Musculoskeletal: Clinical Interpretation & Advanced Imaging Course
Sunday, 31 May 2015 14:30 – 15:00

Timothy J. Mosher tmosher@hmc.psu.edu

Advanced Evaluation of Osteochondral Injuries

 TARGET AUDIENCE: This course is designed for radiologists, clinician scientists and clinical care providers who wish to update their knowledge on the mechanism of osteochondral injuries, and MR imaging features that can be used to improve diagnosis

 OUTCOME/OBJECTIVES: At the conclusion of this talk the participant should:

- Understand the composition and structural organization of cartilage and the osteochondral junction
- Recognize patterns of osteochondral injuries and mechanism of injury
- Appreciate the contribution of the type II collagen network in defining the regional variation in cartilage signal intensity and the relationship to regional tissue biomechanics
- Differentiate features of acute and chronic osteochondral injuries
- Identify applications for quantitative MRI techniques used in the assessment of osteochondral injury

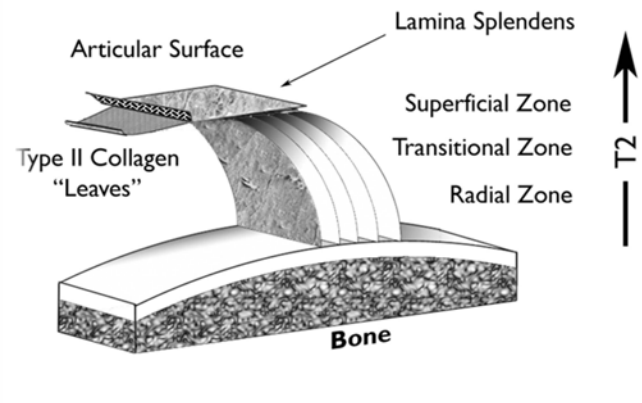
 PURPOSE The purpose of this talk is to allow the user to apply understanding of cartilage composition and biomechanics to improve the diagnosis of osteochondral injury using MRI.

 METHODS: The presentation will first provide an overview of cartilage composition and structure of the osteochondral unit. This will serve as a foundation for understanding cartilage biomechanics and mechanisms of osteochondral injury. Case studies will be used to illustrate patterns of osteochondral injury and MRI features that can be observed with clinical imaging techniques and quantitative mapping tools.

Highlights

- The 3D organization of the type II collagen matrix predisposes cartilage to specific patterns of injury when exposed to excessive shear or compressive strain.
- Disruption of the type II collagen network leads to loss of tissue anisotropy, and prolongation of cartilage T2 values in the acute phase of injury. With progressive degeneration of the extracellular matrix T2 shortening can be observed.
- The perturbation in cartilage T2 relaxation can be measured quantitatively with MSME techniques, and is observed subjectively on PD-weighted images. While quantitative measurement of cartilage relaxation parameters has been used in longitudinal clinical trials, the clinical value in evaluation of individual patients has not been clearly demonstrated.

 BASIC SCIENCE SUMMARY



Cartilage Composition:

- Water: 70 to 75%
- Collagen: 15 to 20%
- Proteoglycan: 5 to 10%
- Chondrocytes: < 5%

Figure 1: Schematic of cartilage collagen structure within the load bearing portion of the joint

The type II collagen matrix is organized into a 3D meshwork that varies regionally within the joint as well as with respect to the depth from the articular surface (Figure 1). At the articular surface the collagen fibers are aligned parallel with the surface along the direction of maximal shear strain within the joint (superficial zone). At the surface there is a specialized zone termed the lamina splendens that expresses proteoglycans such as lubricin which reduces the coefficient of friction. Beneath the surface collagen has an oblique orientation (transitional zone) becoming perpendicular to bone in the deeper layer termed the radial zone. As illustrated in Figure 2, the collagen fibers terminate in the zone of calcified cartilage. There is a potential cleavage plane between the calcified cartilage zone and the underlying bone that is at risk for delamination injury when exposed to excessive shear strain.

