Skeletal Radiol (1999) 28:305–311

ARTICLE

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Posteromedial corner of the knee: MR imaging with gross anatomic correlation

Received: 26 October 1998
Revision requested: 11 December 1998
Revision received: 21 January 1999
Accepted: 26 January 1999

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Abstract *Objective.* The objective of this study was to illustrate the magnetic resonance (MR) image appearance of the structures of the posteromedial "corner" of the knee with particular emphasis on the anatomy and differentiation between the medial collateral ligament and the posterior oblique ligament.
Design. Six cadaveric knee specimens underwent MR imaging, before and following instillation of intra-articular contrast material. The knees were sectioned in the axial, coronal, and coronal oblique planes and the gross morphology of the posteromedial corner and surrounding structures was studied and correlated with the MR images.
Patients. The human cadaveric specimens were from two female and four male patients (age at death, 72–86 years; average, 78 years).
Results and conclusions. The contrast-enhanced sequences and the coronal oblique images allowed for improved visualization of the structures.

Key words Joint · Knee · Anatomy · Magnetic resonance imaging · Posteromedial corner · Intra-articular contrast

Introduction

Despite the multitude of magnetic resonance (MR) sequences that are available, it remains difficult to delineate the capsular structures of the knee joint, namely the posteromedial corner of the knee, owing in large part to the anatomic variability and relatively thin capsular components. Knowledge of the normal anatomic appearance of these structures is significant following injury to the medial compartment of the knee as demonstration of posteromedial capsular and ligamentous injuries or tears is extremely important for proper surgical repair and restoration of normal joint stability [1].

Using preoperative MR imaging, it would be useful to identify unsuspected soft tissue, ligamentous, and capsular injuries in this region so that presurgical planning of repair can be done. The purpose of this cadaveric study was to study the gross appearance of the normal capsular and ligamentous structures of the posteromedial corner of the knee and correlate the anatomic appearance with MR images in the axial, coronal, and coronal oblique imaging planes, before and following instillation of intra-articular contrast material.

Anatomic considerations

Several descriptions related to the anatomy and function of the posteromedial ligaments and capsule have been contradictory or incomplete, perhaps related to the anatomic variability in this area and to the difficulty in dissection as the structures are relatively deep and thin [2]. According to Warren et al. [3], the medial supporting structures of the knee may be divided into three layers: the superficial (I) and intermediate (II) layers and the capsule proper (III) (Fig. 1).

Layer I. The most superficial layer is made up of fascial extensions, formed by the deep (crural) fascia that invests the sartorius muscle and is reinforced by fascial fibers of the vastus medialis. The fascial fibers of layer I extend posteriorly over the heads of the gastrocnemius muscle and the popliteal fossa and anteriorly to unite with layer II to form the medial patellar retinaculum [4, 5].

Layer II. The intermediate layer is made up by the medial collateral ligament (MCL), also called the tibial collateral ligament or the superficial medial ligament. In traditional anatomic descriptions, the MCL is said to consist of combined anterior vertical and posterior oblique fibers. The anterior portion of the MCL attaches proximally at the medial femoral epicondyle about 5 cm above the joint line. The distal attachment is at the medial aspect of the tibial metadiaphysis, about 6–7 cm below the joint, deep to the gracilis and semitendinosus tendons [5]. The vertical anterior component may be 10–11 cm in length and approximately 1.5 cm wide [2, 6]. The posterior oblique fibers arise from the proximal attachment of the MCL and extend distally in a posterior and oblique orientation to attach to the posteromedial aspect of the knee, forming an envelope around the semimembranosus tendon [6].

