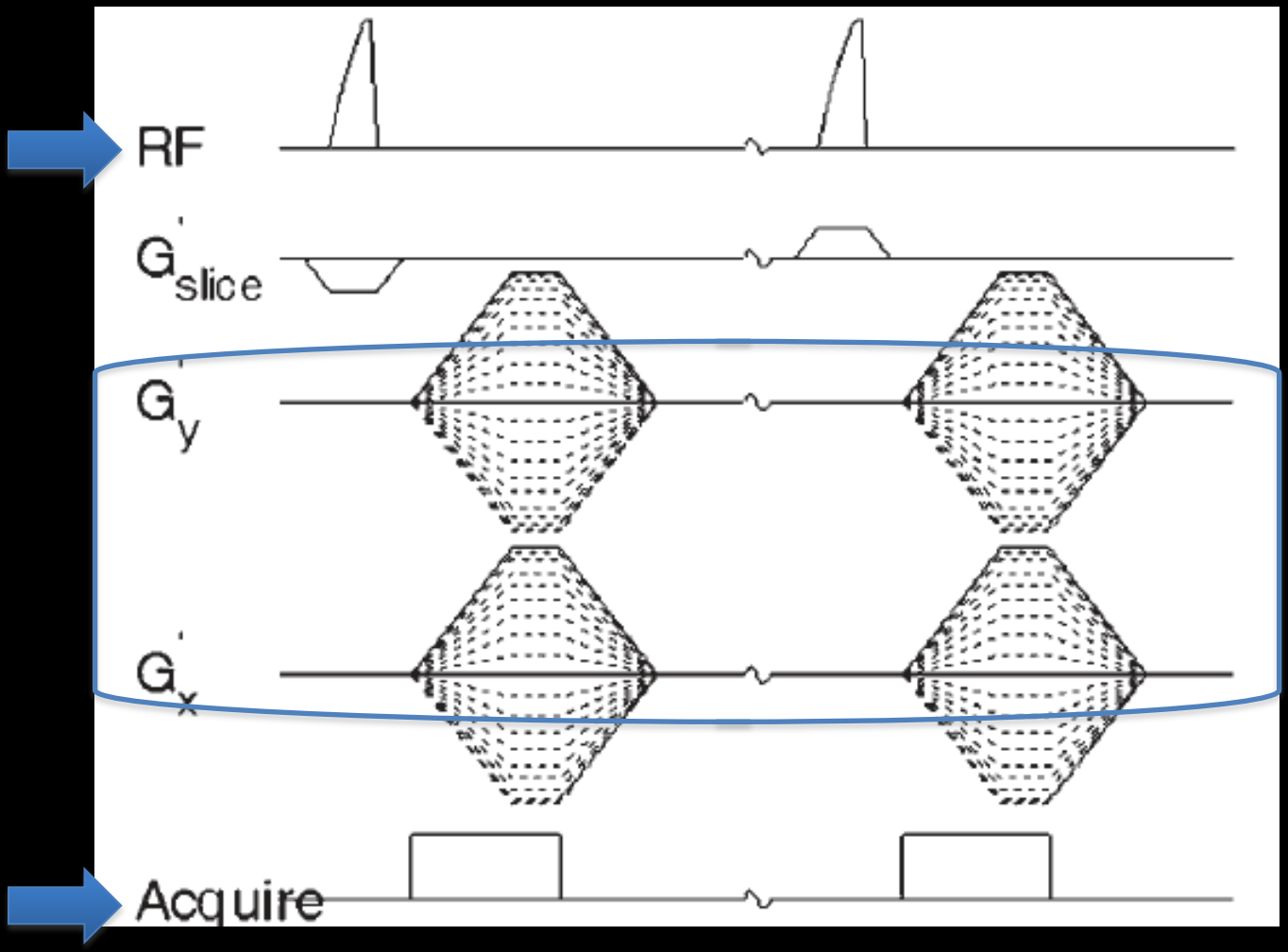
UTE Clinical Applications

Novel MRI techniques can be utilized to quantify microstructural changes.

- DIR UTE
- UTE T1 rho
- UTE T2*

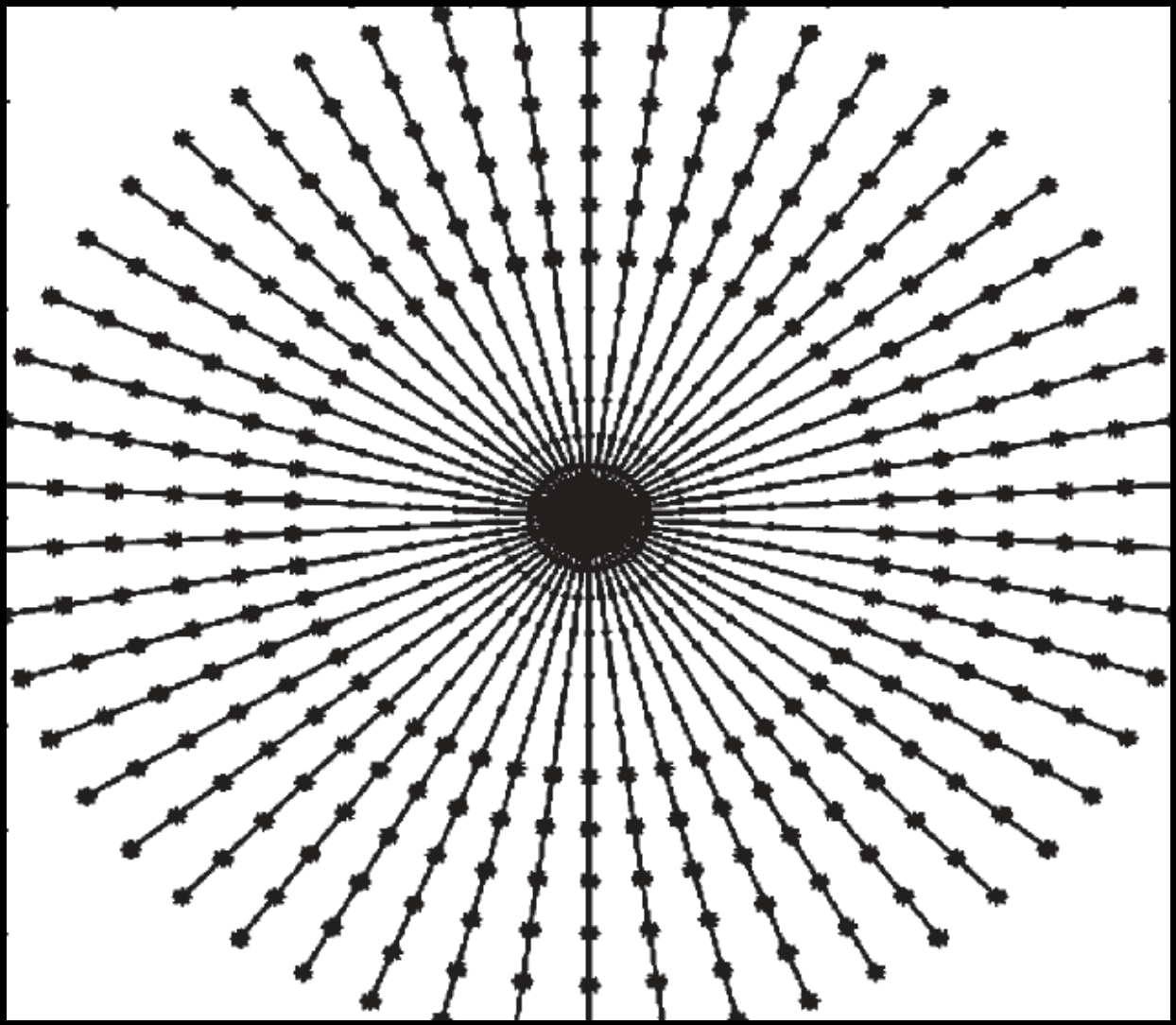
Early detection and quantify response to treatment

UTE pulse sequence



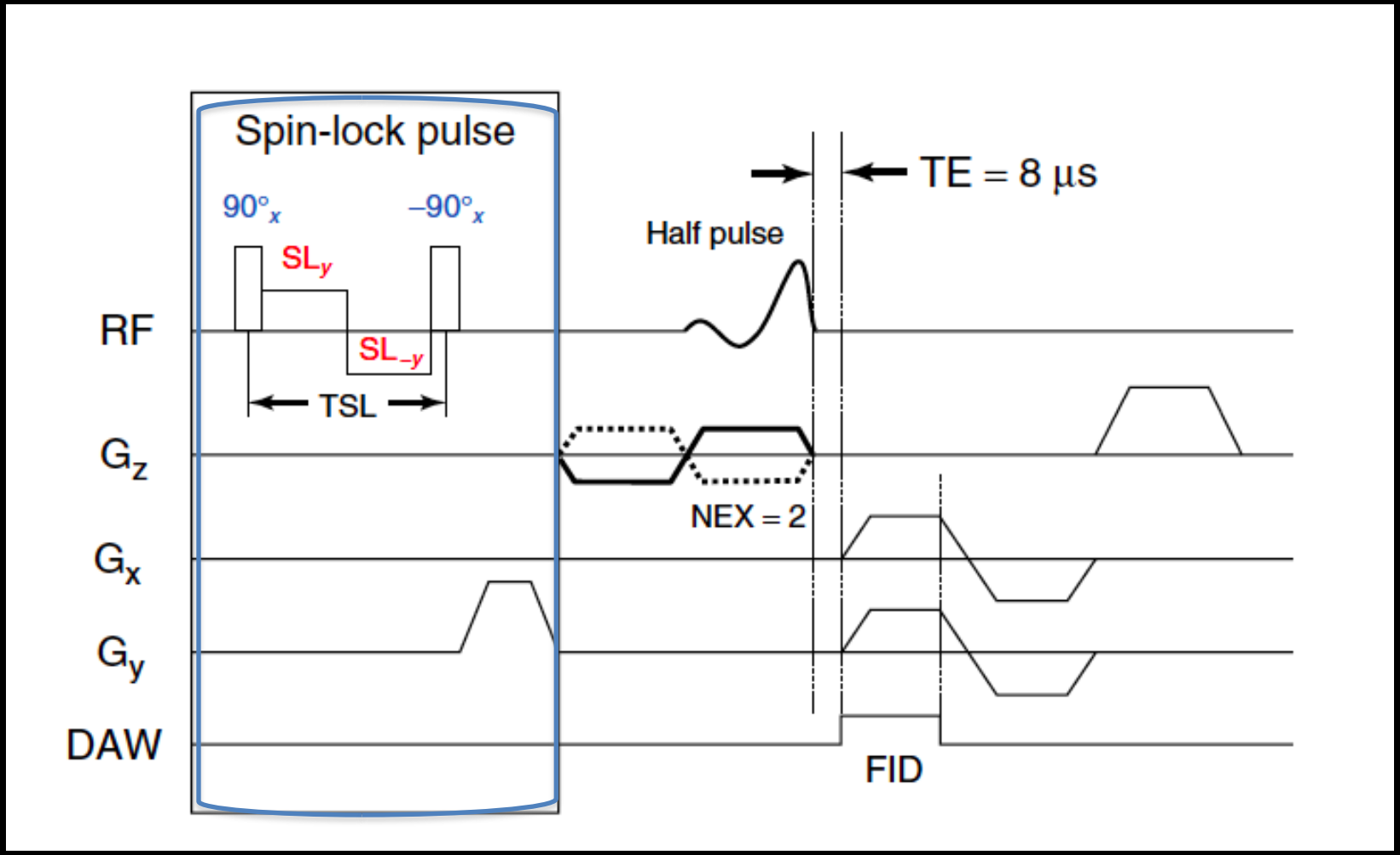
Robson MD, Bydder GM. NMR Biomed 2006.

Radial K-space acquisition



Robson MD, Bydder GM. NMR Biomed 2006.

UTE T1 rho
Spin-lock pulse

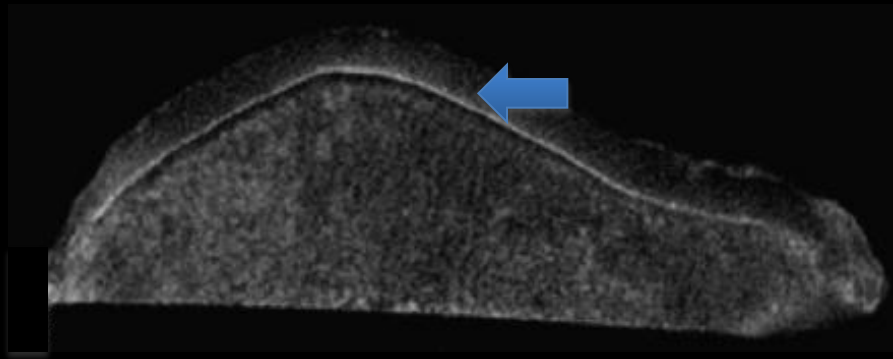


Du, Chung, Bydder, et al. MRM 2010.

UTE Clinical Applications

Articular Cartilage

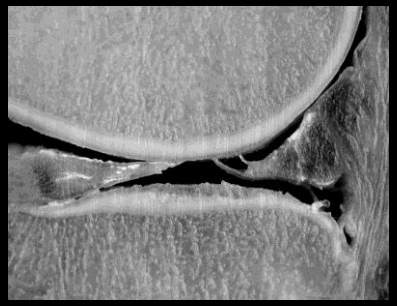
- Patella



Fibrocartilage

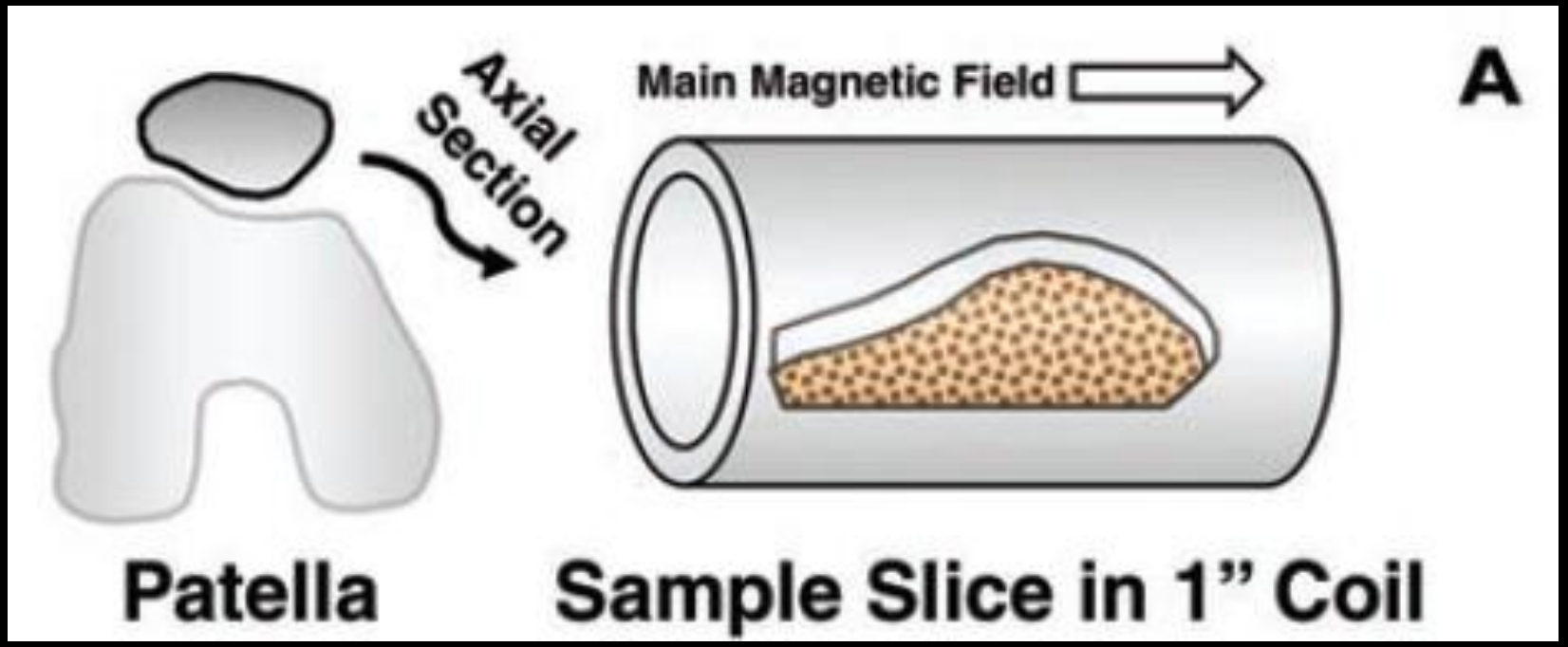
- Intervertebral disc
- Temporomandibular joint
- Triangular fibrocartilage complex

Meniscus



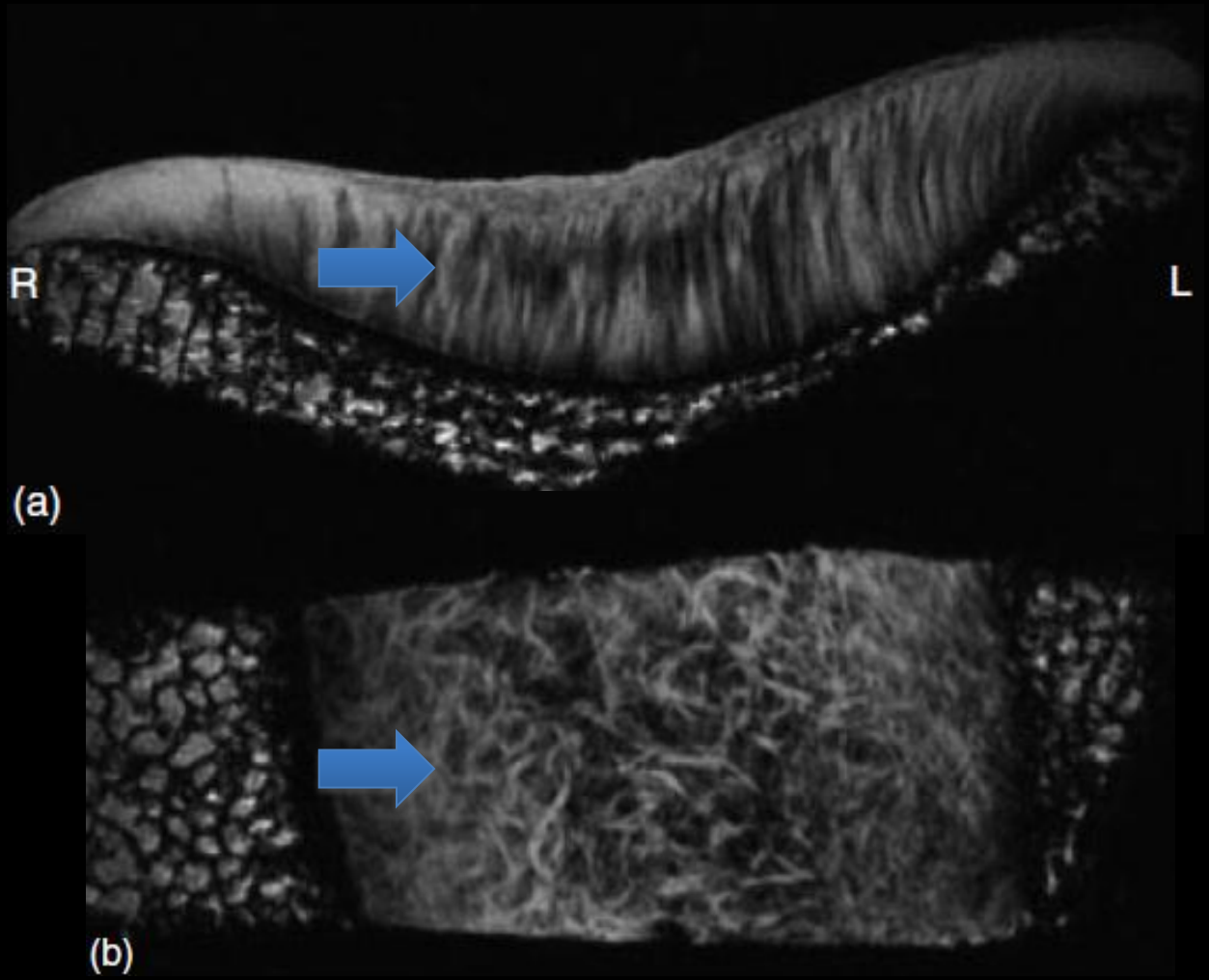
Bae, Du, Bydder, Chung. TMRI 2010.

Protocol for MRI of cartilage



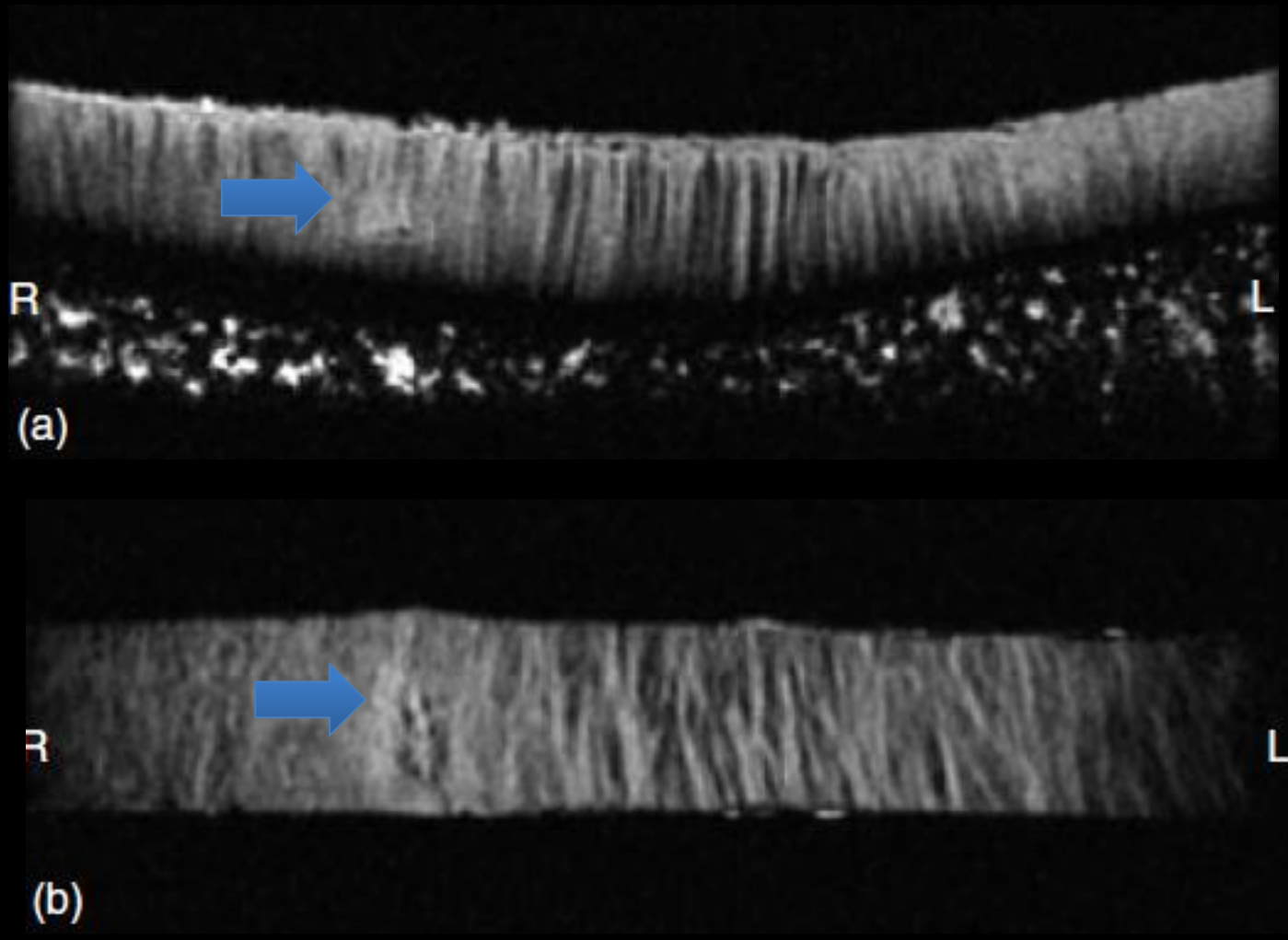
Buck, Chung, et al. AJR 2011.

