Regional Variation in Canine Knee Meniscus T2* Relaxation Times: Assessment of Normative Values and Histologic Correlation

Sarah L. Powder[1], Parina H. Shah[1], Kei Hayashi[2], Hollis G. Potter[1], and Matthew F. Koff[1]

[1]*Department of Radiology and Imaging - MRI, Hospital for Special Surgery, New York, New York, United States,* [2]*College of Veterinary Medicine, Cornell University, Ithaca, New York, United States*

Target Audience: Orthopaedic surgeons and scientists with an interest in preclinical models of meniscal degeneration.

Purpose: Canine models of anterior cruciate ligament (ACL) reconstruction are commonly used to compare different reconstruction techniques, assess host site morbidity, evaluate graft fixation devices, or to study the effects of supplemental treatments such as platelet rich plasma (1-3). In naturally occurring cruciate deficient dogs, the posterior horn of the medial meniscus is a common site of injury secondary resulting from knee instability (4, 5). This may be an inherent point of weakness or susceptible region due to the unique conformation of the canine knee. Injury in this region may reflect instability after repair therefore this site is of interest to researchers when assessing total knee joint pathology.

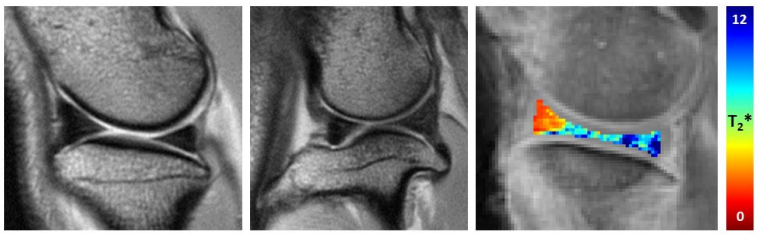

Figure 1. Medial meniscus (left) and lateral meniscus (center) of the canine knee. A representative T2* map of the medial meniscus (right) shows prolongation of T2* values in the posterior horn

Initial studies in our laboratory noted prolongation of T2* in the posterior horn of the medial meniscus as compared to the anterior horn as well both horns of the lateral meniscus (Figure 1). The purpose of this study was to establish normative T2* values of the canine meniscus and determine if subclinical pathology was detected on histology to explain the initial impression of prolongation of T2* values.

Methods: Institutional IACUC approval was obtained for this study. 5 dogs (10 knees) were obtained immediately post-mortem from juvenile male beagles from an unrelated study with no evidence of lameness. The limbs put in cold storage at 4°C and were scanned within 72 hours of death. MR Imaging: All scanning was performed on a clinical 3T scanner (GE Healthcare, Waukesha, WI) with an 8 channel phased-array wrist coil (Invivo, Gainesville, FL). Morphologic multi-planar fast-spin-echo (FSE) images were acquired: echo time (TE): 24 ms, repetition time (TR): 4000 ms, receiver bandwidth (RBW): ±62.5 kHz, acquisition matrix (AM): 384x384, number of excitations (NEX): 2-3, field-of-view (FOV): 6-8 cm, slice thickness (SL): 1-2.0 mm, slice spacing (SS): 0mm. Multi-slice multi-echo 3D ultrashort echo (UTE) images were acquired in the sagittal plane for meniscal T2* calculations: TEs=0.05, 3.7, 7.4, 11.1 ms, TR=19 ms, RBW=±83.33 kHz, AM=384x384, NEX=1, FOV=12 flip angle = 13°, ST= 3mm, SS = 0 mm. Microscopy: The knees were disarticulated after imaging and histological samples were taken for preparation with hematoxylin and eosin (H&E) staining. The specimens were evaluated for defects, cell population and matrix appearance Image Analysis: Meniscal T2* values were calculated by fitting the TE to the corresponding signal intensity: $SI(TE)=S_o*e(-TE/T2*)+C$, where SI (TE) is the signal intensity at echo time TE, S_o is proportional to apparent proton density, T2* is the inherent transverse relaxation time constant, and C is a constant to account for image noise. Average bulk T2* values from all slices comprising individual horns of a single meniscus were generated for statistical analysis. Statistics: A one-way repeated measures analysis of variance (ANOVA) was performed to detect differences of meniscal T2* values by meniscal compartment (lateral or medial) and region (anterior or posterior) (SAS V9.3, Cary NC). Significance was set at $p<0.05$. A post-hoc Student-Newman-Keuls (SNK) test was performed when statistical significance was found.