In contrast to these traditional descriptions, the anatomic studies of Hughston and Eilers [1] have shown that the posterior oblique fibers are a discrete anatomic structure, designated the posterior oblique ligament (POL). They have shown further that the POL arises from the medial femoral adductor tubercle, while the MCL arises from the epicondyle, approximately 1 cm anterior and distal to the adductor tubercle (Fig. 2). The POL is attached firmly to the medial meniscus at the posteromedial corner of the knee, whereas the medial collateral ligament is superficial to the mid-third of the medial capsular ligament and does not attach to the medial meniscus. The distal attachment of the POL is composed of three arms: (1) the prominent central, or tibial arm, which attaches to the medial meniscus, close to the articular margin of the posterior surface of the tibia and central to the upper edge of the semimembranosus tendon; (2) the superior or capsular arm, which is continuous with the posterior capsule and the proximal part of

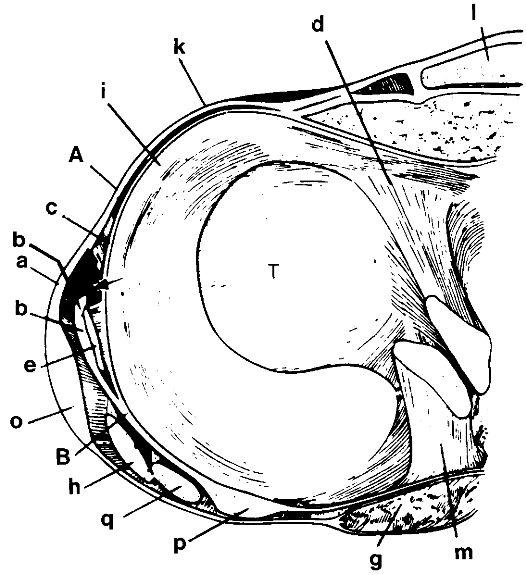

Fig. 1 Drawing of the medial aspect of the knee shows components of the medial supporting structures. (Derived with permission from Warren LF, Marshall L. The supporting structures and layers on the medial side of the knee: an anatomical analysis. J Bone Joint Surg Am 1979; 61:56–62. *Abbreviations* (used in Figs. 1, 2, and 4): *a* layer I, *b* layer II of medial collateral ligament (MCL), *c* layer III, *A* junction of layers I and II anteriorly, *B* merging of layers II and III posteriorly, *d* anterior cruciate ligament, *e* deep medial ligament, *F* femur (Figs. 2, 4), *g* gastrocnemius (medial head), *h* gracilis muscle/tendon, *i* medial meniscus, *k* medial patellar retinaculum, *l* patellar tendon, *m* posterior cruciate ligament, *n* posterior oblique ligament (POL) (Figs. 2, 4), *o* sartorius muscle/tendon, *p* semimembranosus muscle/tendon, *q* semitendinosus muscle/tendon, *T* tibia

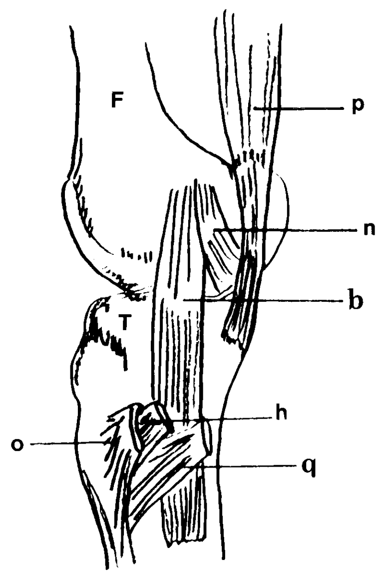

Fig. 2 Schematic drawing of the medial aspect of the knee illustrating the MCL (*b*), POL (*n*), and surrounding tendons of the knee (see legend to Fig. 1 for abbreviations)

the oblique popliteal ligament; and (3) the distal arm, which attaches both to the sheath covering the semimembranosus tendon and to the tibia just distal to the direct insertion of the semimembranosus tendon. The semimembranosus tendon and its aponeurosis, the POL, and the oblique popliteal ligament comprise the posteromedial "corner" of the knee [1].