DIR UTE
Tibial cartilage



Bae, Chang, Chung. EMR 2012.

DIR UTE
Tibial cartilage



Bae, Chang, Chung. EMR 2012.

Cartilage composition

Extracellular matrix

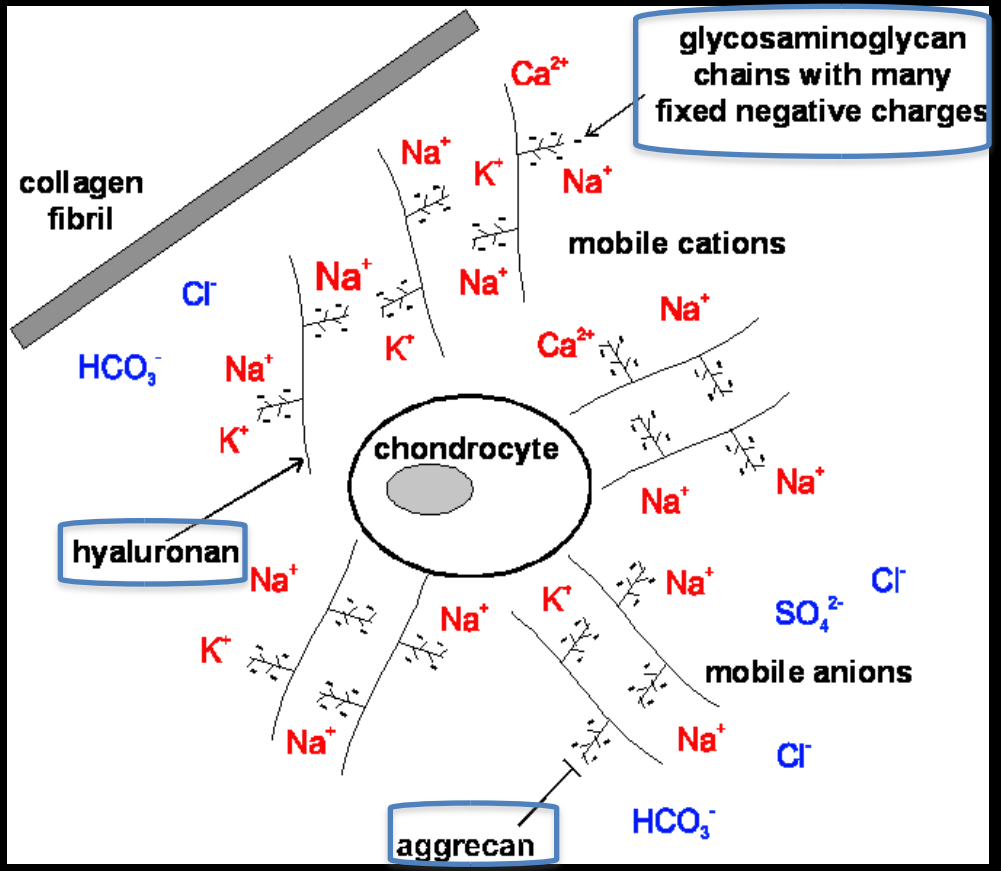
Tissue fluid

- Water (65-80%)

Macromolecules

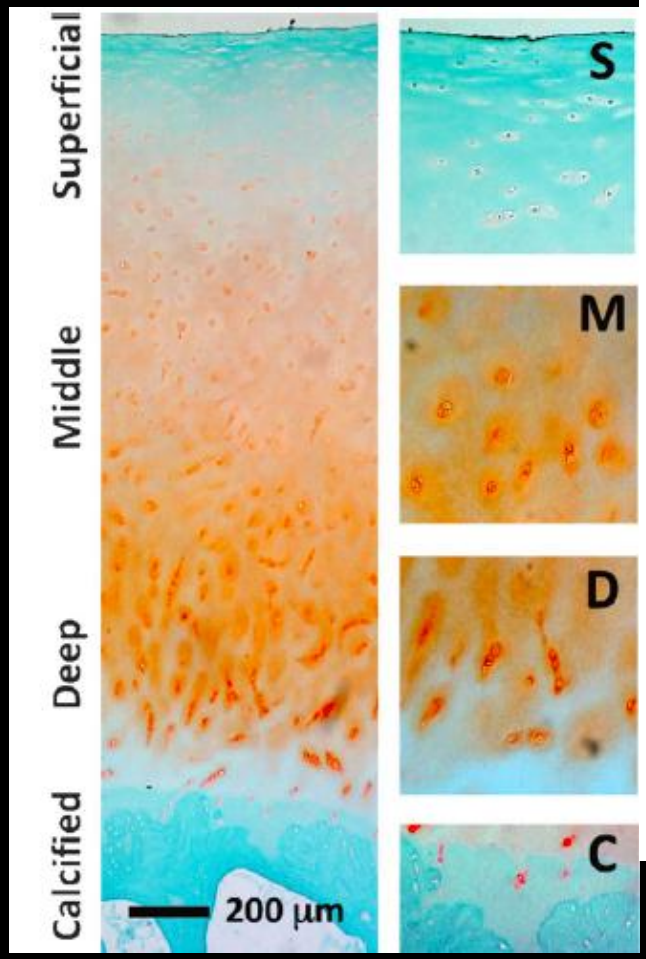
- Collagen II (15-25%)
- Proteoglycans (3-10%)
- Non-collagenous proteins

Chondrocytes (1%)



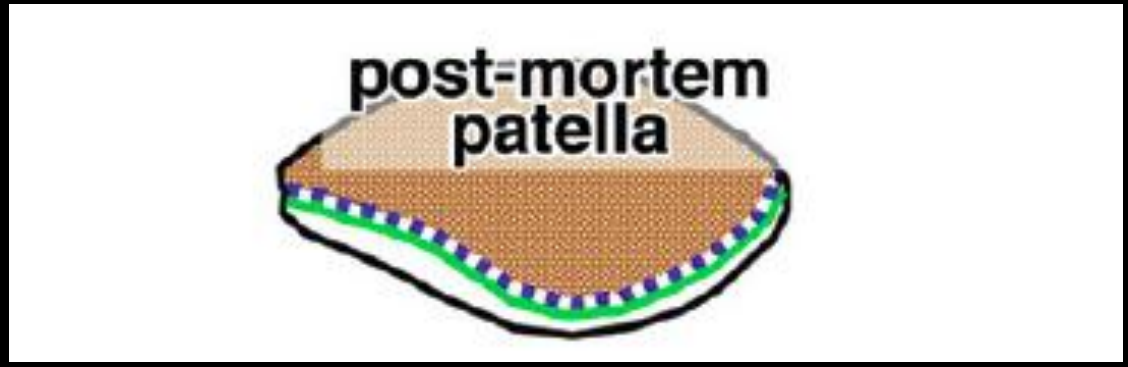
Hall, Newman SA. 1991.

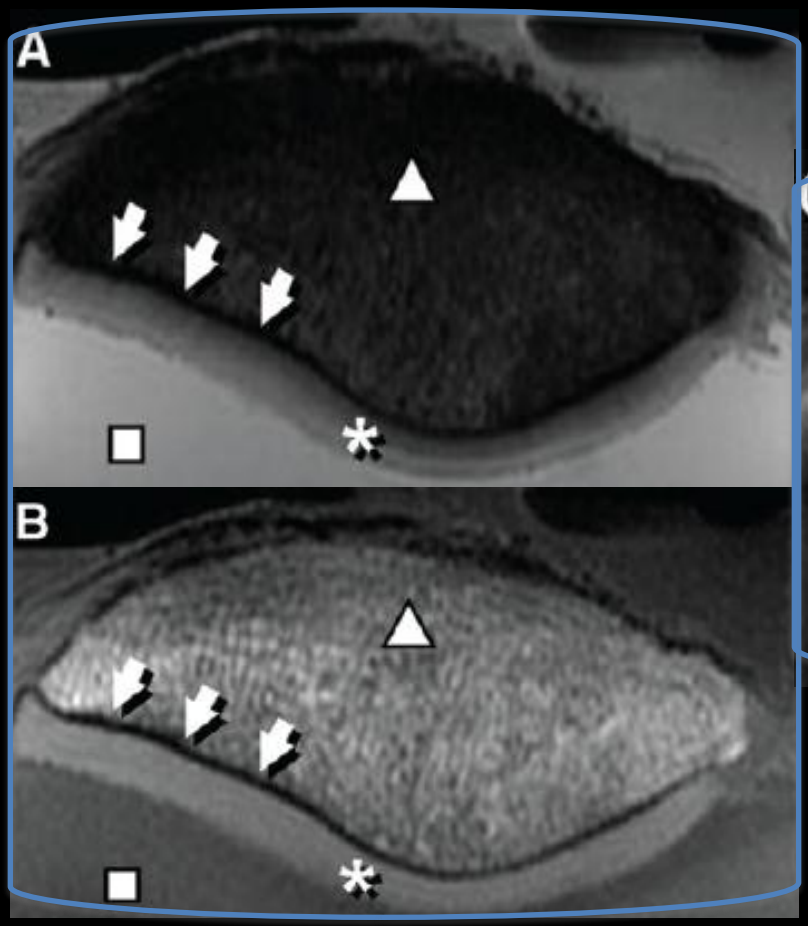
Histology
Articular Cartilage

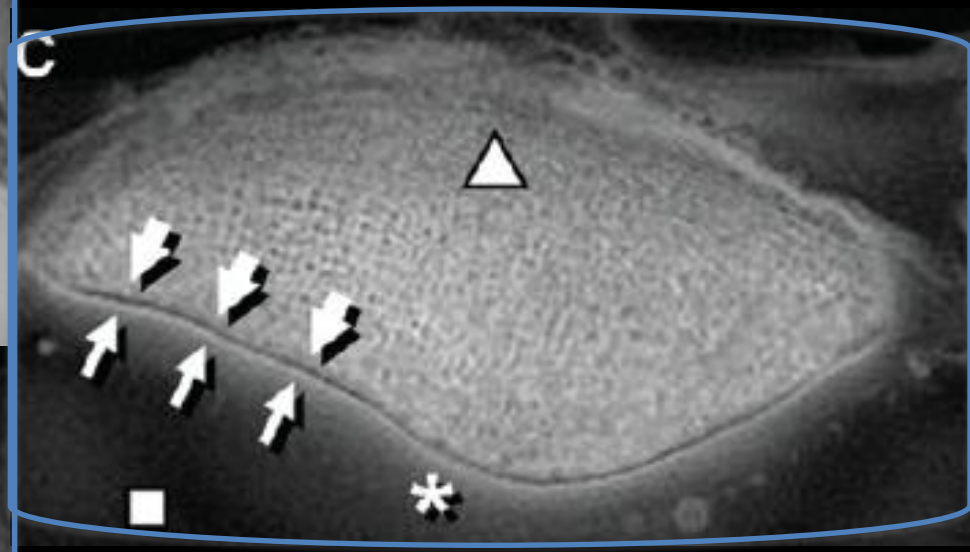


	GAG content, Comp Stiffness	Collagen Orientation	Chondrocyte Density	T2 MR Value
S	low	|| sz	high	med
M	med	random	med	med
D	high	⊥ sz	med	low
C				Ultralow

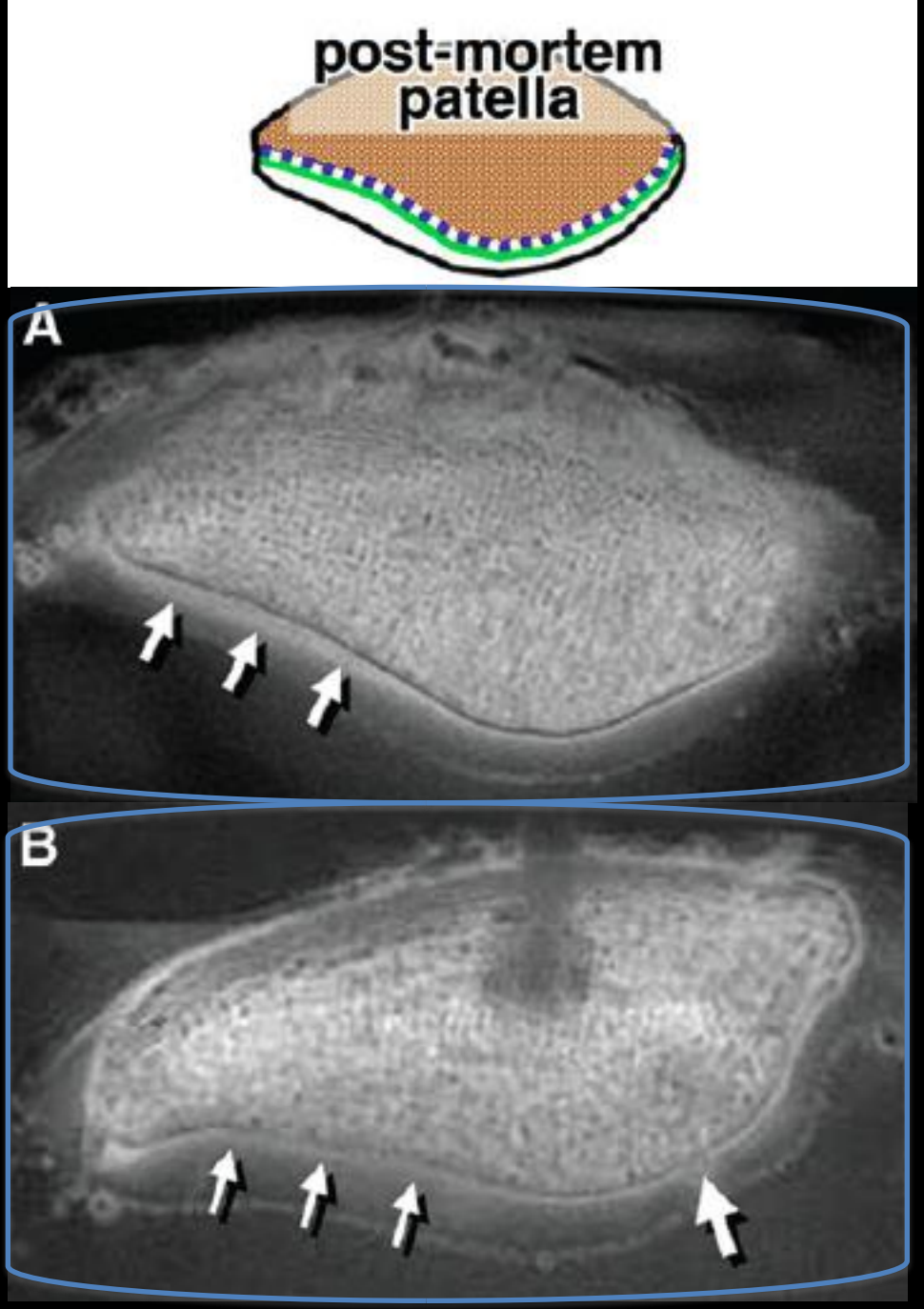
Bae, Du, Bydder, Chung. TMRI 2010.





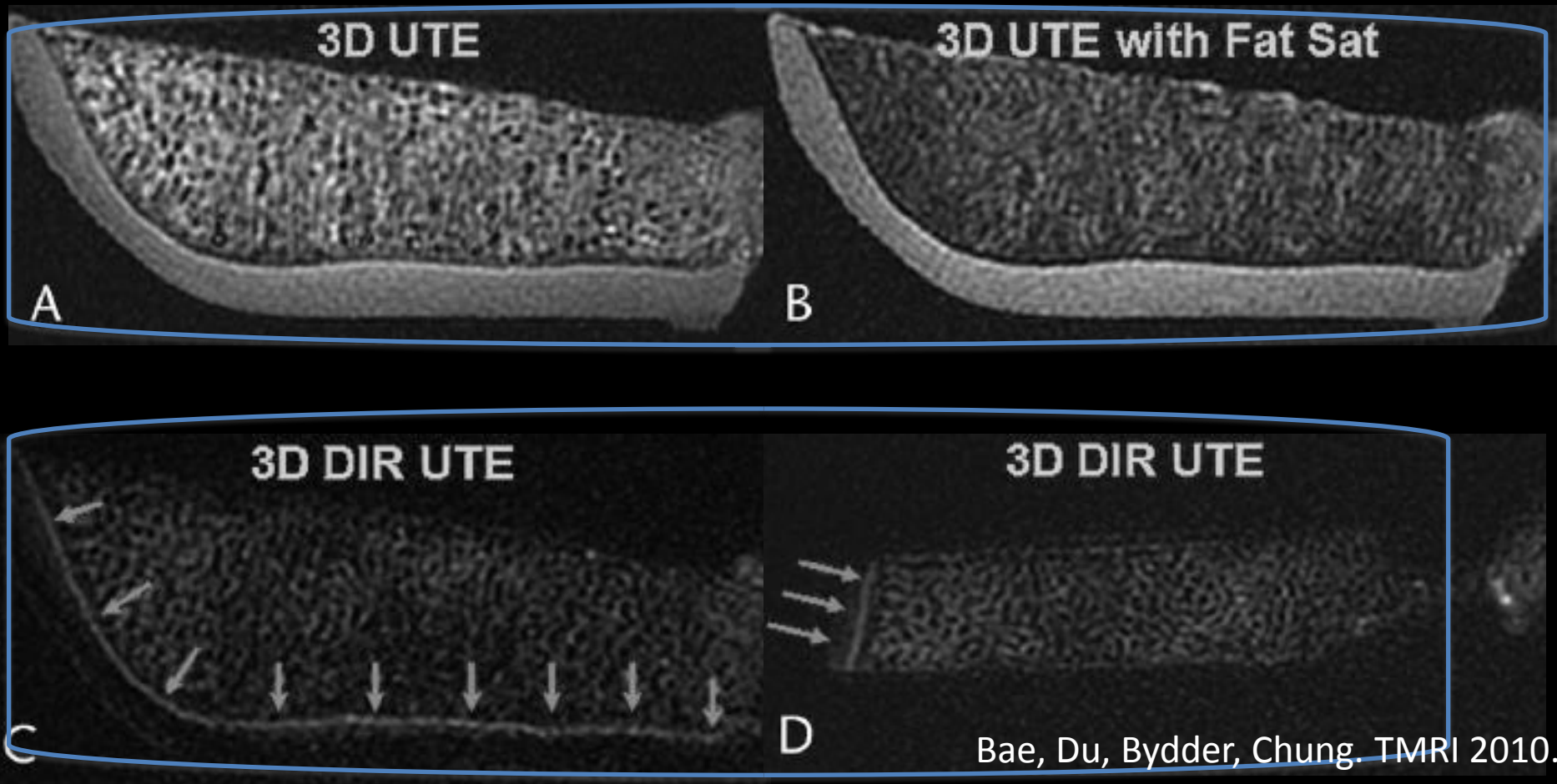


Bae, Dwek, Chung, et al. Radiology 2010.



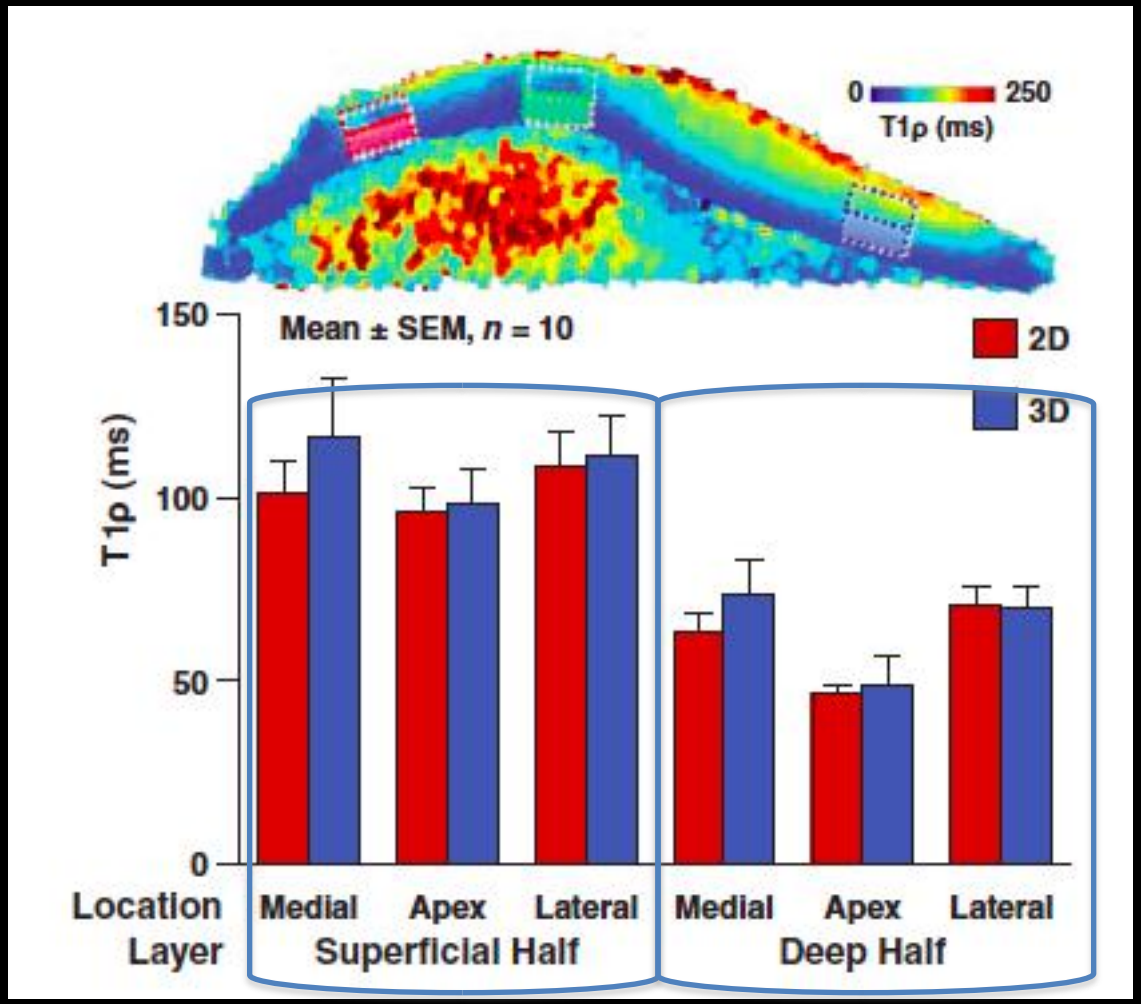
Bae, Dwek, Chung, et al. Radiology 2010.

