Comparison of 7.0 Tesla MRI and Histology Measurements in Knee Articular Cartilage in an in Vivo Canine Model

INTRODUCTION

The validation of high resolution MRI techniques will enable investigators to follow the natural history of early osteoarthritic changes and measure responses to treatments for this disease. The objective of this study was to measure articular cartilage area and thickness six months after surgical transection of posterolateral knee structures in adult dogs using 7.0 Tesla MRI and histological techniques and to compare the results of these two modalities.

METHODS

Injury model: Approval for the study was obtained from the Institutional Animal Care and Use Committee at the University of Minnesota. Six skeletally mature, mixed breed canines underwent surgery on alternating right and left limbs with the contralateral limb as an unoperated control. During surgery the fibular collateral ligament, popliteus tendon, and popliteofibular ligament were exposed and resected [1]. The dogs then were allowed unrestricted activity and were exercised twice daily in 4 x 6 foot pens. They were humanely euthanized 6 months after the surgery and both rear limbs were collected for evaluation of the knee joints.

MRI: Three-dimensional gradient echo images were acquired on both intact knee joints from all dogs with a 7.0T scanner fitted with a Siemens (Erlangen, Germany) console. The images were viewed with iQ-View 2.5.0 (IMAGE Information Systems Ltd., London, England). Coronal plane images in the same location as that chosen for histology were exported to Adobe Photoshop (San Jose, CA) and articular cartilage areas and maximum thicknesses were measured. Measurements were repeated twice, two weeks apart, to test intraobserver reliability.

Histology: After opening the knee joints and fixing them in 10% neutral-buffered formalin, each proximal tibia was serially sectioned in a coronal plane at 4 mm increments, after which each set of serial sections was radiographed using a fixatron microradiography unit. A midcoronal paraffin-embedded specimen from each proximal tibia was sectioned at 4 μm and stained with hematoxylin & eosin and Safranin-O stains. The histomorphometry system (OsteoMetrics Inc, Decatur, GA)

Statistics: Data were analyzed using correlation analyses and a two-tailed Student’s t-test with significance set at p < 0.05. Intraclass correlation coefficients were also calculated for intraobserver reliability with a Pearson regression coefficient.

RESULTS

MRI

The MRI results revealed an increase in articular cartilage area (Table 1 and Figure 1) and thickness (data not shown) in surgical knees compared with controls in all of the dogs; these changes were significant for both parameters (p<0.01 for area; p<0.001 for thickness). The average increase in area was 14.3% and the average increase in thickness was 16%. The interclass regression coefficient was 0.96 for the area measurements and 0.76 for the thickness measurements.

Histology

The histological results revealed an increase in articular cartilage area in 4 out of 6 surgical knees (Table 1 and Figure 1) and an increase in articular cartilage thickness in 5 out of 6 surgical knees compared with controls (data not shown). The average increase in area was 15.6% and the average increase in thickness was 22.5%; however, there was no significant effect of treatment on either parameter. The histological results for Canine #1 were unusual, in that both articular cartilage area and thickness were decreased in the surgical knees compared with the control knees. Removing data from this dog from the analysis resulted in a significant treatment effect (p<0.05) for area but not thickness (p=0.09) of articular cartilage.

DISCUSSION

We found that 7.0T MRI provides an alternative method to histology to evaluate early osteoarthritic changes of the articular cartilage by detecting increases in articular cartilage area and thickness. The increase observed in articular cartilage area and thickness was expected in early stages of osteoarthritis [2]. Even with a relatively small sample size of 6 animals (12 joints), there were significant correlations between articular cartilage area measurements completed using MRI vs. histological techniques. Explanations for the fact that there were some differences in results between these two modalities may include alteration of histological tissues during processing, positioning that may have caused compression of tibial articular cartilage by femoral articular cartilage during MRI scanning, differences in plane of section of the MRI image vs. the histological section, and lack of resolution at the lowest boundary of articular cartilage (most superficial tidemark) for the MRI measurements. High field MRI may allow for improved analysis of osteoarthritis changes over time.

REFERENCES