Layer III. The deepest layer represents the capsule proper and it attaches primarily to the articular margins [5] and to the medial meniscus. Beneath the superficial MCL, this layer is thickened and is designated the deep MCL, deep medial ligament, deep collateral ligament, or middle capsular ligament [5]. The deep MCL may be divided into the meniscofemoral and meniscotibial ligaments, which extend from the meniscus to the femur and from the meniscus to the tibia (coronary ligament), respectively. Layers II and III are readily separable at their midportion; however, approximately 1–2 cm posterior to the anterior edge of the superficial MCL, layers II and III blend into the posteromedial corner of the knee [5].

The semimembranosus muscle and its tendon sheath are important contributors to the posteromedial corner (Figs. 1, 2). The tendon is described as having five arms of insertions, one being a principal attachment and additional attachments consisting of a series of slips of tendon. The principal or direct attachment is to the tibial tubercle on the posterior aspect of the medial tibial condyle (just below the joint line). The second attachment is located anteriorly just beneath the superficial MCL. A third arm, derived mainly from the tendon sheath, blends with the posteromedial capsule. A fourth contributes substantially to the oblique popliteal ligament which extends over the posterior surface of the joint capsule. The fifth arm blends distally with the superficial MCL [5].

Materials and methods

Anatomic-MR image correlation was accomplished using six human cadaveric knees (2 female, 4 male; age at death, 72–86 years; average, 78 years). One of the knees was dissected by an experienced orthopedic surgeon (R.P.) in order to investigate the anatomy of the posteromedial corner and to determine the obliquity of the functionally important POL. The knee was exposed and the anatomy of the posteromedial structures was analyzed, discussed, and shown to the radiologist in attendance (R.L.). A metallic wire was sewn onto the MCL and the POL. The knee was then closed and a lateral radiograph was obtained of the knee in extension (Fig. 3). The lateral radiograph of the extended knee showed a 25° posterior oblique course of the POL compared with the MCL and the shafts of the tibia and femur. On the basis of the obliquity of the POL demonstrated on the radiograph, a 25° posterior oblique coronal imaging plane was selected for subsequent acquisition of MR images.

According to the technique described in the literature [7], the remaining five knees were frozen and sectioned to a diameter that fit in a GE send-receive extremity coil (General Electric, Milwaukee, Wis.). Once thawed, the knees were scanned with a 1.5 T MR scanner (Signa; GE Medical Systems). Each knee was scanned in the axial, coronal, and oblique coronal planes utilizing the following technical parameters for T1-weighted images: repetition time (TR) 600 ms, echo time (TE) 20 ms, field-of-view (FOV) 12 cm, slice thickness 3 mm, number of excitations 2, and image matrix 256×256. Selection of the oblique coronal plane was accomplished using an initial sagittal MR image localizer, with the knees extended, and selecting a 25° posterior oblique plane of section to parallel the course of the POL. Upon completion of the contrast-free sequences, intra-articular injection of 25 cm^3 of a solution of gadopentetate dimeglumine (Gd) in saline (1 ml Gd in 250 ml normal saline) was carried out using fluoroscopic guidance. Postcontrast, T1-weighted fat-saturated sequences were acquired in the three imaging planes described above.

Fig. 3 Oblique course of the POL. Lateral radiograph of the extended knee shows a 25° posterior oblique course of the POL (*curved arrow*) compared with the vertical course of the MCL (*straight arrow*)

The five knees were refrozen and sections 3 mm thick obtained with a bandsaw. Axial, coronal, and oblique coronal sections were correlated with the MR image appearance of the posteromedial corner structures by one of the authors (R.L.), experienced in musculoskeletal MR imaging. Based on the reader's experience with images of the normal knee ligaments obtained for other indications, the radiologist subjectively compared the appearance of the structures to determine whether the oblique coronal plane or instillation of the gadolinium-containing compound changed the shape and appearance of the structures.