3D DIR UTE
Contrast for calcified cartilage



Bae, Du, Bydder, Chung. TMRI 2010.

UTE T1 rho
Patellar cartilage

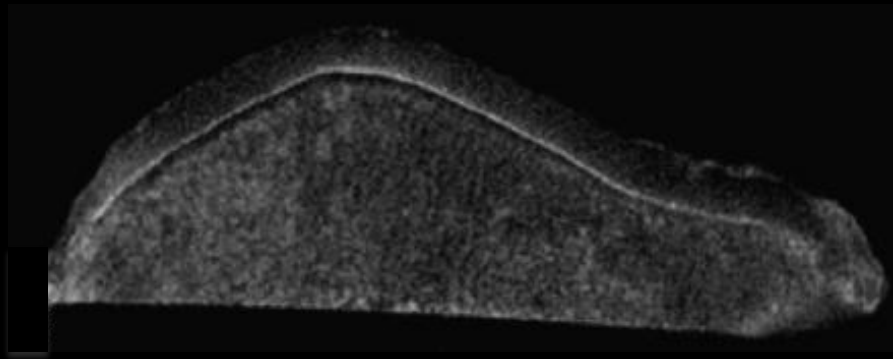


Buck, Chung et al. AJR 2011

UTE Clinical Applications

Articular Cartilage

Patella



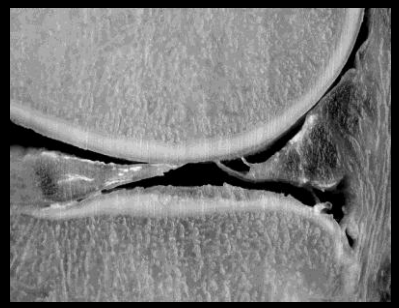
Fibrocartilage

Intervertebral disc

Temporomandibular joint

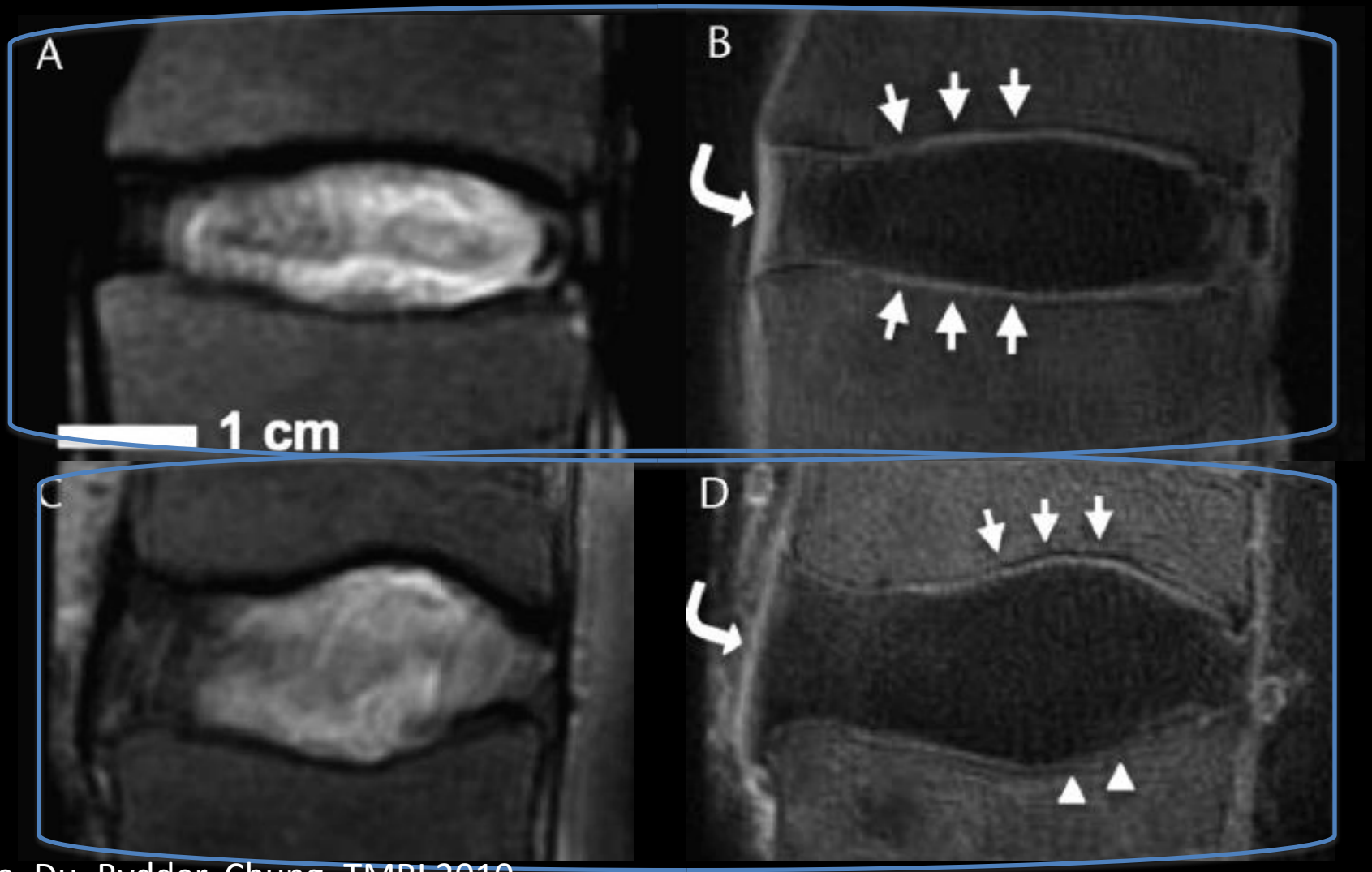
Triangular fibrocartilage complex

Meniscus



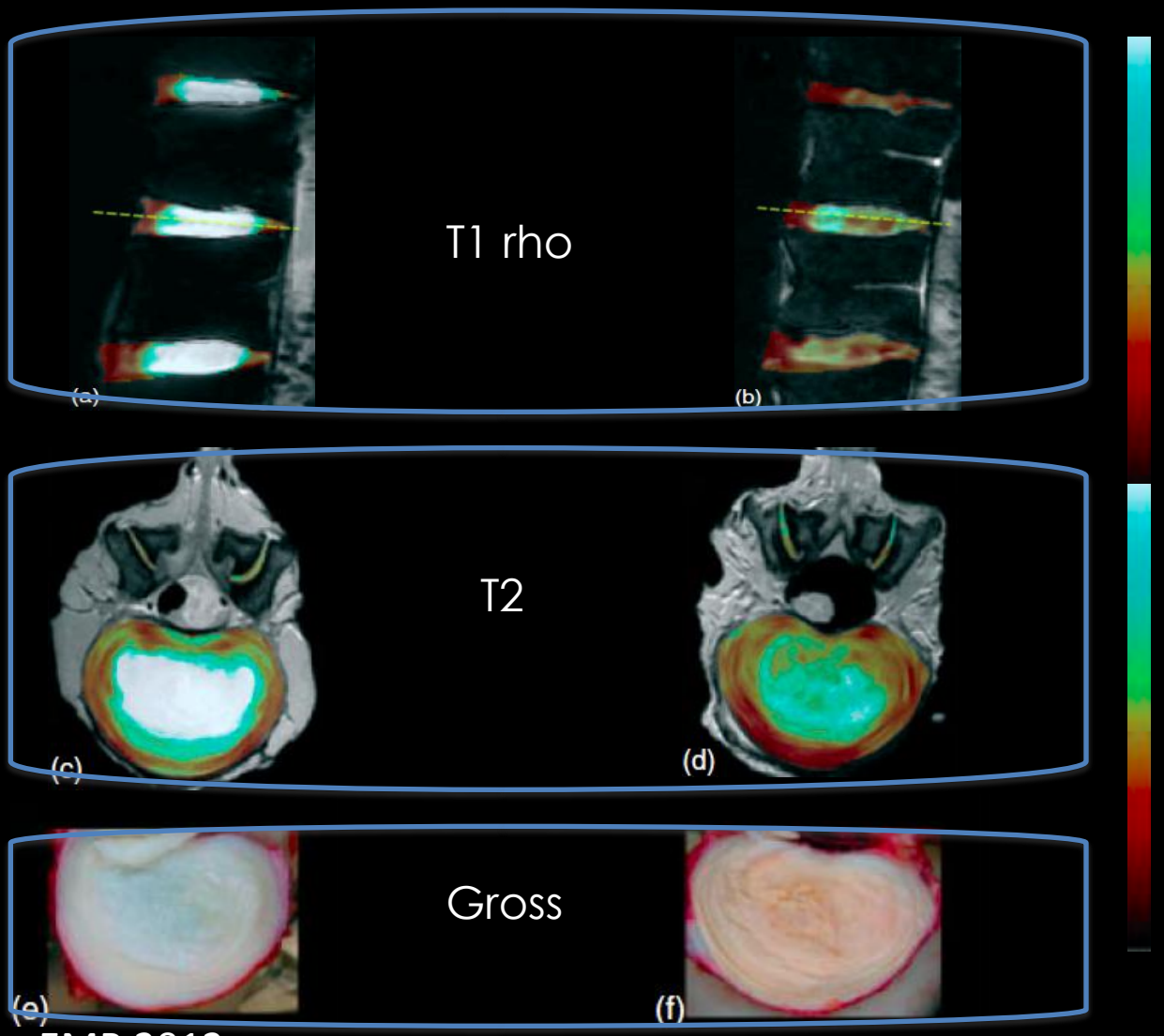
Bae, Du, Bydder, Chung. TMRI 2010.

UTE
Cartilaginous endplates



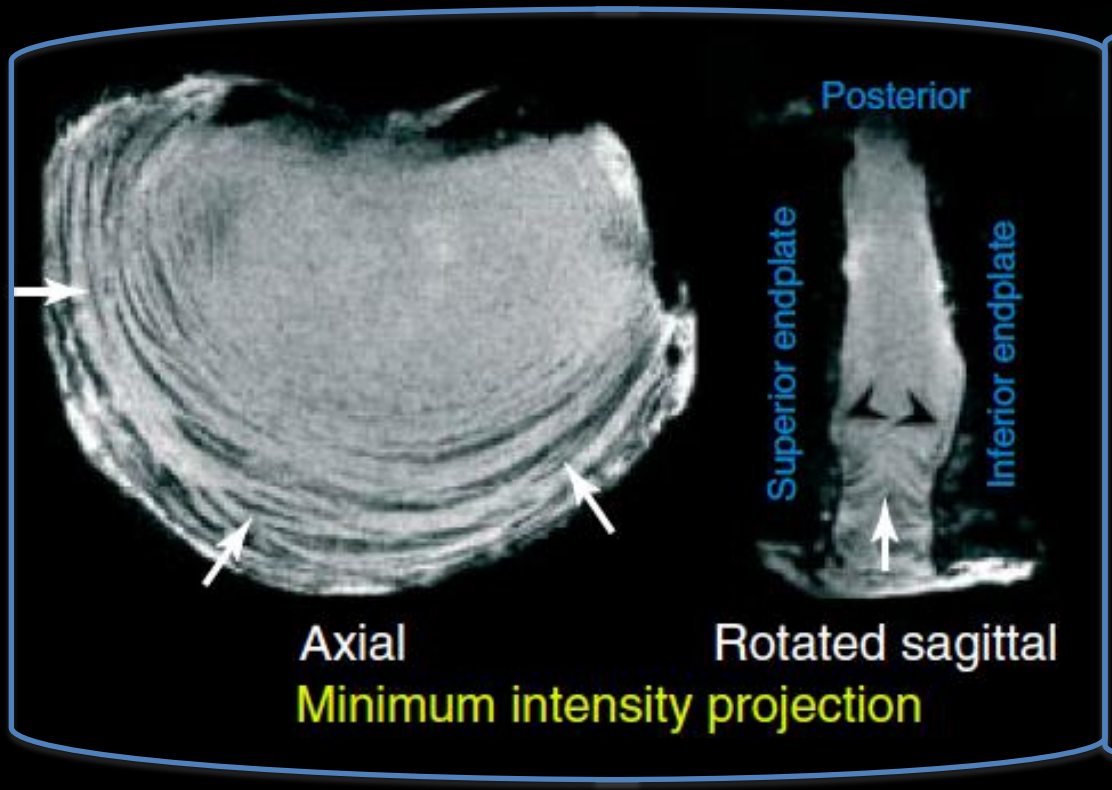
Bae, Du, Bydder, Chung. TMRI 2010.

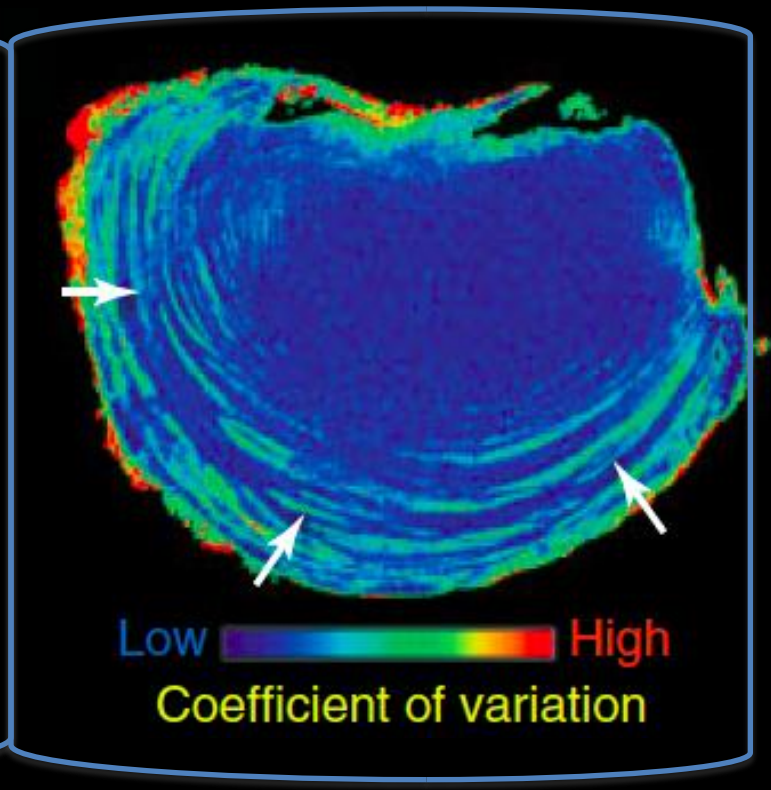
Lumbar disc
Normal vs. Degenerate



Bae, Chang, Chung. EMR 2012.

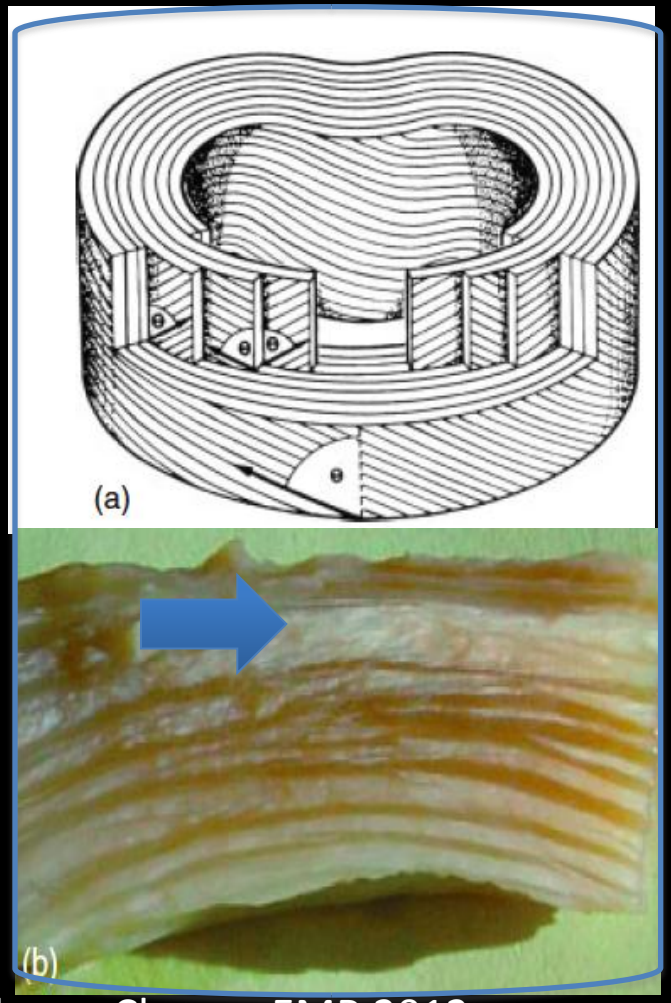
Short TE
Annulus fibrosus

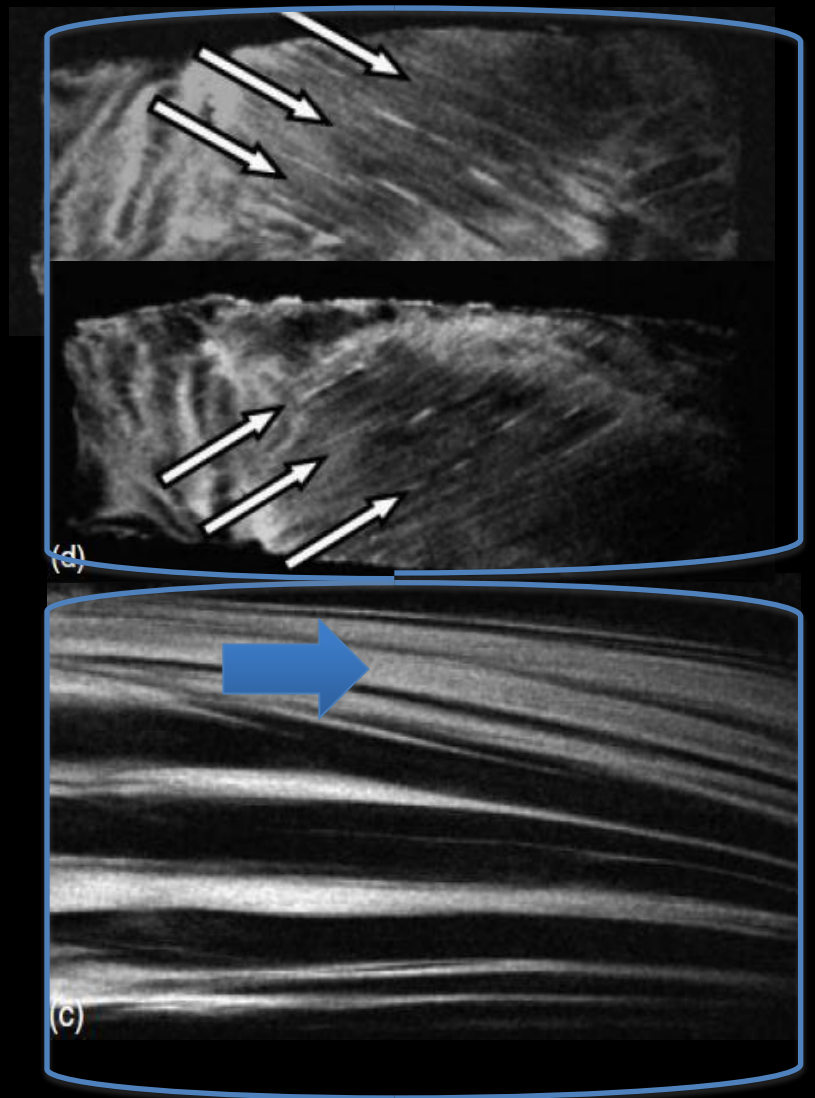




Bae, Chang, Chung. EMR 2012.

