Anatomy of the Cruciate Ligaments and Menisci in Seven Species

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Introduction:
The purpose of this descriptive laboratory study was to define the anatomical differences of the cruciate ligaments and menisci to provide a resource for investigators who are interested in studying diseases of these structures in animal and/or human patients. We compared the knee anatomy of bovine, ovine, caprine, canine, porcine, and lapine models to evaluate the anatomy of the meniscal and cruciate attachments.

Materials and Methods

Specimens
Fresh bovine (n=4), ovine (n=3), caprine (n=4), canine (n=4), porcine (n=5), lapine (n=5), and human (n=4) adult knees were retrieved for study. All animal knees were harvested within 2 hours of euthanasia. The human knees were obtained from a willed body program and were obtained from 3 females and 1 male with an age range of 47 to 60 years. All specimens were frozen at the time of collection and maintained at -20°C until the time of analysis.

Quantitative Measurements

Vernier calipers were used to measure the intra-articular structures. The digital imaging software ImageJ was used to measure the area of the insertions of the cruciates and menisci. In addition to the absolute measurements, all measurements were normalized by the width of tibial plateau to facilitate comparison between knees of different sizes. This value was referred to as a Tibial Index (TI). Both the measured values and the TI were compared using ANOVA, with Bonferroni correction for post-hoc testing. A p-value of 5% was considered significant.

Results

Table 1 summarizes the quantitative assessment. The bovine and human knees had wider notches than other species (a; p<0.0004) with the exception of the porcine (p>0.007 for porcine v human). The normalized notch width was greater in the bovine knees than in the ovine and caprine (b; p<0.001 both comparisons). The ACL length in the bovine and human knees was greater than in the other knees (c; p<0.002 all comparisons). Normalized by tibial plateau width, the porcine ACL was significantly longer than the human, caprine, canine, and lapine (d; p<0.002 all comparisons).

The femoral origin of the ACL was consistently located at the posteromedial edge of the posterior lateral condyle in all species. The tibial insertion site varied among species. Table 1 summarizes the quantitative assessment. The bovine and human knees had wider notches than other species (a; p<0.0004) with the exception of the porcine (p>0.007 for porcine v human). The normalized notch width was greater in the bovine knees than in the ovine and caprine (b; p<0.001 both comparisons). The ACL length in the bovine and human knees was greater than in the other knees (c; p<0.002 all comparisons). Normalized by tibial plateau width, the porcine ACL was significantly longer than the human, caprine, canine, and lapine (d; p<0.002 all comparisons).

The anterior medial meniscal bony insertion was the most anterior structure in the human, bovine, ovine, caprine, porcine, and lapine knees. Three of the four canine knees had an intermeniscal ligament, not individual insertions, in one the anterior insertion to the tibial plateau. The ovine and porcine knees also had a small connection between the anterior MM and LM insertions. The posterior MM attachment originated from the posterior horn, passing posterior to the medial spine and inserted on the lateral edge of its posterolateral surface. Anteriorly, the human LM was attached to the lateral aspect of the lateral spine of the intercondylar eminence, while coursing through the center of the tibial insertion of the ACL and inserting on medial tibial spine in bovine, ovine, and porcine knees. In the caprine and canine knees, the anterior attachment of the LM coursed behind the ACL. In the lapine knee, the anterior attachment was located even more medial, adjacent to the anterior horn of the MM. Posteriorly all knees had a band of fibrous tissue which connected the posterior LM to the lateral side of the posterior medial femoral condyle.

Discussion:
In summary, many of the features of the cruciate ligament and meniscal anatomy are relatively conserved among species. However, there are differences, particularly in insertion sites that should be considered when evaluating surgical procedures in these species. Thus, when translating methods of cruciate or meniscal treatment to a different species, caution should be used and the specific anatomy of these structures considered.

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