Results

MR imaging-anatomic correlation

Correlation of the dissected appearance of the posteromedial corner with the anatomic sections and MR images illustrated that the MCL and the POL were separate structures that originated as intertwined fibers proximal-

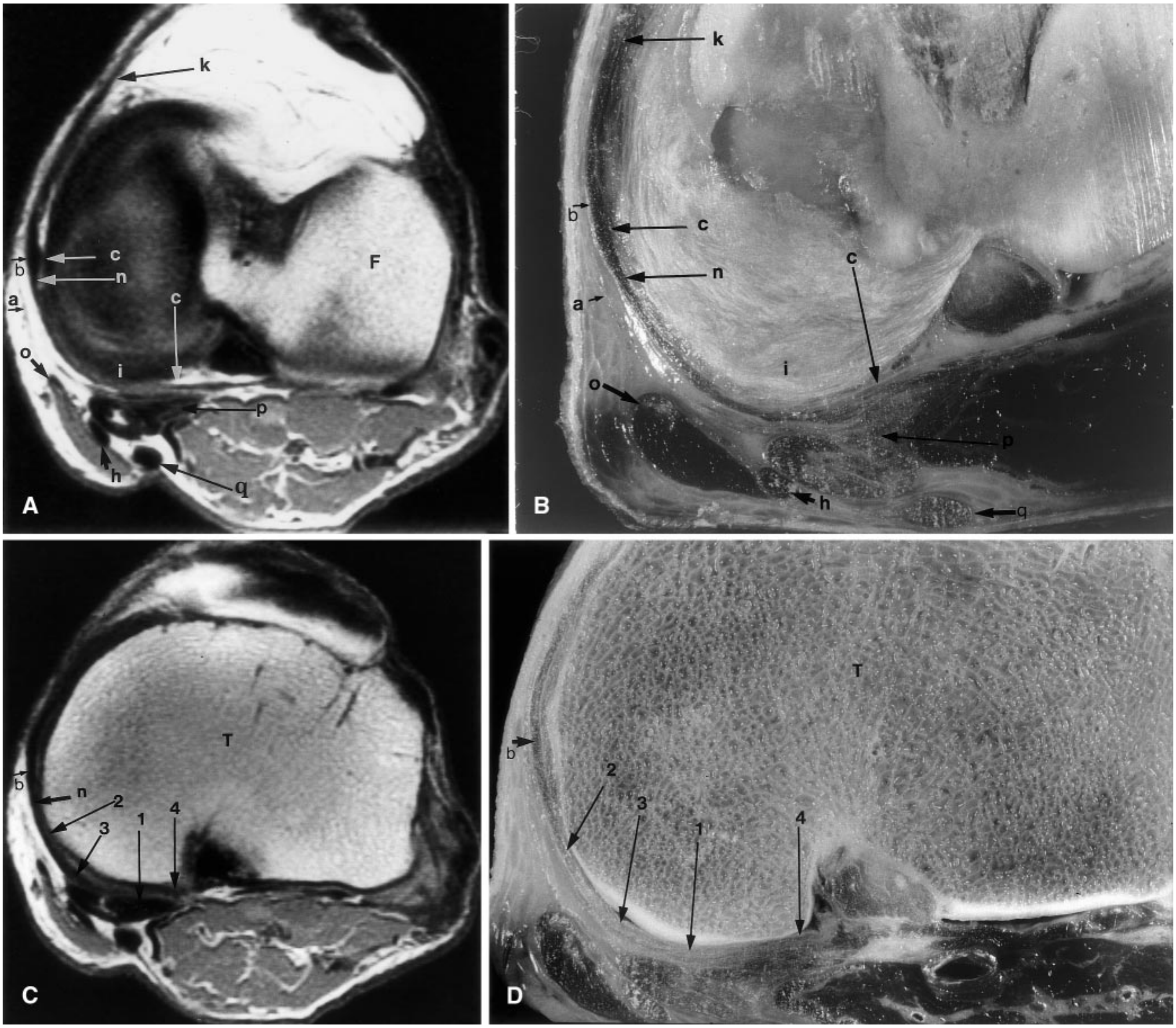

Fig. 4 **A** Transaxial T1-weighted MR image (600/20) at the level of the medial meniscus illustrates the POL (*n*), MCL (*b*), semimembranosus tendon (*p*), layers of the capsule, and surrounding supporting structures (see legend to Fig. 1 for abbreviations). **B** Photograph of the correlative gross anatomic specimen in the same knee demonstrates the structures that are labeled in **A**. **C** Transaxial T1-weighted MR image (600/20) at the level of the proximal tibia demonstrates the MCL (*b*), POL (*n*), and the first, second, third, and fourth arms of the semimembranosus tendon (1, 2, 3, and 4, respectively). **D** Photograph of the gross anatomic specimen in the same knee shows the structures labeled in **C**