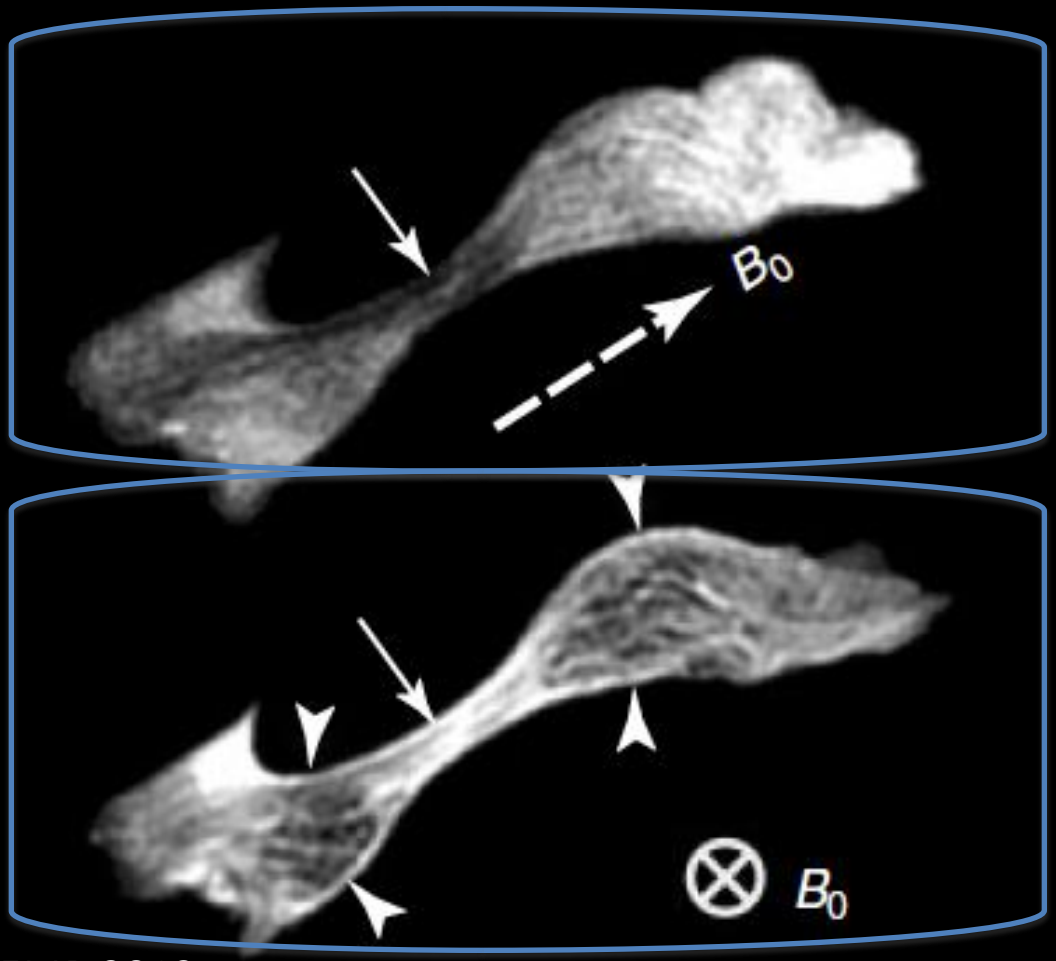
Short TE
Annulus fibrosus





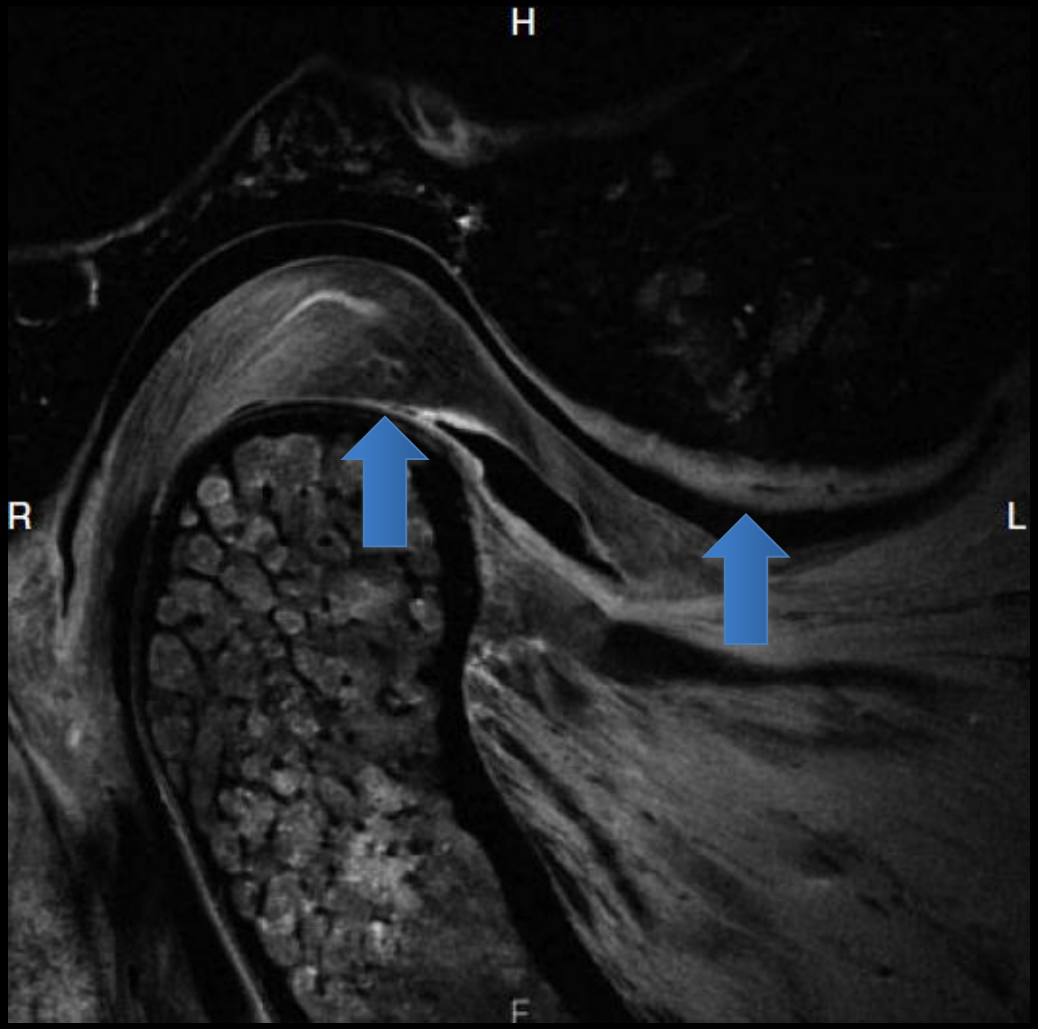
Bae, Chang, Chung. EMR 2012.

UTE and magic angle effect
Temporomandibular joint disc



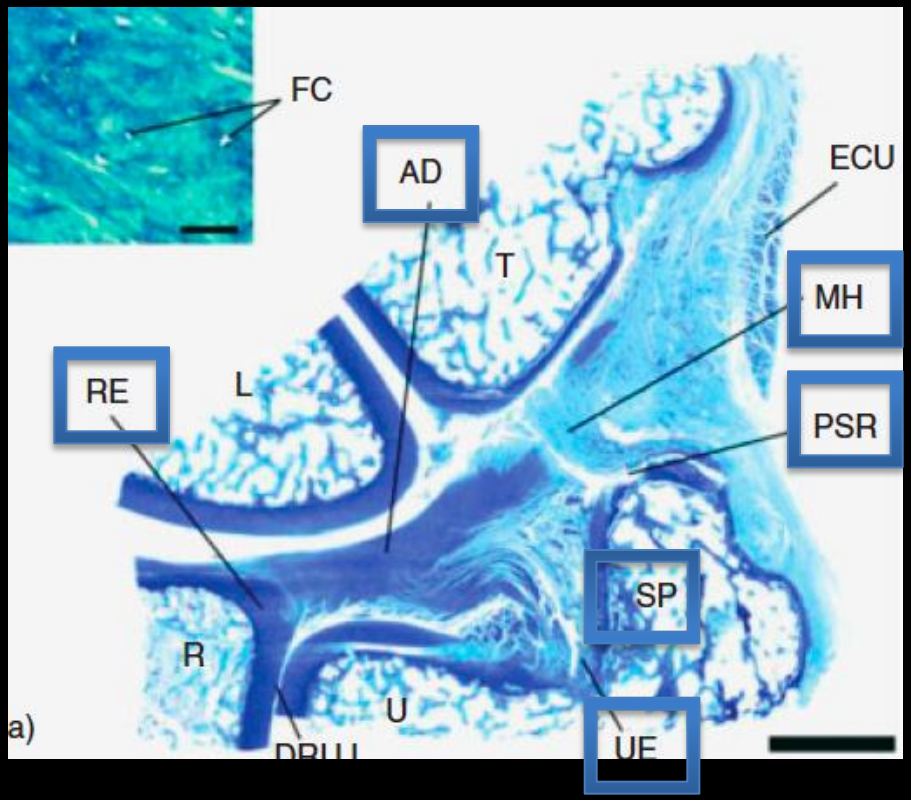
Bae, Chang, Chung. EMR 2012.

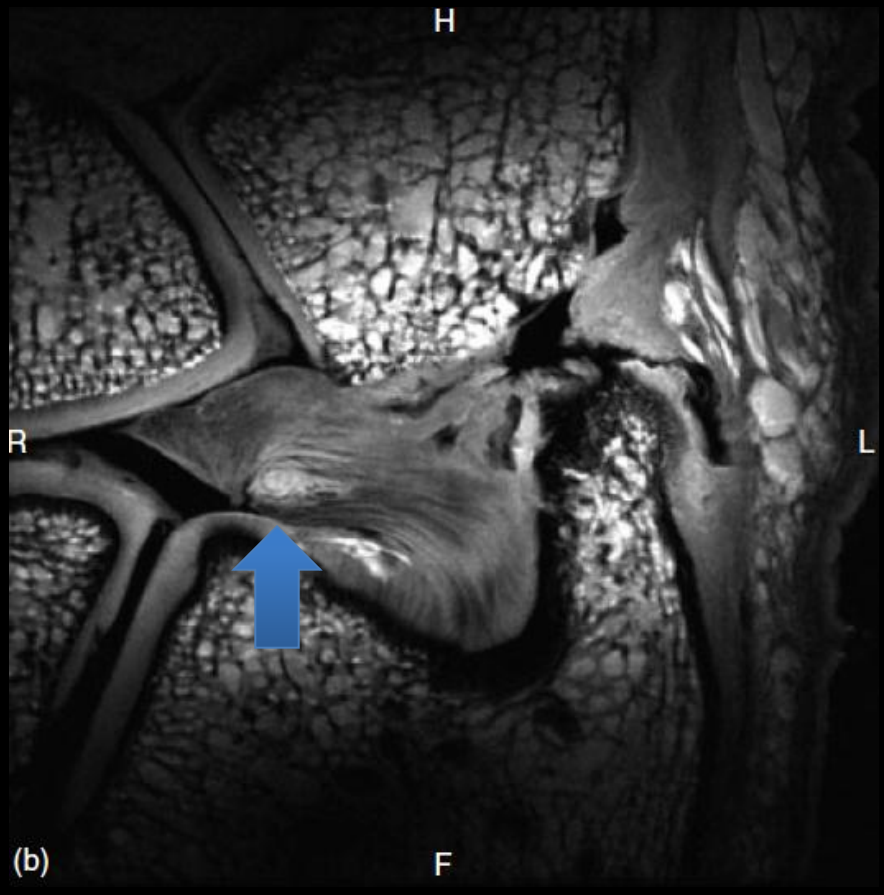
Temporomandibular joint



Bae, Chang, Chung. EMR 2012.

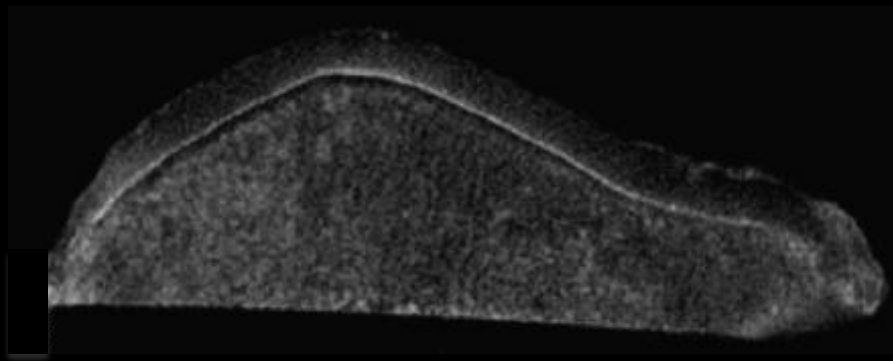
Short TE
Triangular fibrocartilage complex





Bae, Chang, Chung. EMR 2012.

UTE Clinical Applications



Articular Cartilage

- Patella

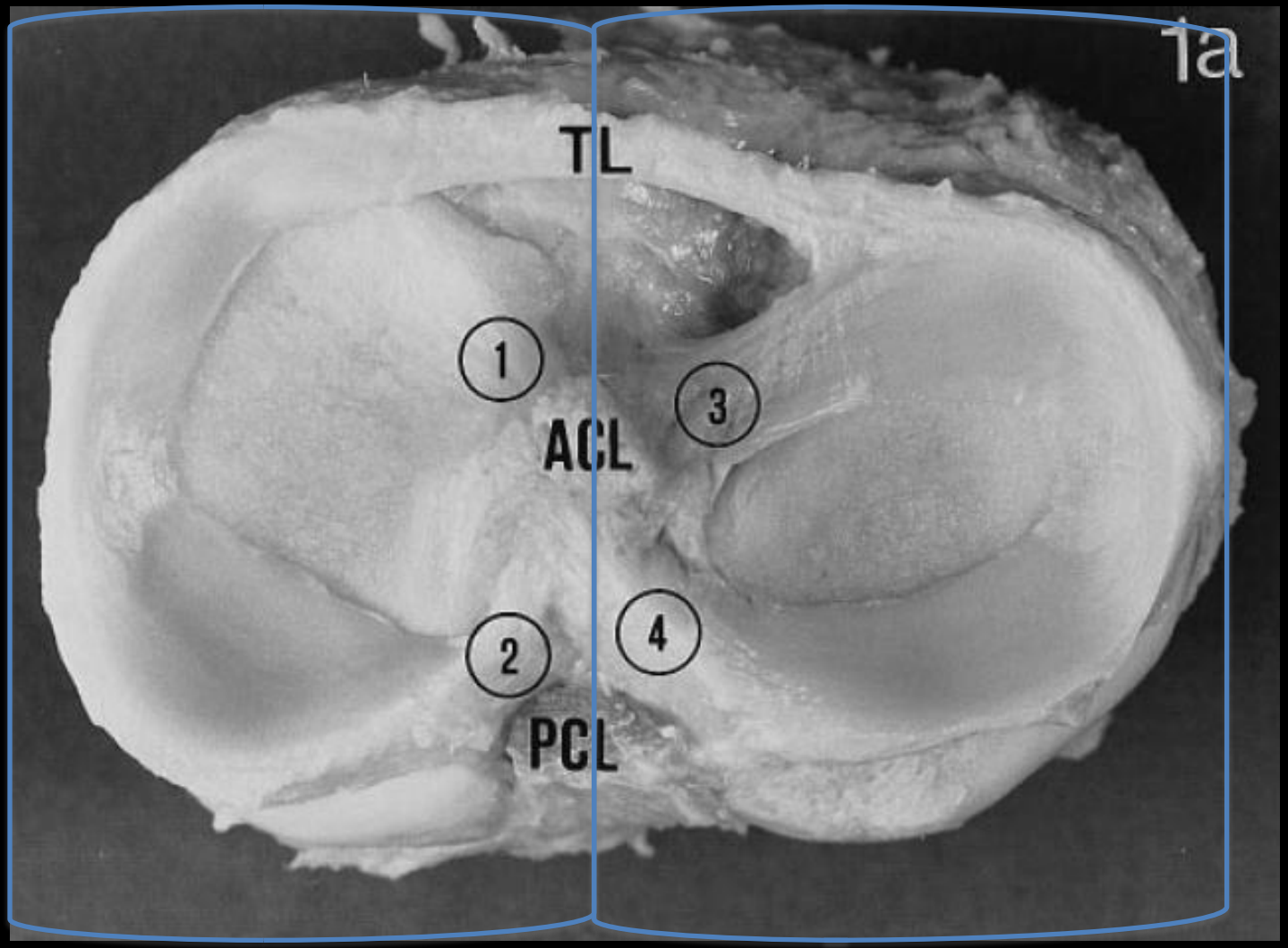
Fibrocartilage

- Intervertebral disc
- Temporomandibular joint
- Triangular fibrocartilage complex

Bae, Du, Bydder, Chung. TMRI 2010.

II. Meniscus

Menisci

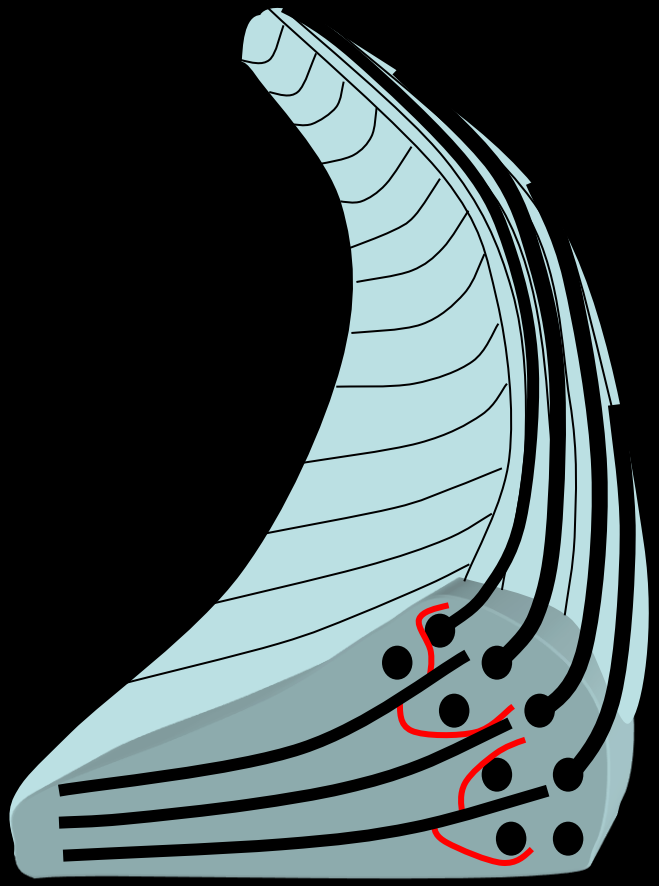


Medial

Lateral

Messner, Gao. J Anat. 1998

Meniscal structure



Fibrocartilage

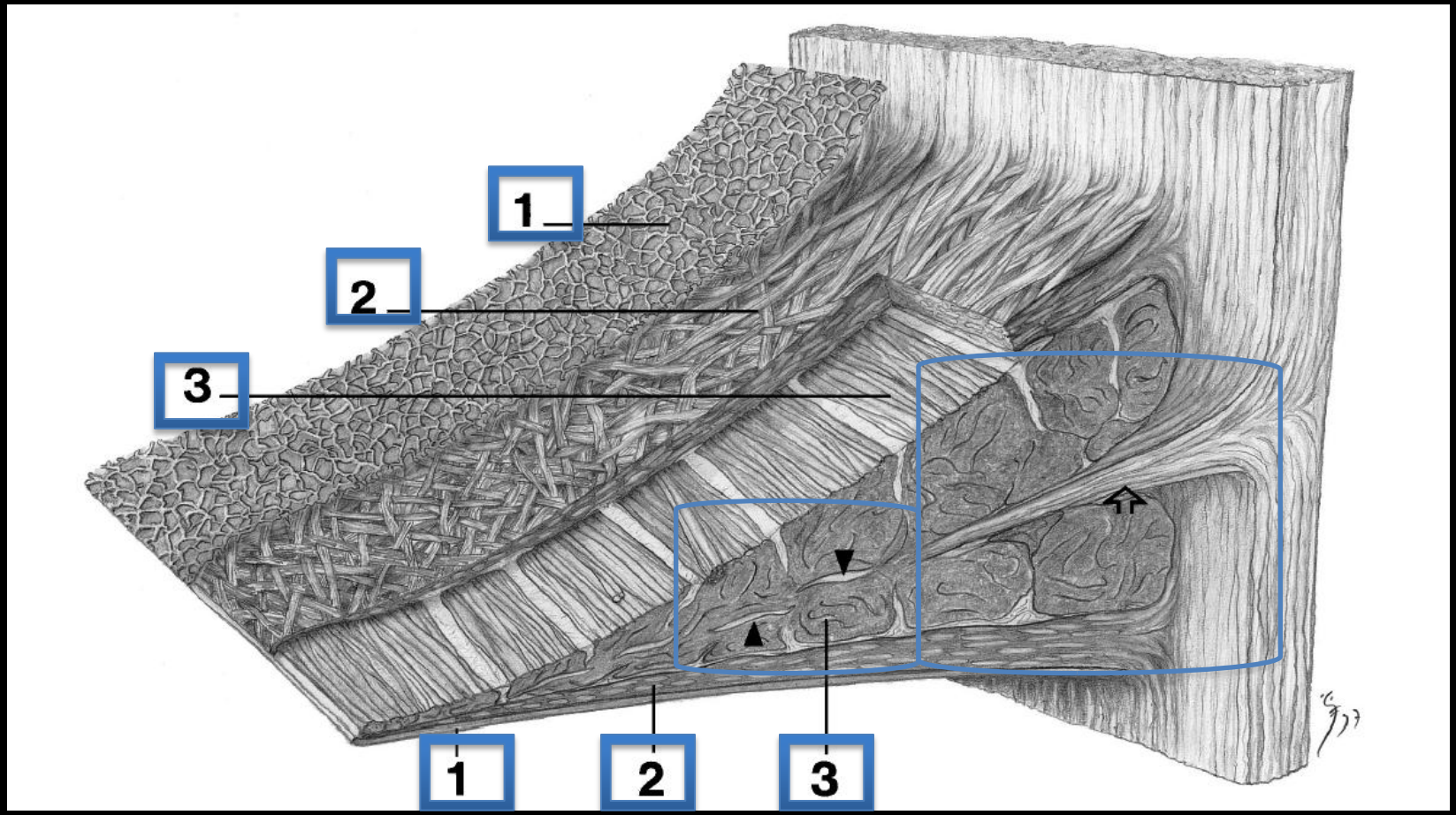
- Water ~75 %
- Collagen fibers ~20 %
  - Type I: ~90%
  - Type II: Inner portion
- Proteoglycans
  - Inner portion
- Elastin
- Cells

Collagen fiber pattern

- Circumferential
  - Majority of fibers
- Radial
- Meshwork (Perforating-Random)

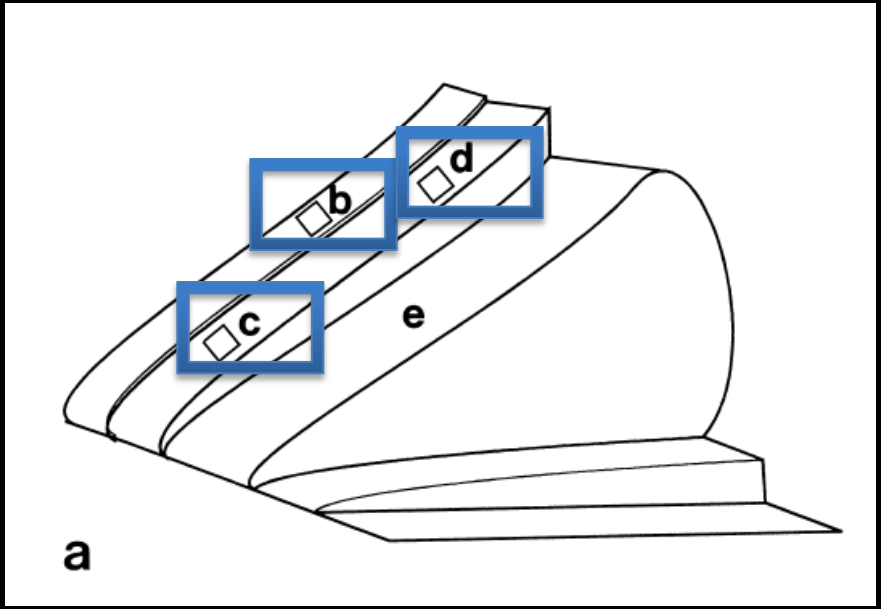
Chung, et al 2013.