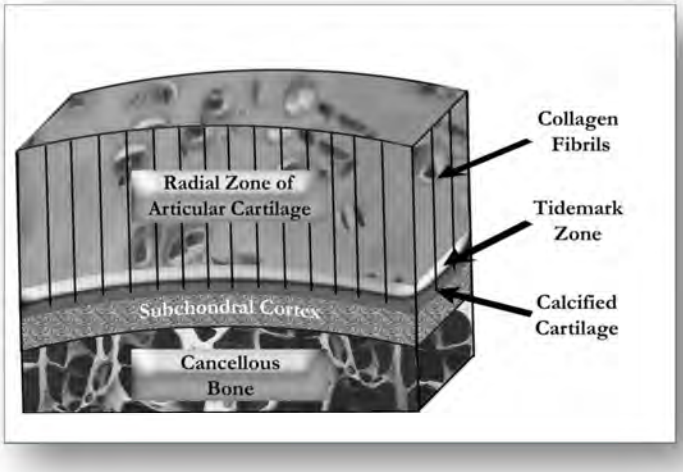


Figure 2: Schematic of the osteochondral junction. Type II collagen fibrils from the deep radial zone pass through the tidemark terminating in the zone of calcified cartilage.

The high degree of tissue anisotropy in cartilage provides an efficient mechanism for spin-spin relaxation in cartilage leading to relative shortening of the cartilage T2 and decreased signal intensity on T2-weighted images. As illustrated in Figure 3 the regional differences in joint loading influence the relative thickness of the cartilage transitional zone and radial zone. In regions predominately exposed to high compressive load such as the patella and the central femoral tibial joint the radial zone is thicker (arrow) with a relatively thin high intensity transitional zone. Near the periphery of the joint where shear strain predominates the radial zone is thinner. There is a wider high intensity transitional zone in which the fibers are aligned obliquely along the direction of primary shear strain.

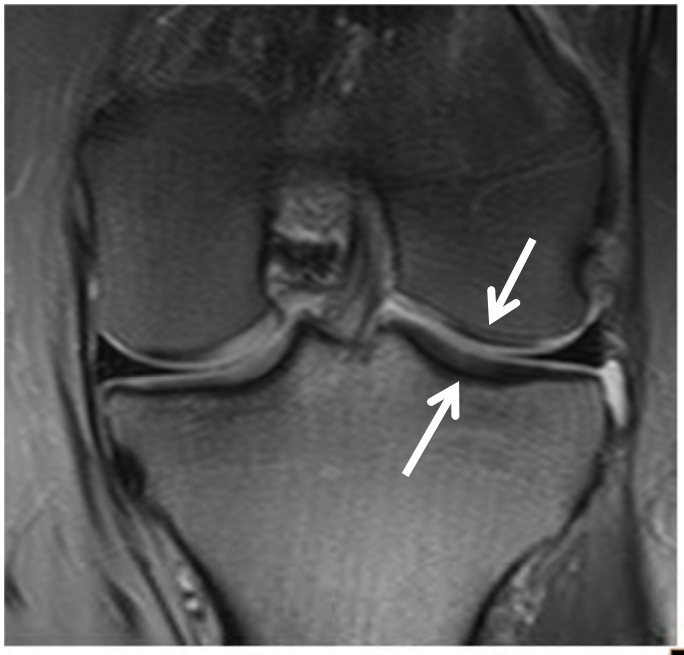


Figure 3: Coronal PD-weighted 3.0 T MRI (TR/TE = 3200 ms/30 ms) demonstrating a normal spatial variation in cartilage signal intensity. Cartilage habitually exposed to high compressive strain demonstrates a thick, highly anisotropic radial zone which appears as low signal intensity (arrows). In contrast the more peripheral cartilage has a thinner radial zone and wider transitional zone