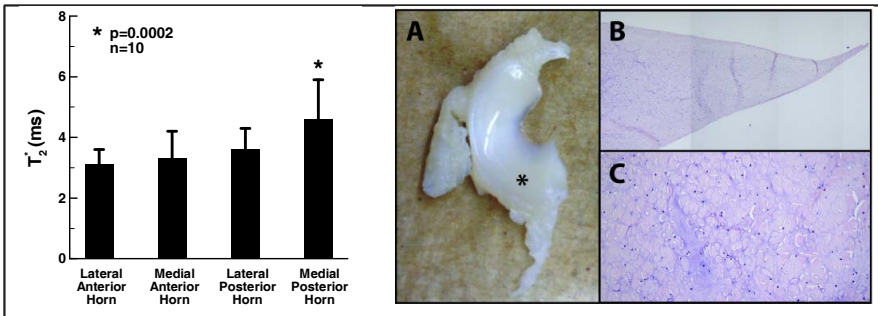

Figure 2. Left – Differences of canine knee meniscal T2* values by anatomic location. Right – (A):Intact meniscal specimen with * noting area of interest on posterior horn, (B) 100X , (C) 200x magnification of tissue showing no gross defect, a normal cell population and a normal matrix appearance.

Results: The posterior horn of the medial meniscus had significantly prolonged T2* values (4.6±1.27 ms; p=0.002) compared to the anterior horn of the medial meniscus (3.25±0.86 ms), and the anterior (3.06 ±0.54 ms) and posterior (3.64±0.72 ms) horns of the lateral meniscus (Fig. 2). Histology of a preliminary specimen demonstrated no gross defects or tears, and normal cell population and matrix appearance (Fig. 2).

Discussion: Normative canine meniscal T2* values were evaluated in this study to provide a baseline for future evaluations. These data suggest an inherent difference in the posterior horn of the medial meniscus compared to the remaining meniscal regions. Previous studies have shown meniscal UTE T2* mapping to be sensitive to disruption of collagen fibers (6, 7); however, no degeneration or disruption of the menisci of the current cohort was noted by gross inspection, histologic evaluation, or in morphologic FSE images. We hypothesize that the T2* prolongation of the posterior horn of the medial meniscus is due to magic angle effects often seen in highly ordered collagenous structures, such as tendons and meniscus, when the angle between collagen fibrils and B_o approaches 54.7° (8), and occurs at this location as a result of the unique angle of the tibial plateau on which the posterior horn medial meniscus sits. This has been shown to occur in human menisci with no degeneration or tears present (9). We anticipate that the continued histological evaluation of the remaining menisci will confirm these findings.

Conclusion: Normative canine knee meniscal T2* values vary by anatomic location and may aid for a better understanding of canine model for different anterior cruciate reconstruction techniques.

References: 1. Yuan F et al., Orthopedics 2013;36:e588. 2. Tomita F et al., Arthroscopy 2001;17:461. 3. Xie X et al., J Surg Res 2013;180:80. 4. Franklin SP et al., Compend Contin Educ Vet 2010;32:E1. 5. Olive J et al., Vet Comp Orthop Traumatol 2014;27:1. 6. Koff MF et al., Osteoarthritis Cartilage 2013;21:1083. 7. Williams A et al., Osteoarthritis Cartilage 2012;20:486. 8. Du J et al., Magn Reson Imaging 2009;27:557. 9. Peterfy CG et al., AJR Am J Roentgenol 1994;163:149.