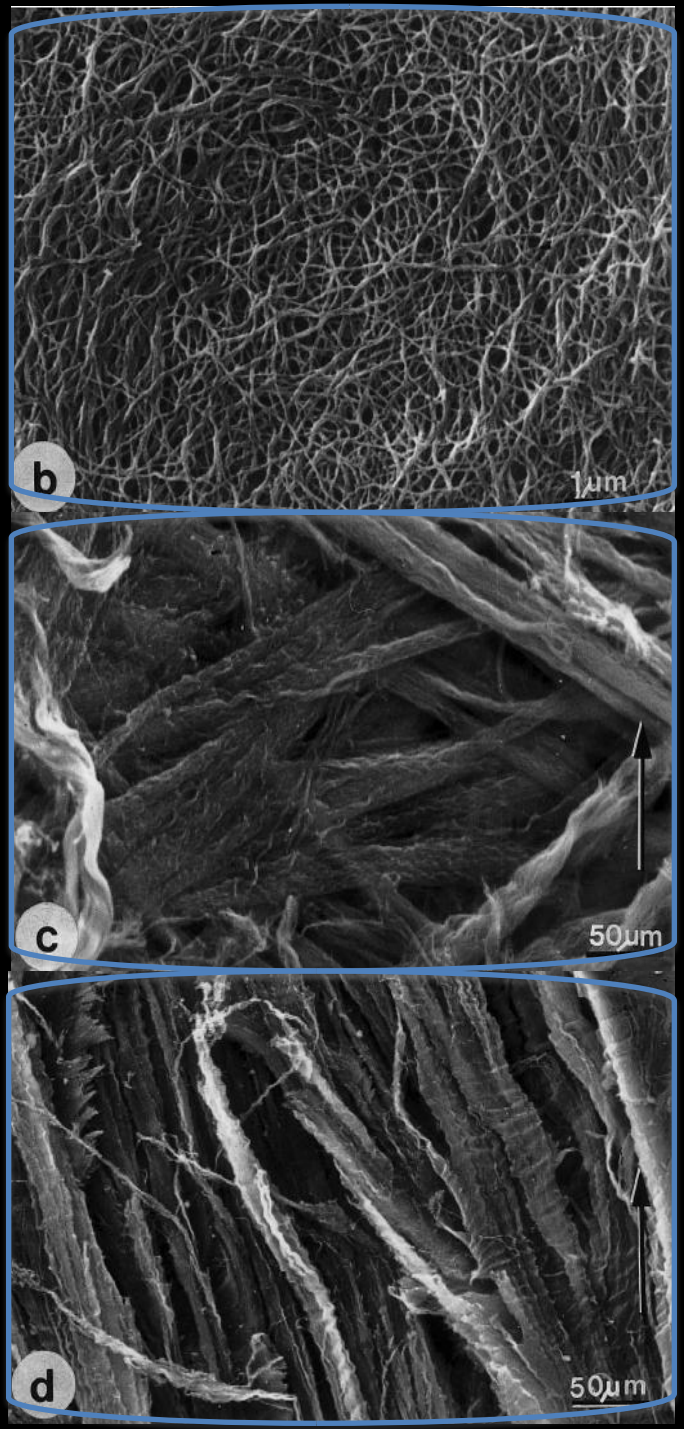
Electron microscopy
Meniscus cross section



Petersen, Tillman. Anat Embryol 1998

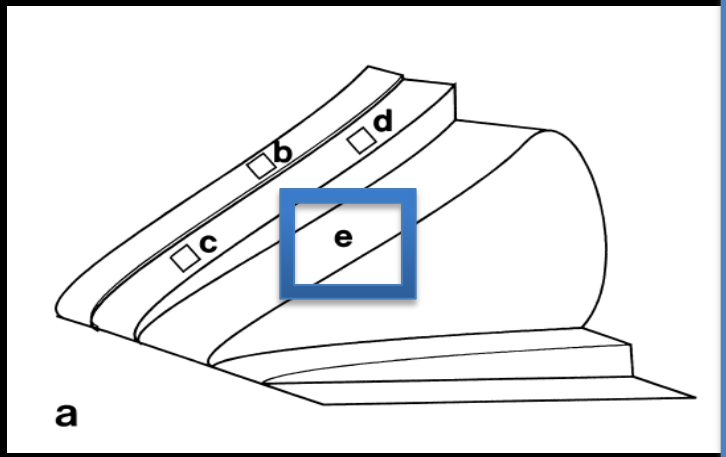
Electron microscopy
Posterior horn of medial meniscus

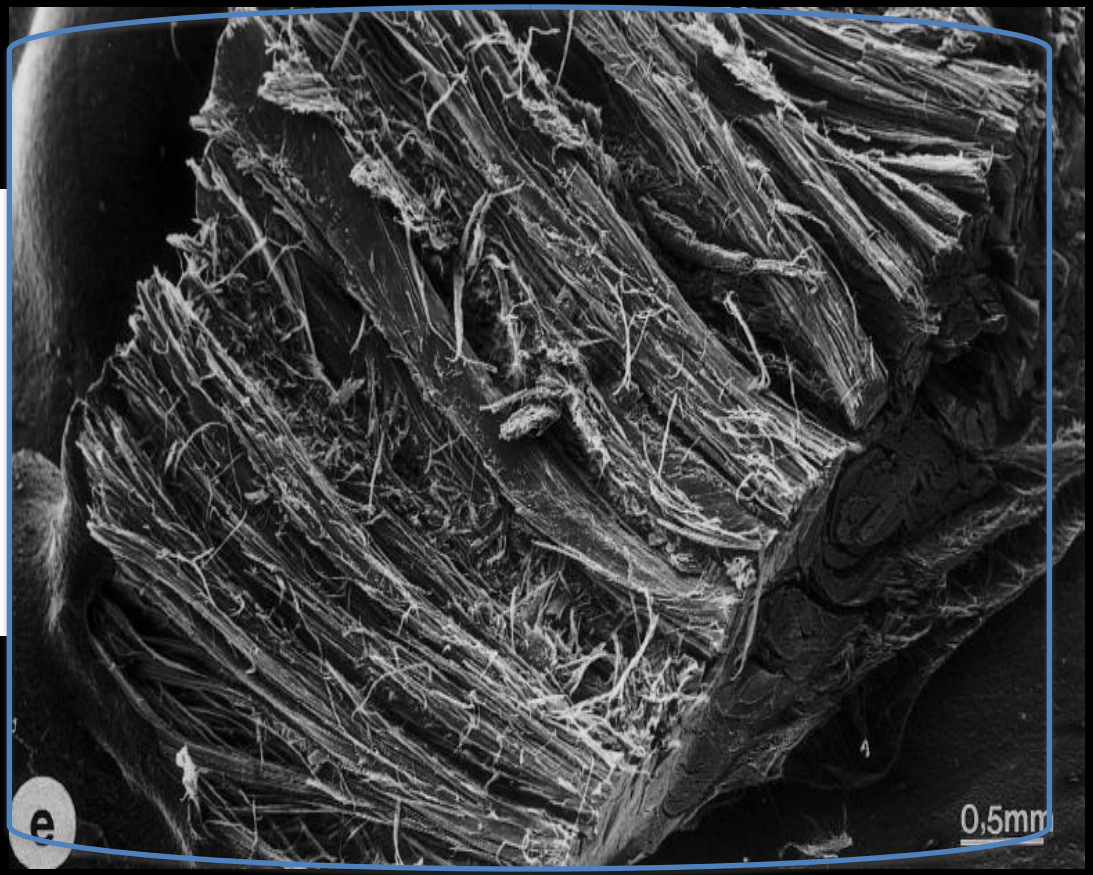




Petersen, Tillman. Anat Embryol 1998

Electron microscopy
Posterior horn of medial meniscus





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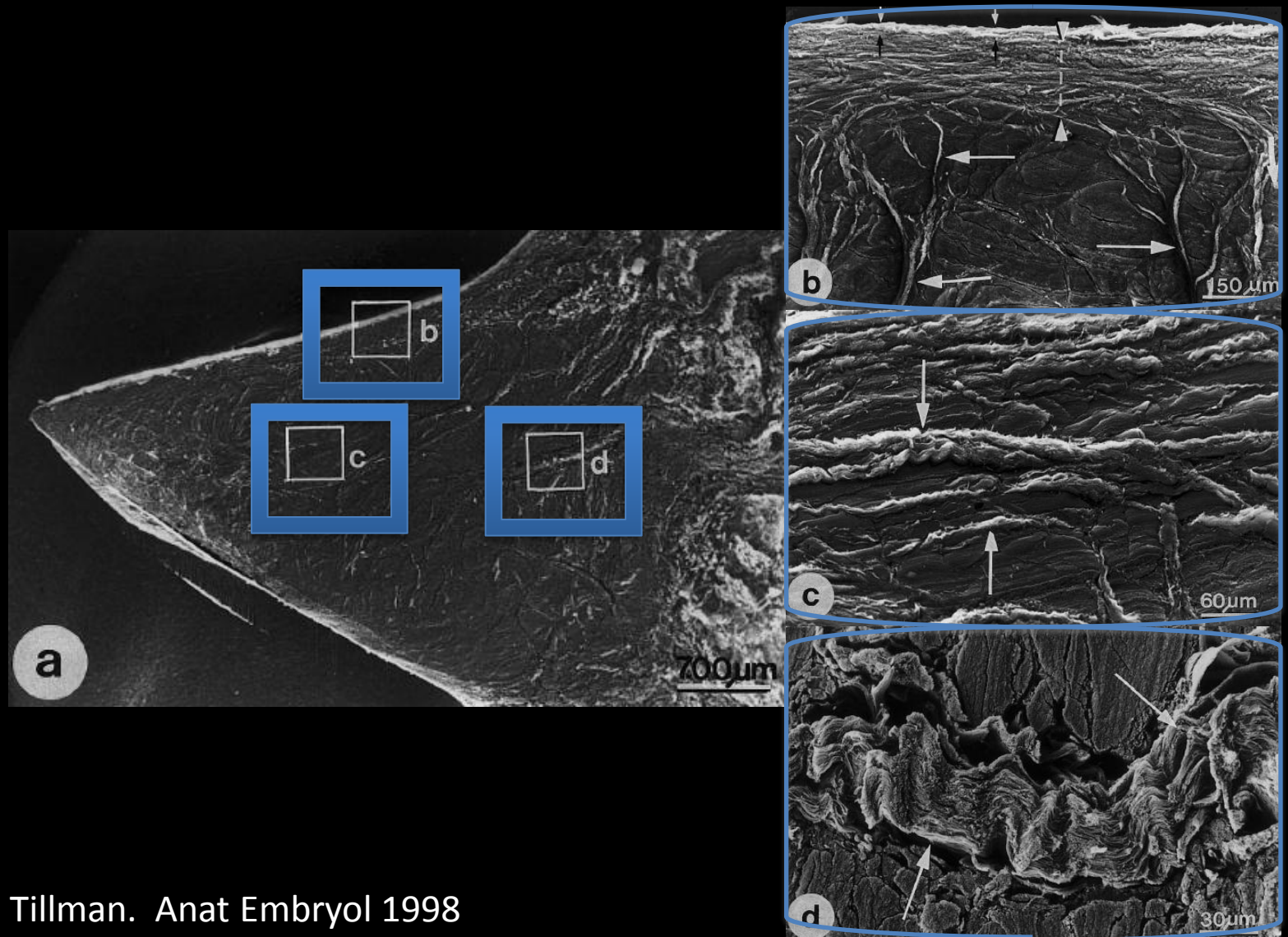
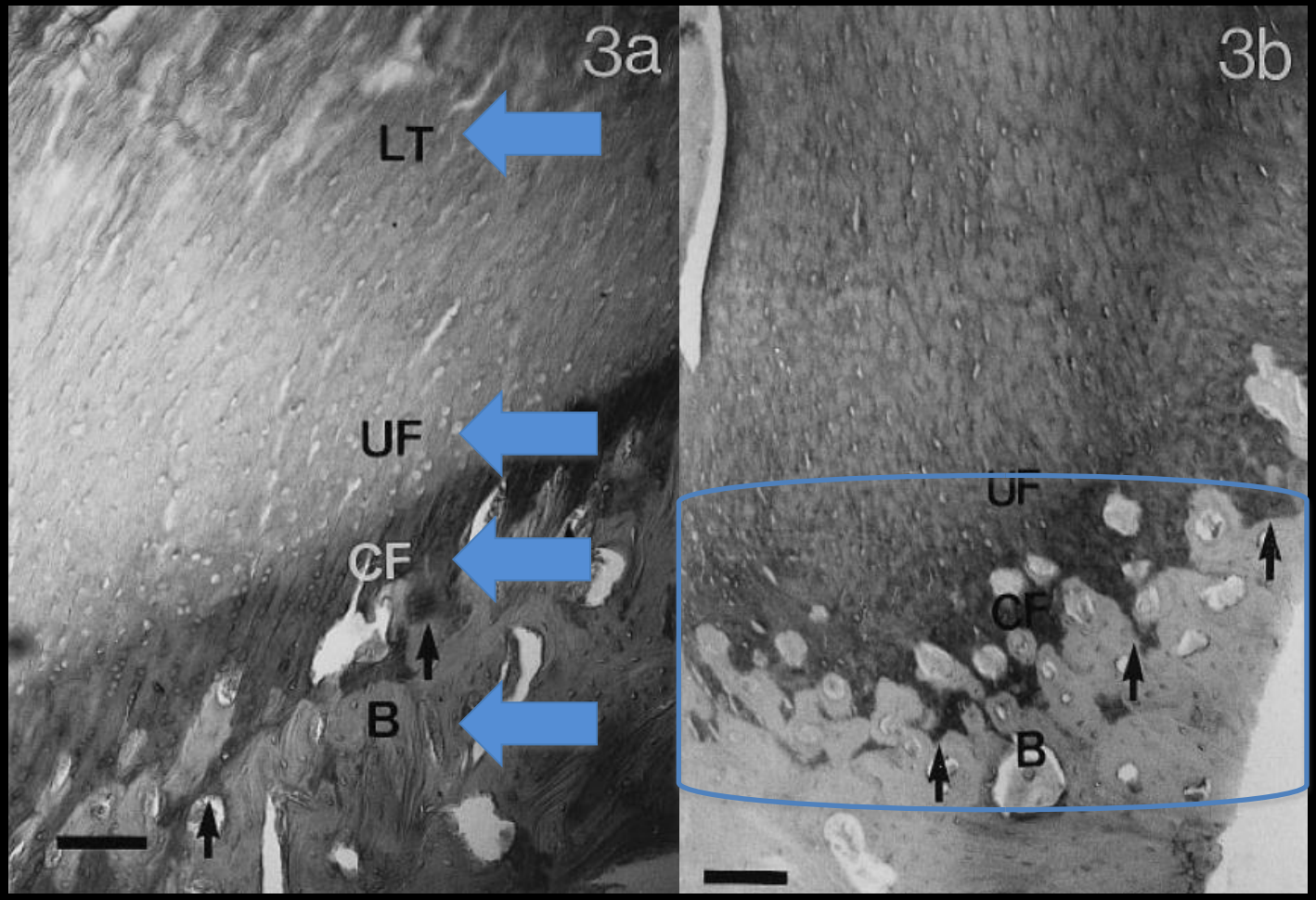


Petersen, Tillman. Anat Embryol 1998

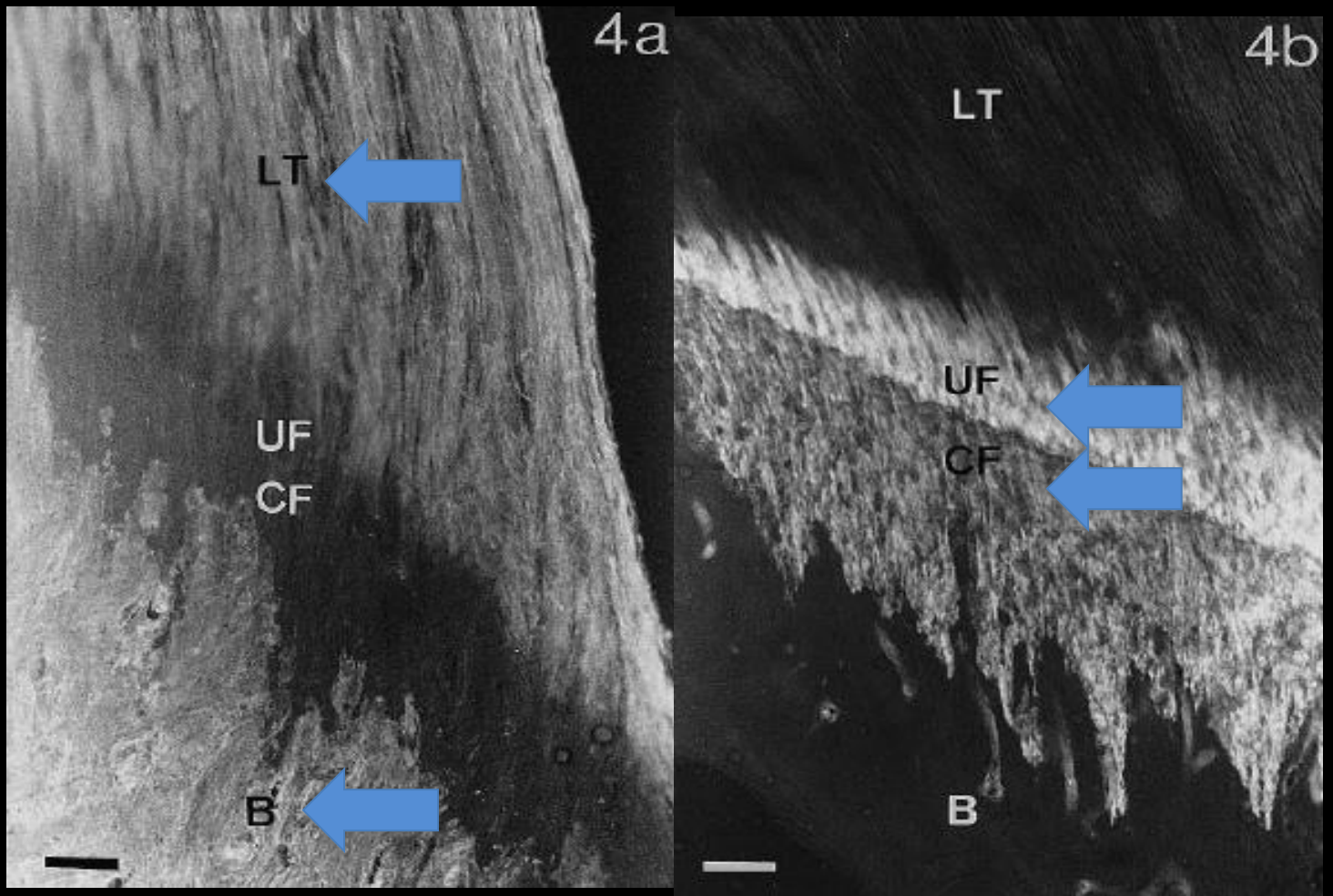
Medial meniscus enthesis

Tissue types



Messner, Gao. J Anat. 1998

Medial meniscus enthesis
Type 1 vs Type 2 collagen



Messner, Gao. J Anat. 1998

UTE Clinical Application

Novel MRI techniques can be utilized to quantify microstructural changes.

- UTE T2*
- UTE T1 rho

Early detection and quantify response to treatment

Case presentation

Clinical history

24 year old male with knee pain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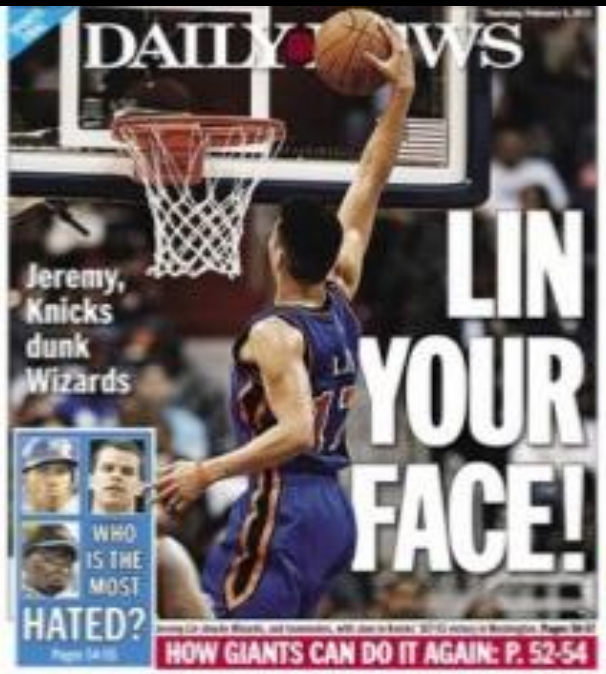
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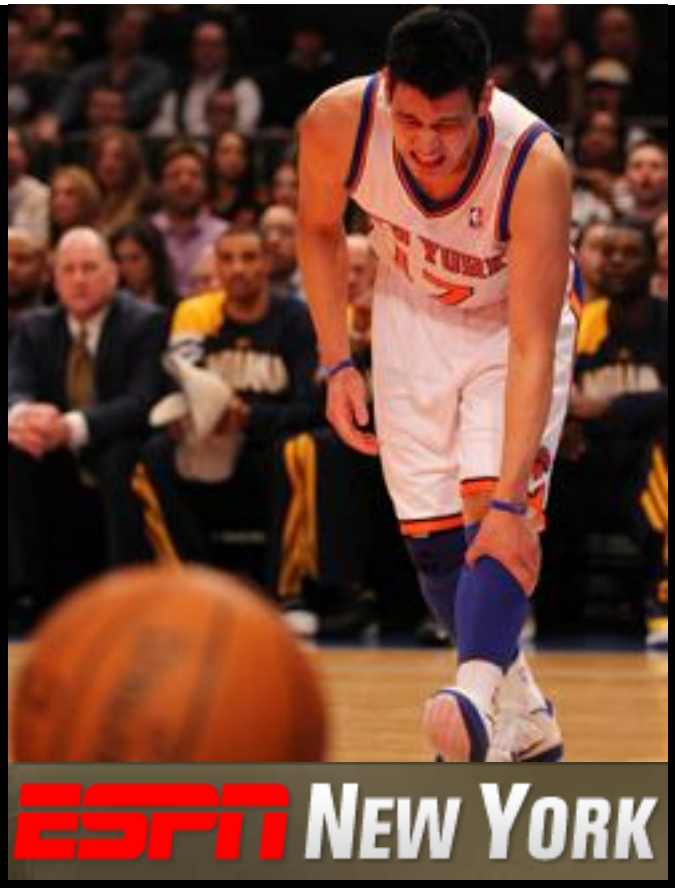
Updated: April 1, 2012, 2:46 PM ET

NEW YORK -- Jeremy Lin will have left knee surgery next week and will miss six weeks, likely ending his amazing breakthrough season.