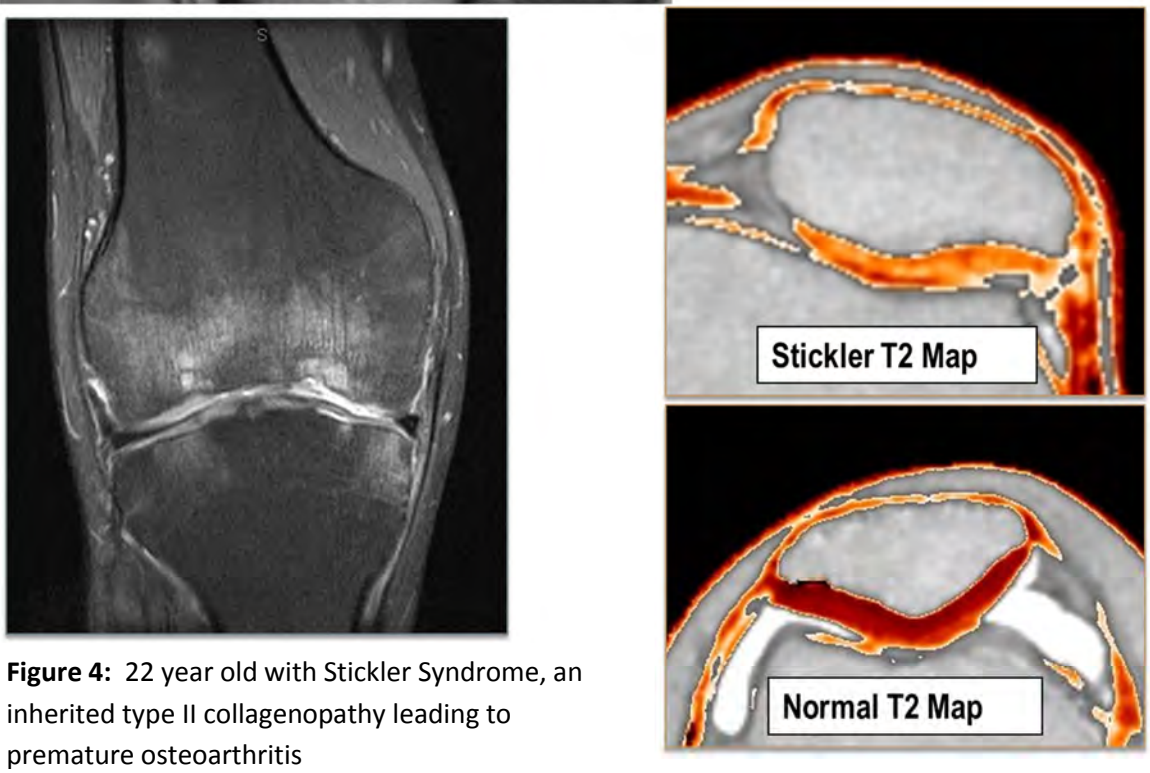


Figure 4: 22 year old with Stickler Syndrome, an inherited type II collagenopathy leading to premature osteoarthritis

Figure 4 illustrates characteristic findings of a patient with Stickler syndrome, a group of hereditary conditions characterized by a distinctive facial appearance, eye abnormalities, hearing loss, and abnormal articular cartilage leading to premature osteoarthritis. Cartilage T2 map of the patella demonstrate diffusely elevated T2 with loss of the depth dependent T2 variation observed in a normal subject of similar age.

KEY TAKE HOME POINTS

1. Cartilage T2 is strongly influenced by the content and orientation of the type II collagen matrix
2. Patterns of cartilage injury reflect the underlying collagen structure
3. Acute disruption of collagen matrix increases cartilage T2. In chronic injuries progressive degeneration of collagen and loss of water content frequently leads to areas of T2 shortening and heterogeneous T2-weighted signal.
4. Change in collagen orientation and cartilage water content with loading is a potential biomarker for in vivo evaluation of tissue strain

 CONCLUSION: Knowledge of the structural composition of articular cartilage and impact of this structure on patterns of osteochondral injury improves the ability to recognize early and sometimes subtle cartilage injury. For clinical trials or applications in which there is a need to monitor cartilage degeneration over time quantitative cartilage T2 mapping is a reliable and sensitive tool.

 REFERENCES

1. Mosher TJ, Dardzinski BJ. Cartilage MRI T2 relaxation time mapping: overview and applications. Semin Musculoskelet Radiol. 2004;8(4):355-68.
2. Bruno MA, Mosher TJ, Gold GE. Arthritis in color : advanced imaging of arthritis. Philadelphia, PA: Saunders/Elsevier; 2009. xii, 221 p. p.
3. Crema MD, Roemer FW, Marra MD, Burstein D, Gold GE, Eckstein F, et al. Articular cartilage in the knee: current MR imaging techniques and applications in clinical practice and research. Radiographics.31(1):37-61.