Knicks Blog

Knicks' Lin won't play with knee at '85 percent'

By MARC BERMAN

Posted: 11:44 AM, May 9, 2012

ESPN NEW YORK

COMMENTARY

Knicks must let Jeremy Lin go

Nothing personal -- he's just not worth the money. Let the sanity begin!

By **Stephen A. Smith** | ESPNNewYork.com **Updated:** July 17, 2012, 12:16 PM ET

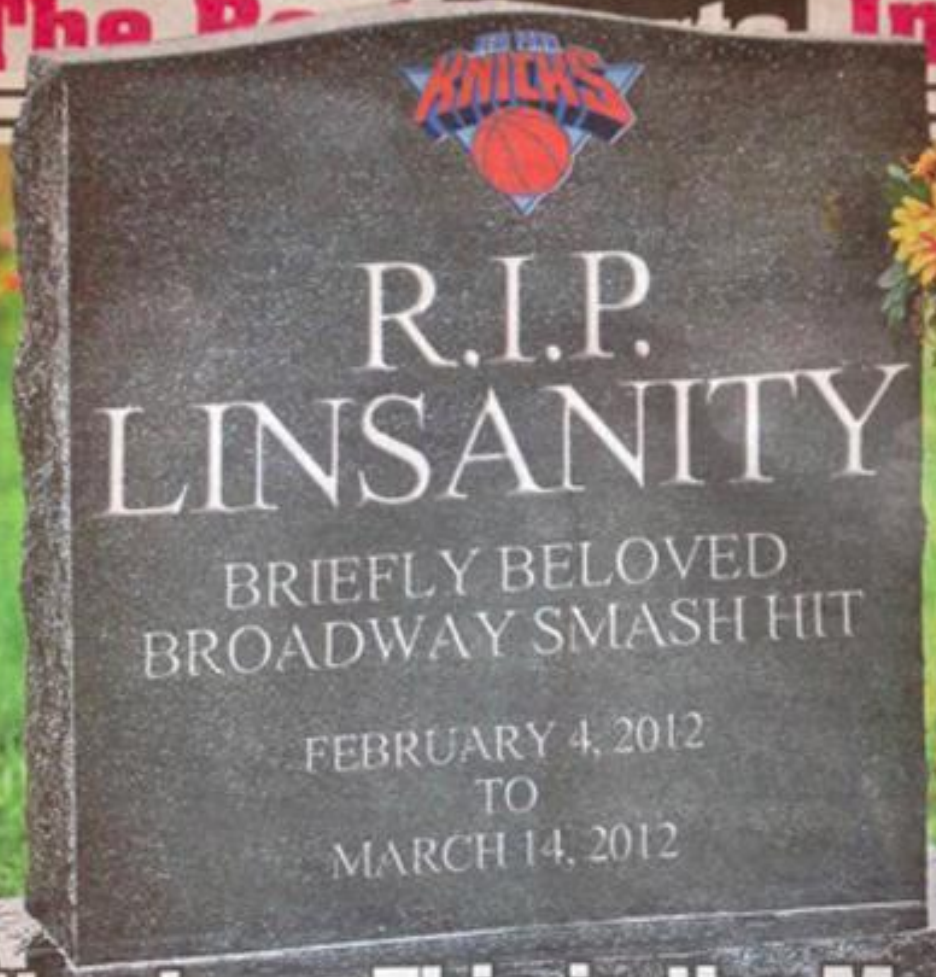
Jeremy Lin has been all about the money since the day he burst onto Broadway.

Lin was about the Benjamins when Linsanity made the cover of Time magazine. He definitely was overcome by dollar signs when he wouldn't play at "85 percent" for the New York Knicks in the playoffs, and it was all about the bottom line once free agency arrived.

Quantitative MRI can quantify response to treatment

- Tear
- Degeneration
- Calcification

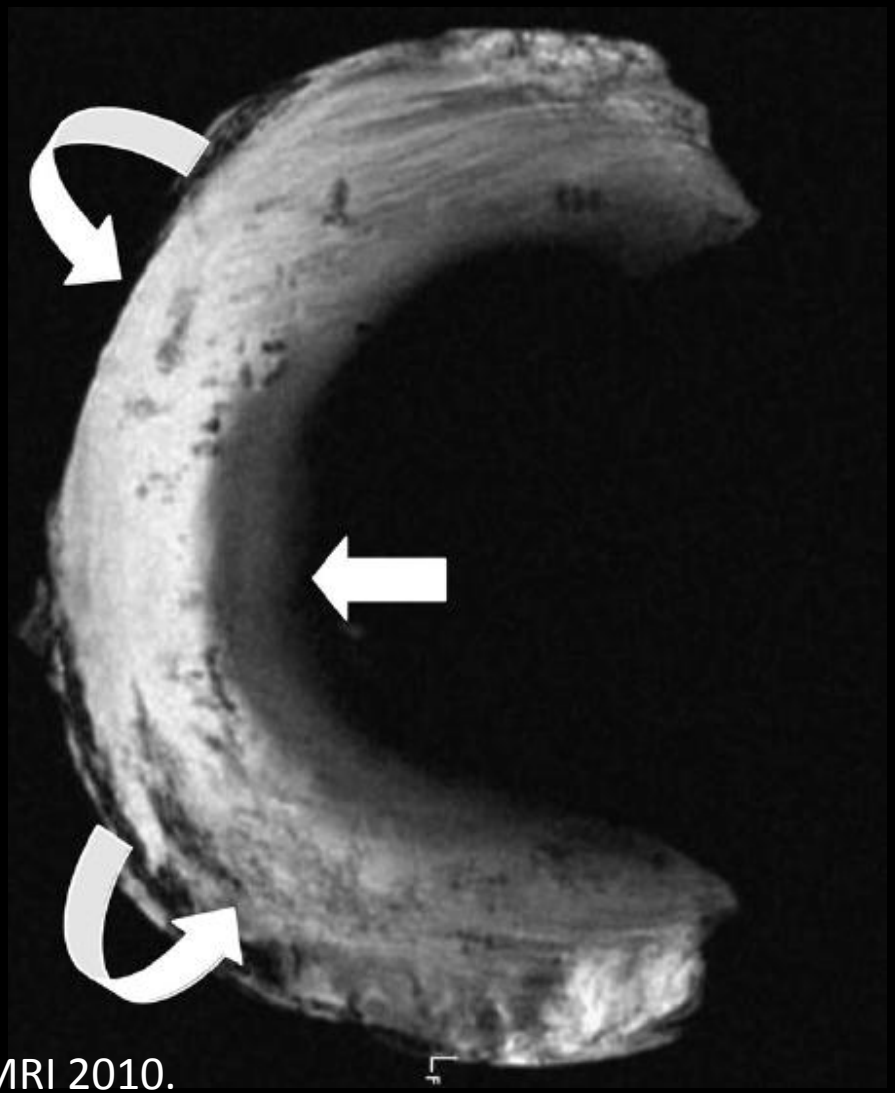
FRIDAY, MARCH 16, 2012 NEW YORK POST



Woodson: This is the Melo and Amar'e show now

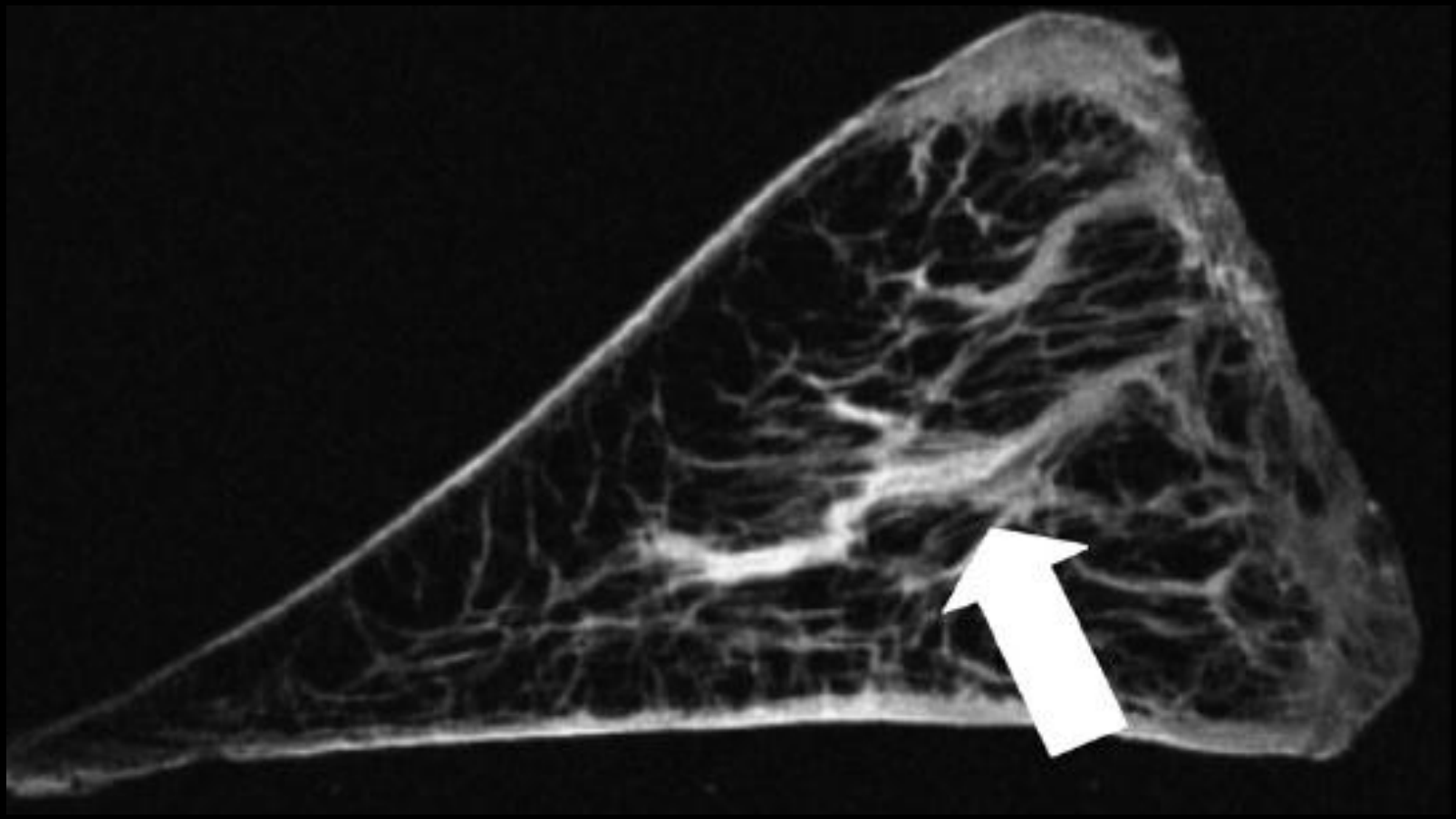
New Knicks coach Mike Woodson made it clear at practice yesterday that the Jeremy Lin era is history and that Carmelo Anthony and Amar'e Stoudemire will become the focus of the team's offense. BERMAN / PAGES 112-113

UTE
Meniscus



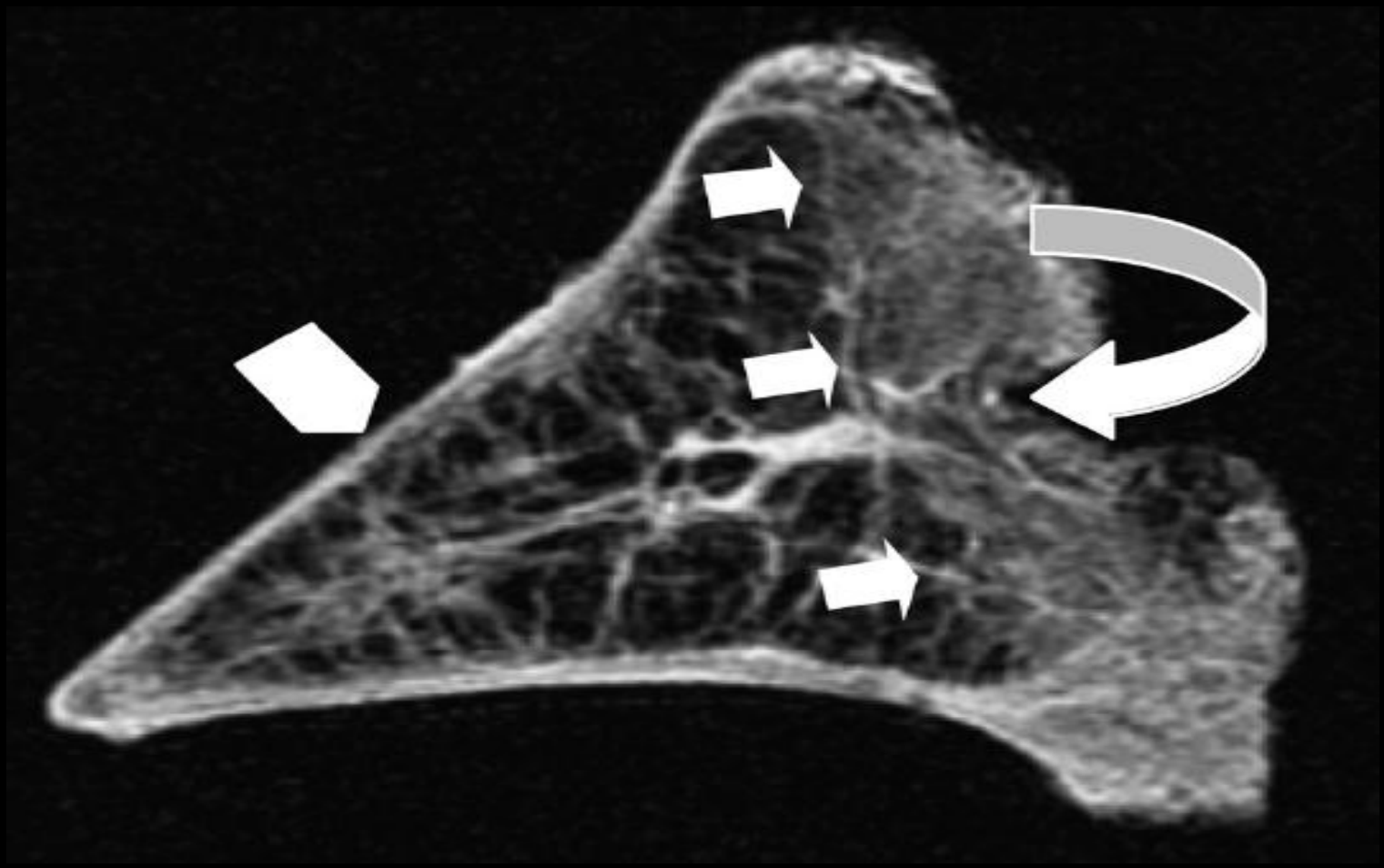
Bae, Du, Bydder, Chung. TMRI 2010.

Short TE
Meniscus



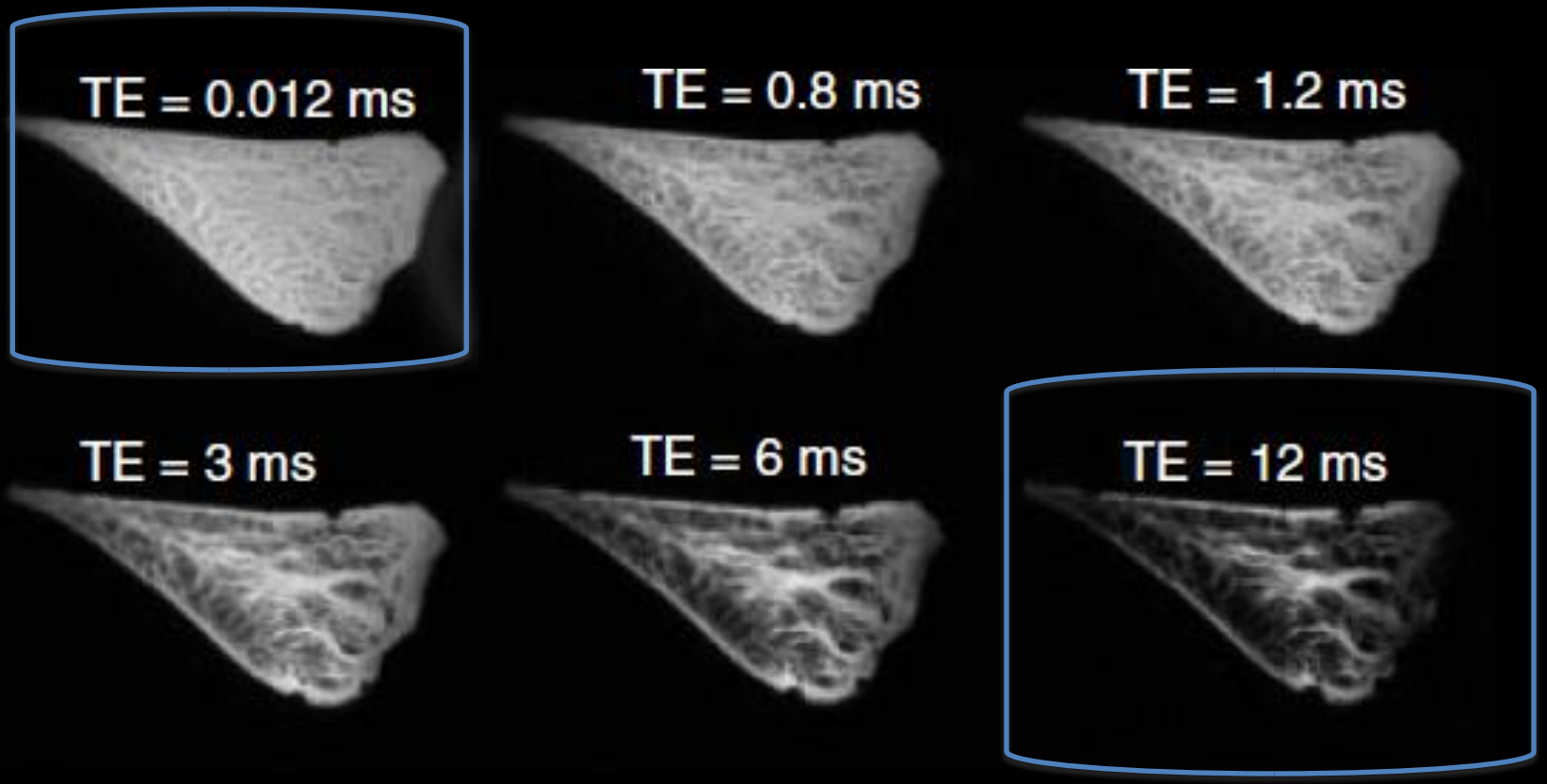
Bae, Du, Bydder, Chung. TMRI 2010.

Short TE
Meniscus



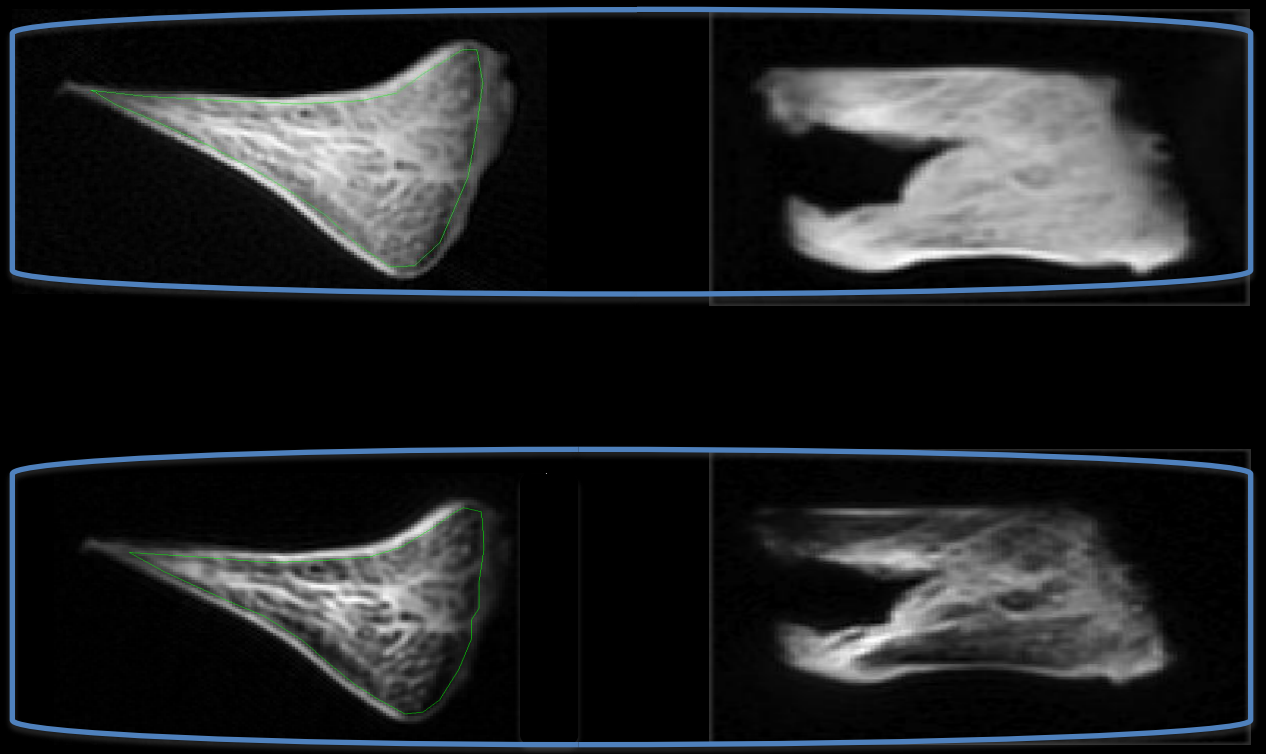
Bae, Du, Bydder, Chung. TMRI 2010.

Meniscus
TE times

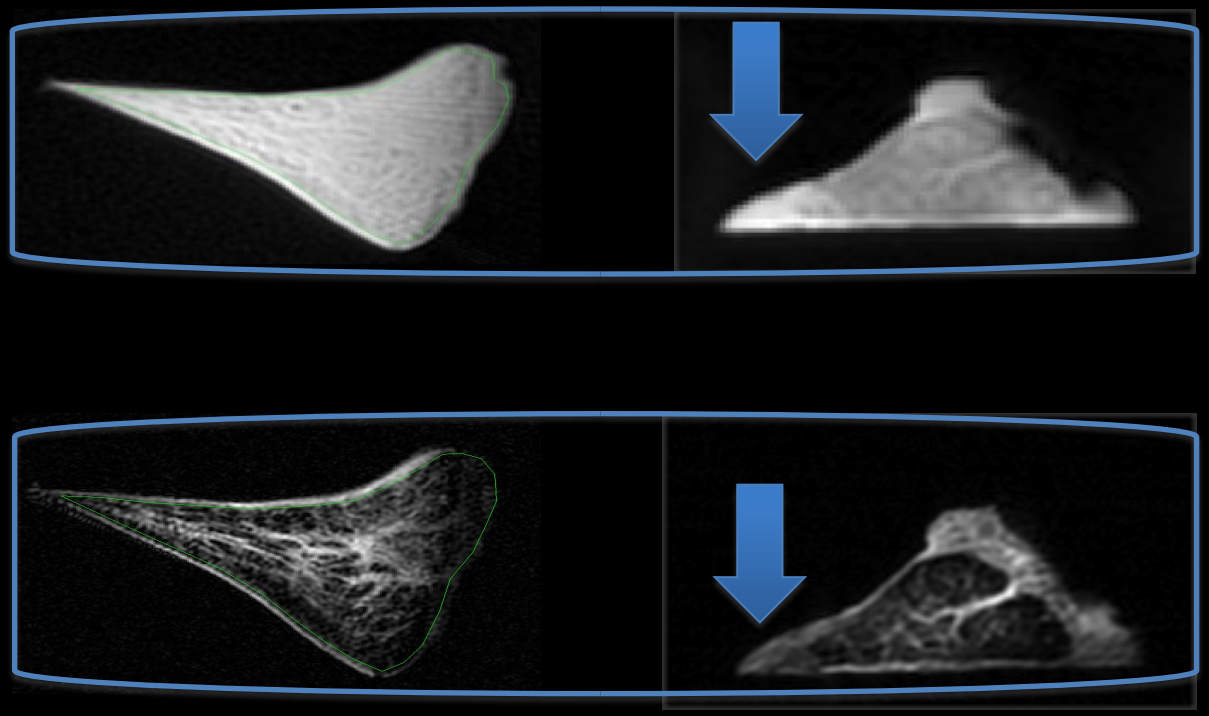


Bae, Chang, Chung. EMR 2012.

UTE T1 rho
Meniscal tear

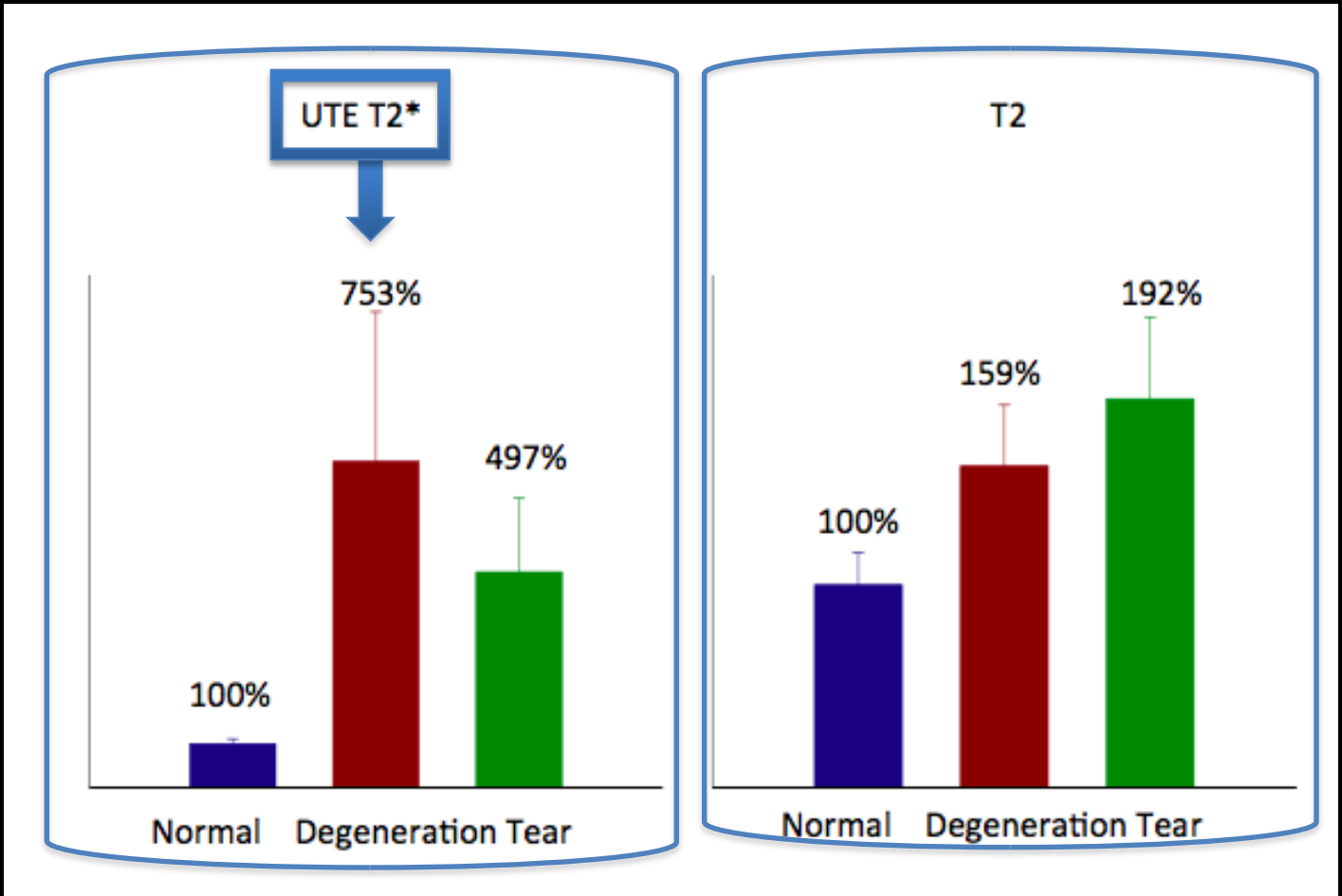


UTE T2*
Meniscal degeneration



UTE T2* vs T2

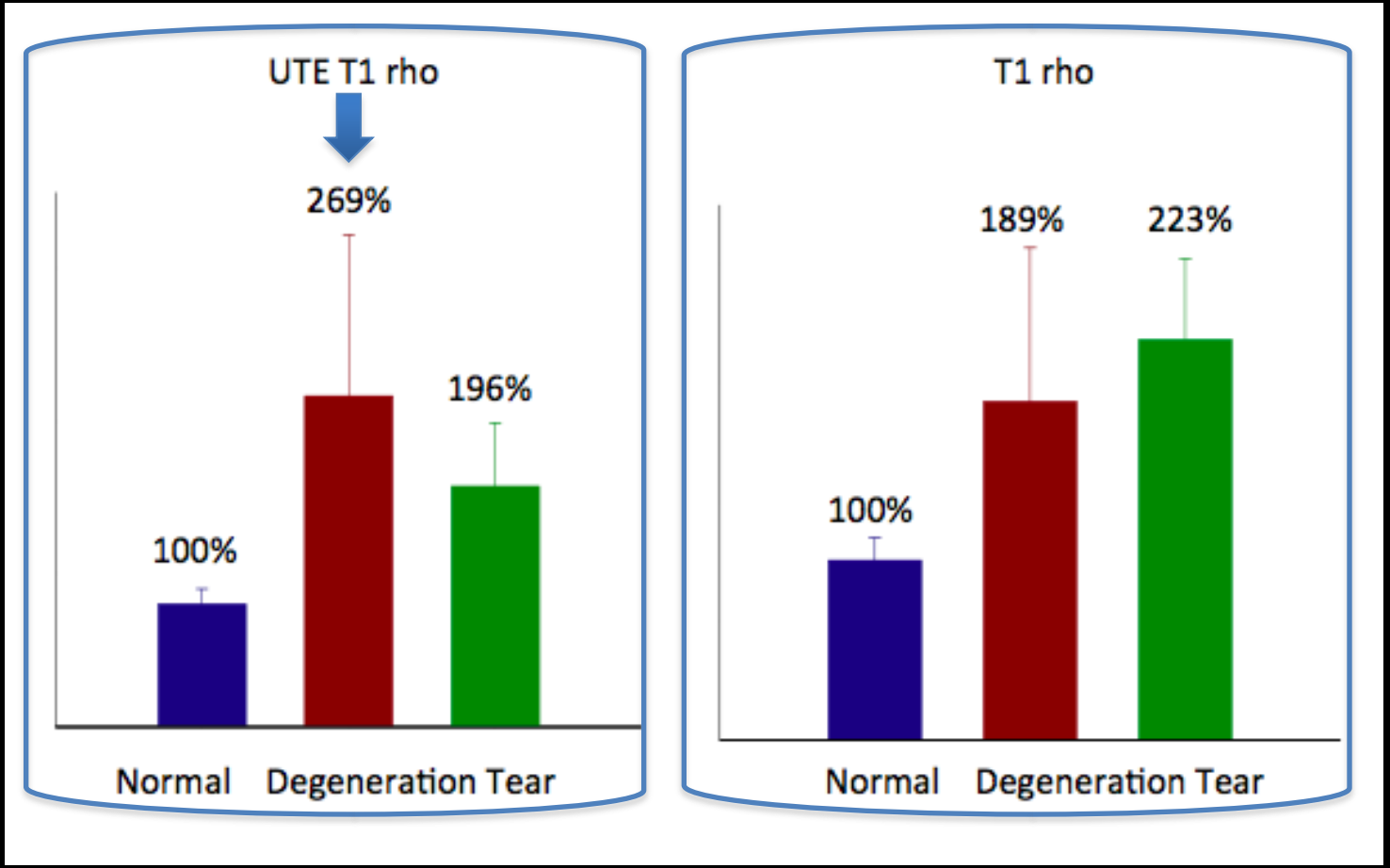
Normal vs degeneration vs tear



UTE T2* more sensitive in identification of pathology than T2 values (p=0.03)

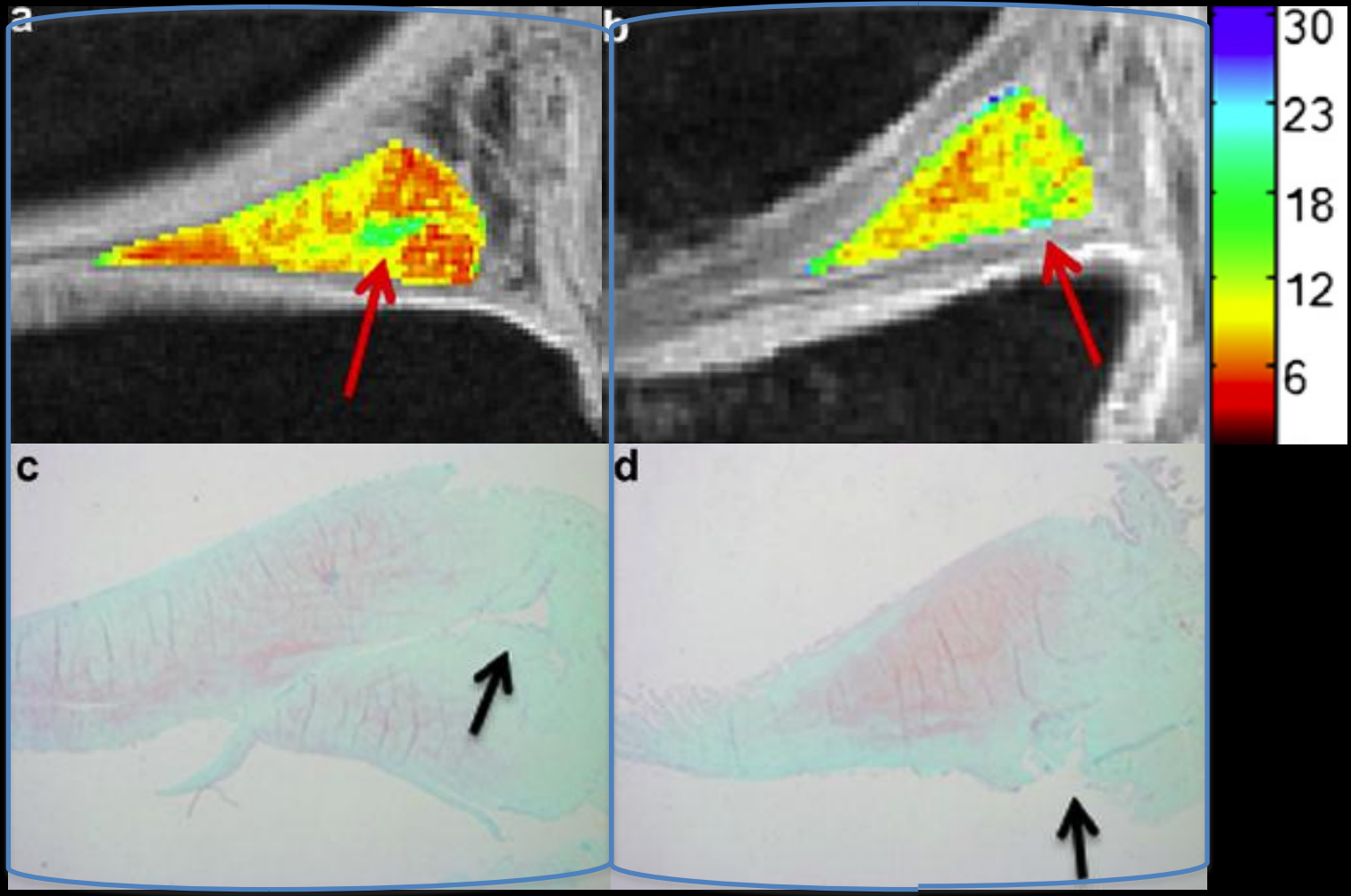
UTE T1 rho vs T1 rho

Normal vs degeneration vs tear



- No statistical significant difference between groups

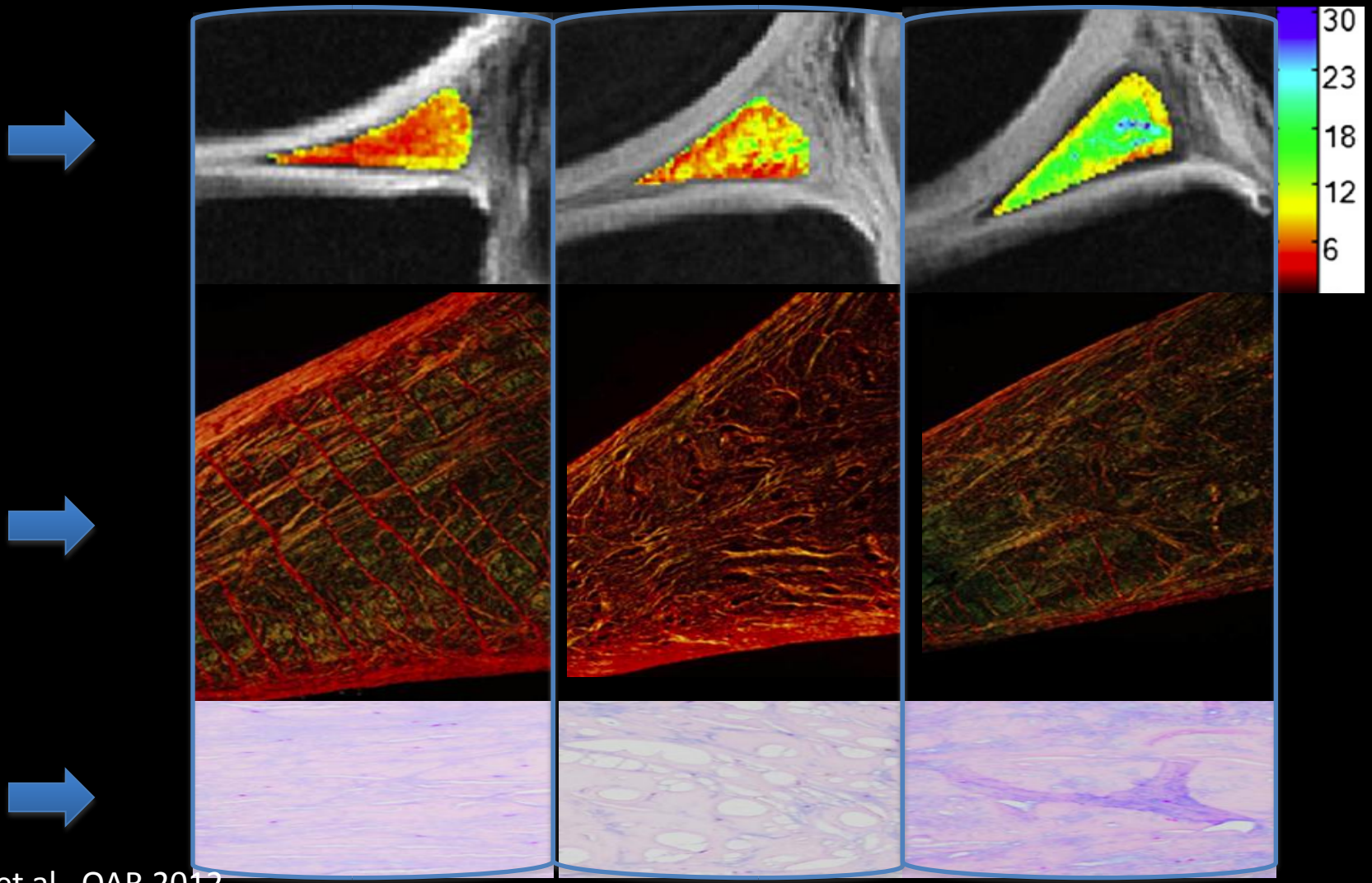
UTE T2*
Posterior horn medial meniscus



Chu, et al. OAR 2012.

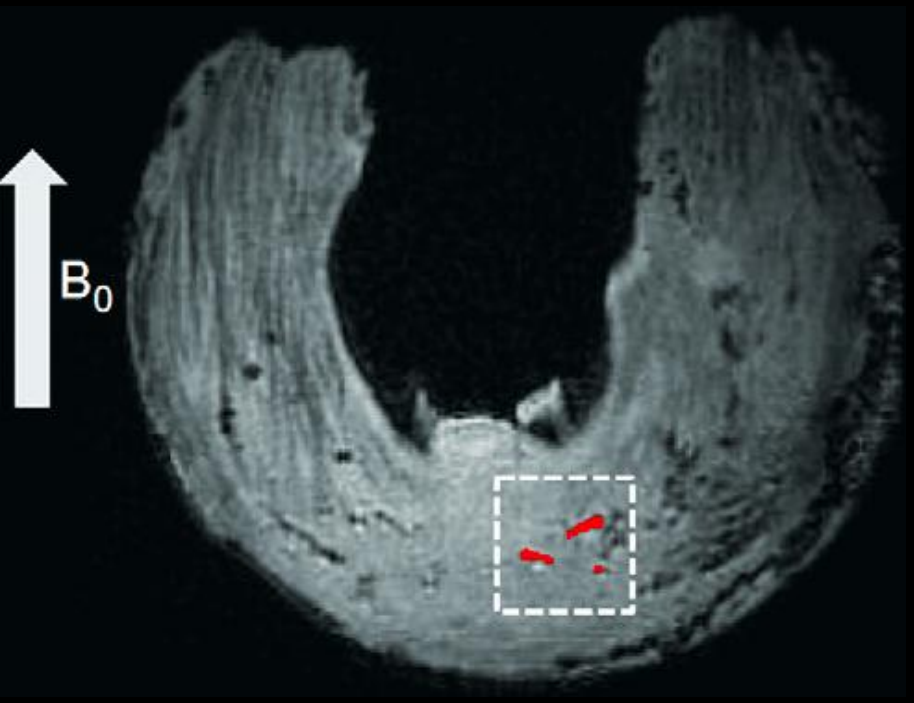
UTE T2*

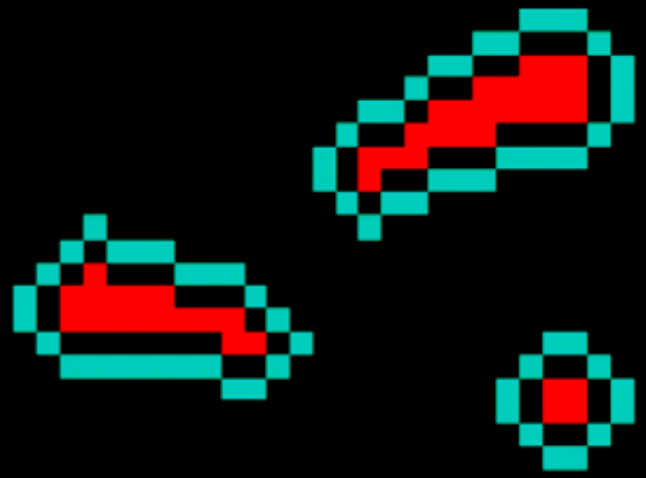
Posterior horn medial meniscus



Chu, et al. OAR 2012.

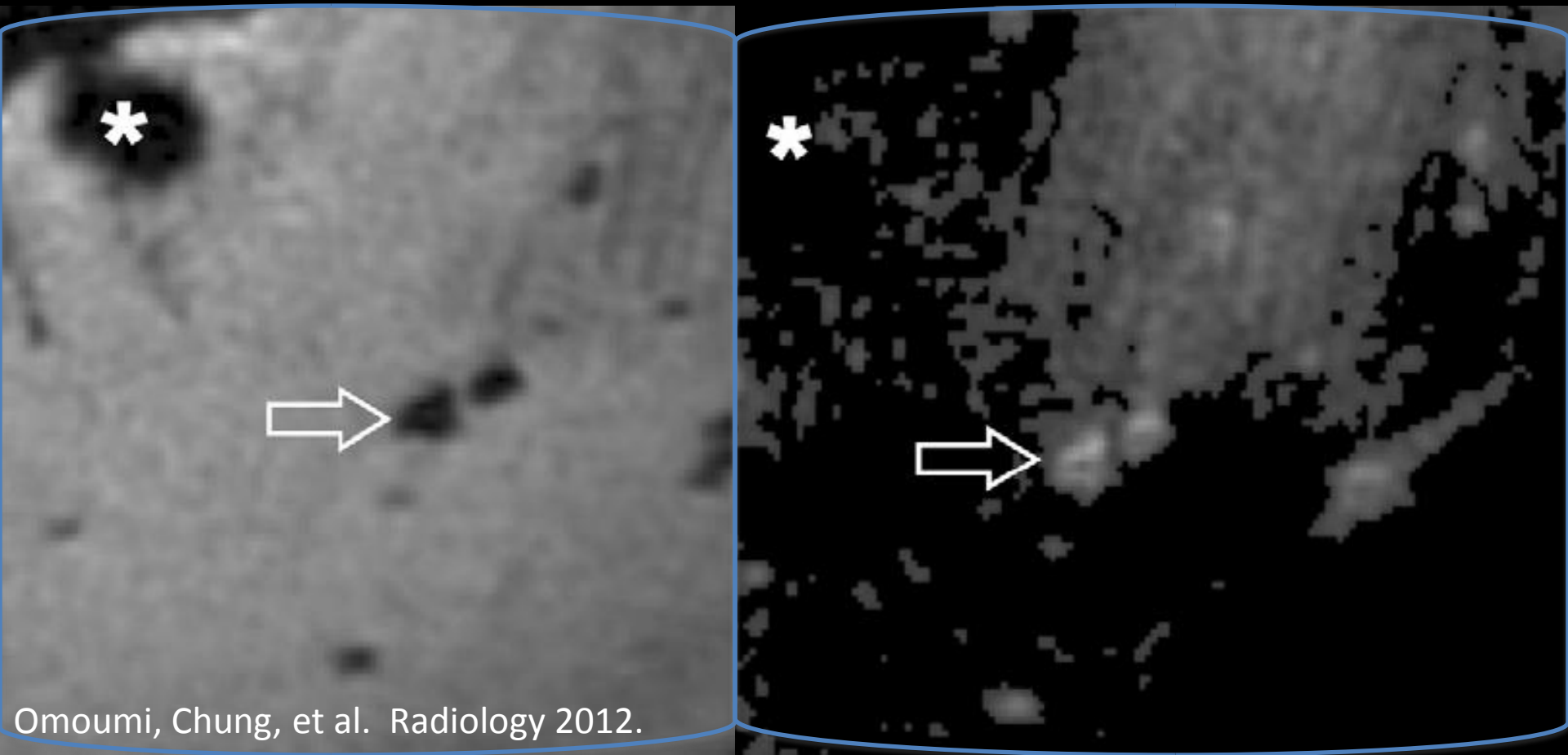
3D UTE
Meniscal calcifications





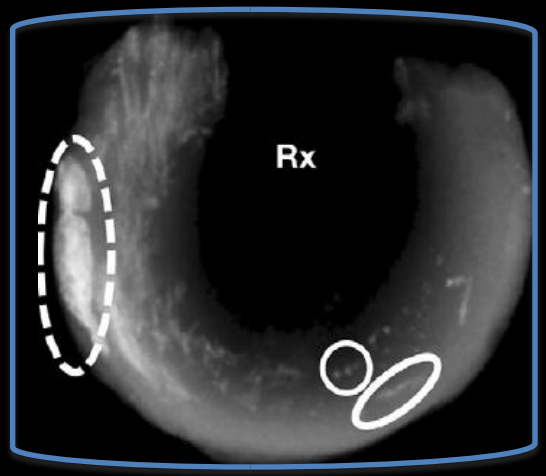
Omoumi, Chung, et al. Radiology 2012.

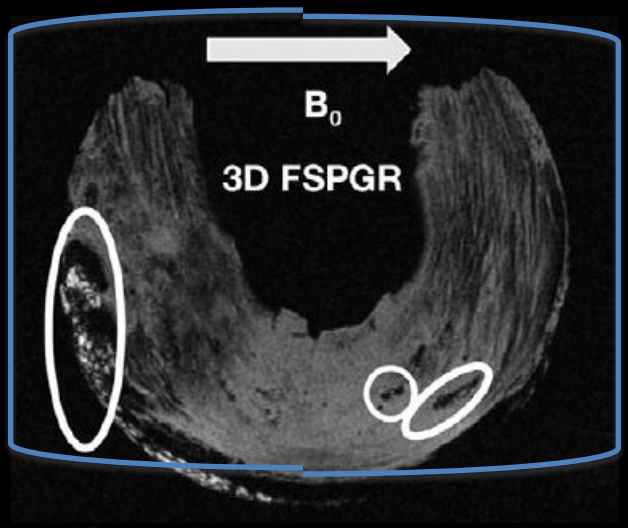
UTE and subtraction
Meniscal calcifications vs gas

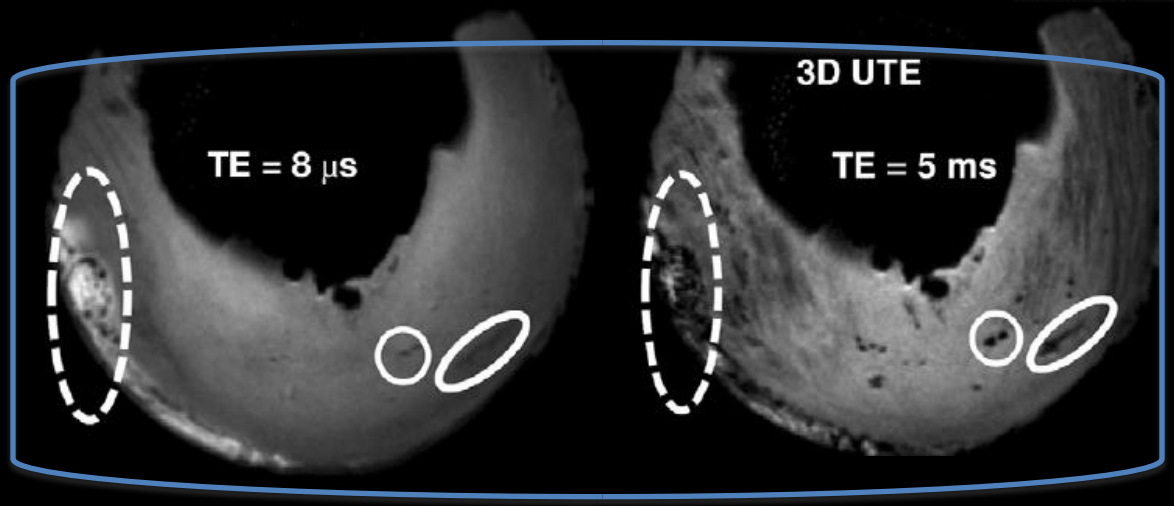


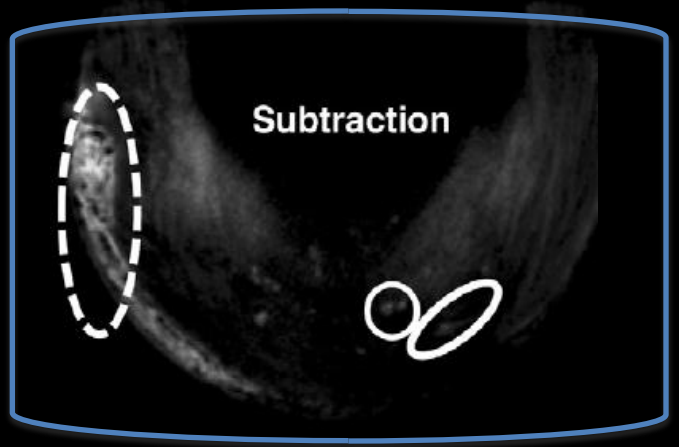
Omoumi, Chung, et al. Radiology 2012.

Meniscal calcifications









Omoumi, Chung, et al. Radiology 2012.

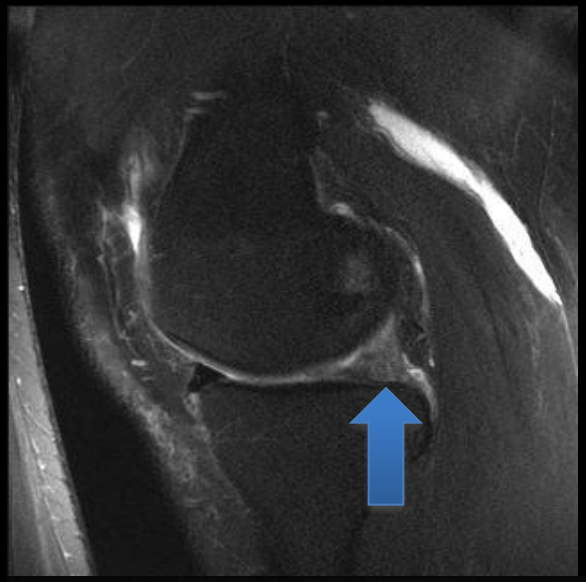
Summary

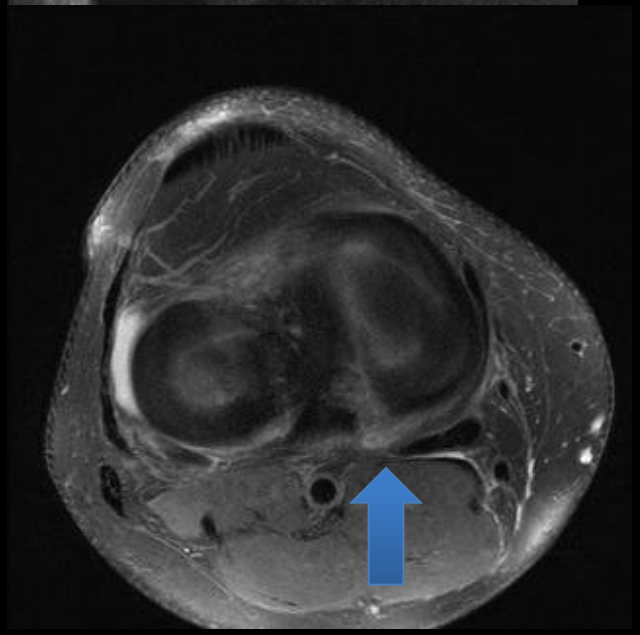
UTE qMRI can distinguish and quantify:

- Proteoglycan integrity
- Collagen organization
- Microcalcifications

Clinical applications include characterization of short T2 tissues

Future Directions

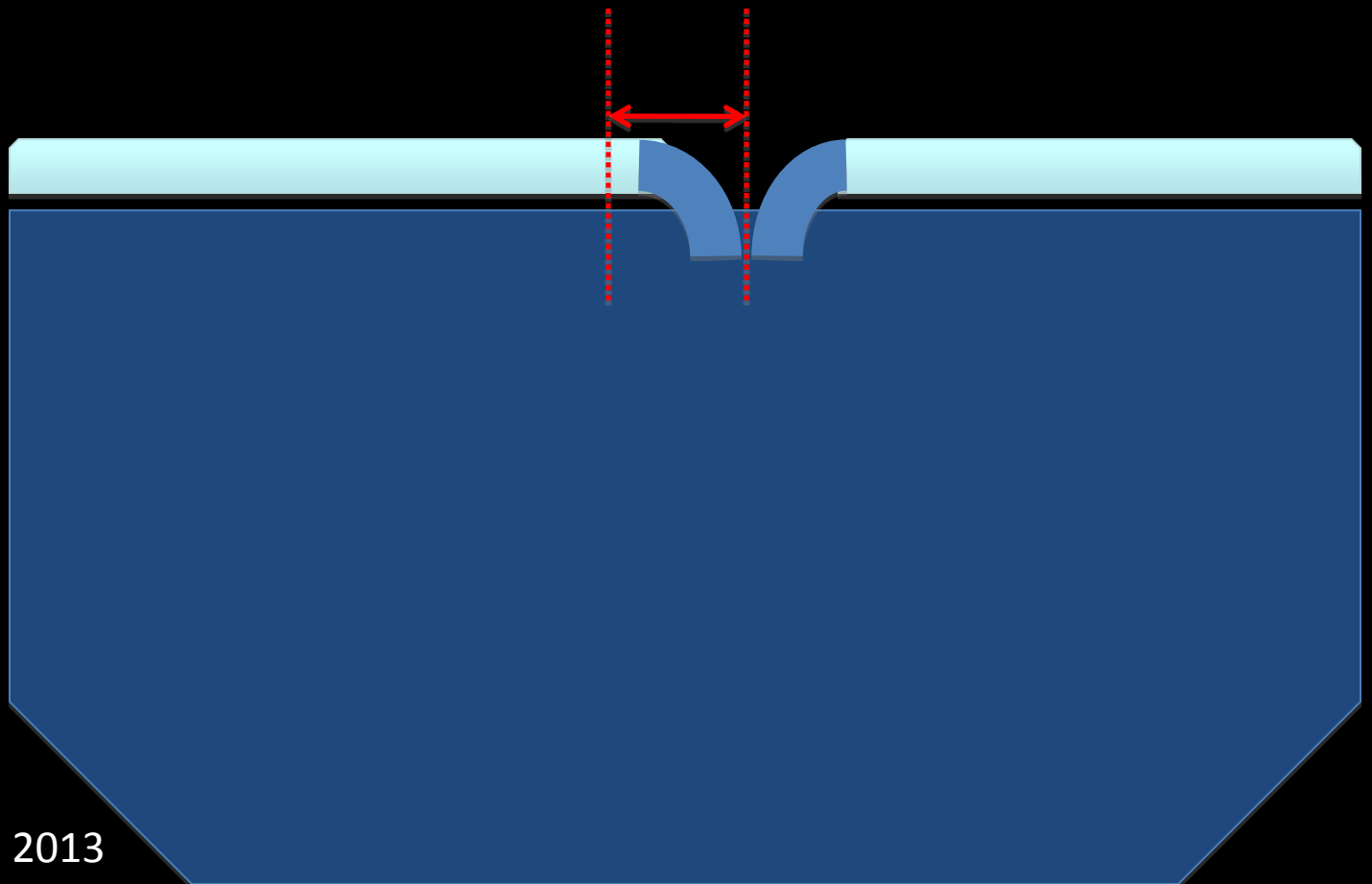




Tear of posterior horn of medial meniscus with involvement of posterior root ligament

Future directions

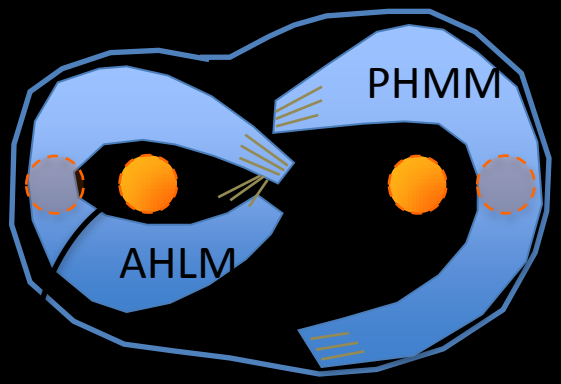
Evaluate normal root ligament morphology through UTE MRI and correlate with histology

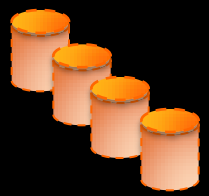


Chung, et al. 2013

Future directions

A. Coring

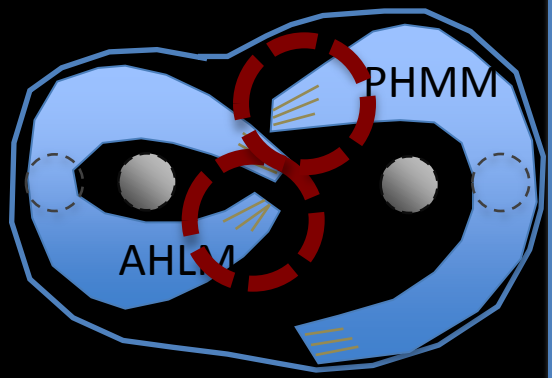




Cartilage/Bone characterization by 3D UTE

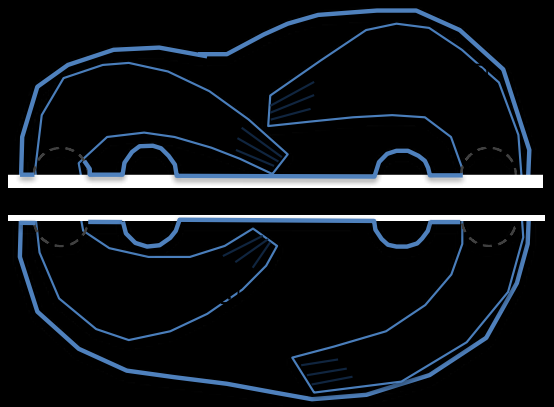
****Core aquisition for project that will explore Bone cartilage interface

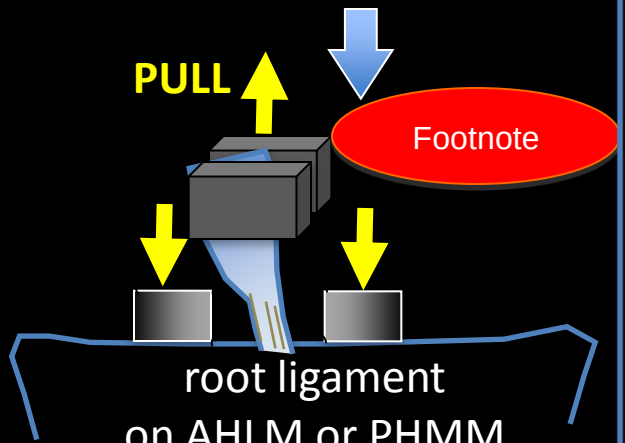
B. Root Ligament



1" Coil Placed On Top
morphologic & qMRI:
- distinguish R.L. from meniscus
-qMRI of root ligament
--orientation to B0 as patient would be placed (perpendicular to bore)

C. Biomechanics



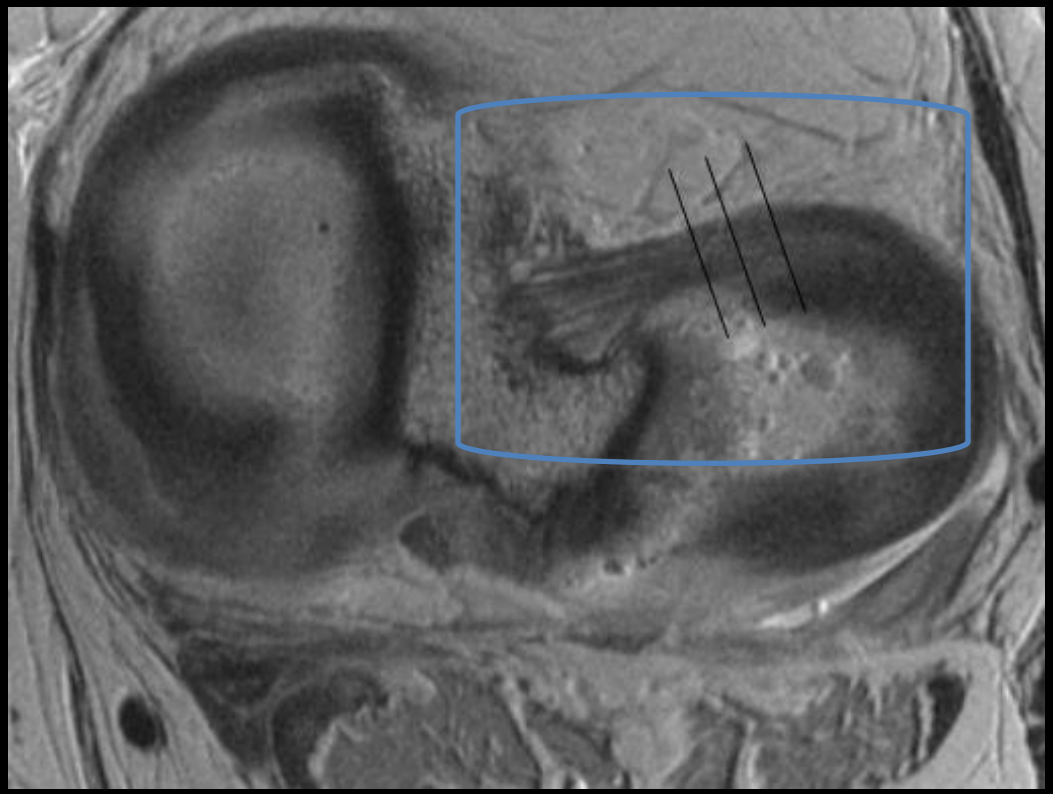


Chung, et al. 2013

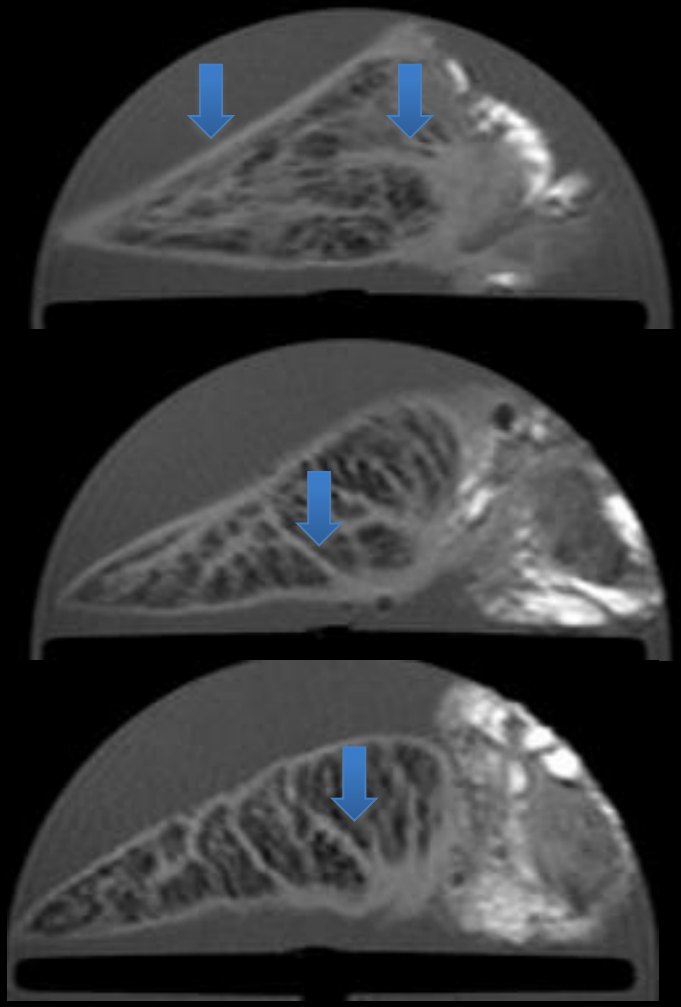
Collagen Network

Transition from Meniscus to Root Ligament

Axial



Sagittal



Chung, et al. 2013

Conclusion

UTE allows visualization of "MRI invisible" short T2 structures.

Menisci are composed of collagen and proteoglycans, and microstructural changes can lead to altered joint mechanics, predisposing to osteoarthritis.

UTE T2* and UTE T1 rho are novel MRI pulse sequences that can detect microstructural changes, which could lead to early diagnosis and quantification of response to treatment.

Thank you

Christine Chung

UCSD MSK Radiology

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