ly and separated distally. The dissected MCL length was 10 cm and the width was 1 cm. It originated from the medial femoral epicondyle and coursed parallel to the shafts of the femur and tibia, to attach distally to the medial aspect of the tibial shaft, well below the joint line. The POL was 5 cm long and 0.6 cm wide. With respect to the long axis of the knee, the angle between the POL and the MCL and tibia was 25°. The proximal aspect of the POL spanned the medial femoral adductor tubercle and ended distally at the posterior articular margin of the tibia with slips of ligament approaching the medial meniscus, the posterior aspect of the joint capsule, and the sheath of the semimembranosus tendon.

Grossly, the five arms of insertion of the semimembranosus tendon appeared as a deltoid-like structure. The primary attachment to the posterior aspect of the medial tibial condyle was well seen. Smaller slips of the tendon and sheath coursed just beneath and towards the distal aspect of the MCL with the more delicate fibers blending with the conjoined appearance of the posteromedial capsule and oblique popliteal ligament.

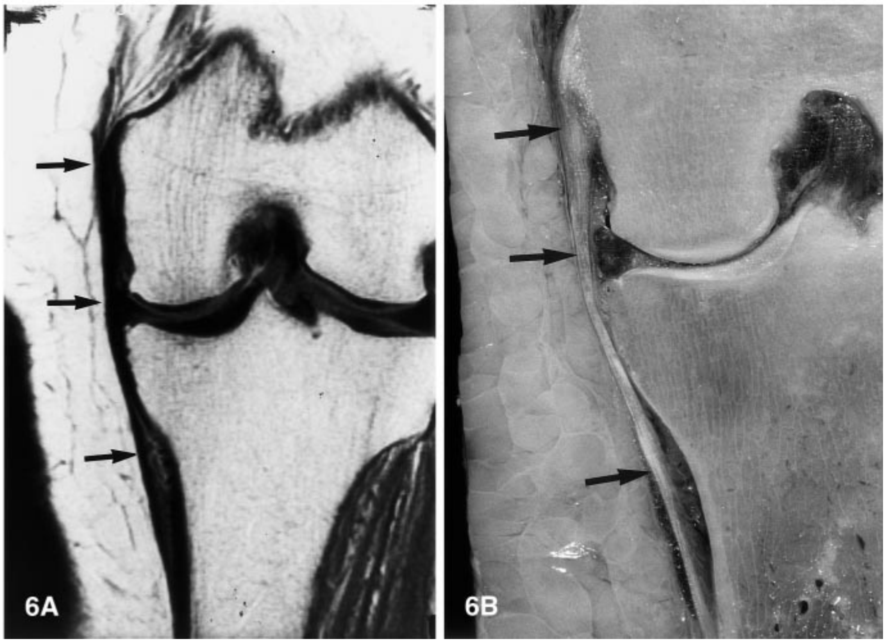

Fig. 5 **A** Transaxial T1-weighted MR image with fat suppression (600/20) and intra-articular gadolinium contrast material demonstrates improved visualization of the POL (*n*) as it arises from the medial femoral adductor tubercle and the MCL (*b*) as it arises from the epicondyle of the femur. The superior or capsular arm of the POL is continuous with the posterior capsule and the proximal part of the oblique popliteal ligament (*small arrows*). The appearance of the MCL remains distinct. **B** Photograph of the gross anatomic specimen in the same knee demonstrates the structures illustrated in **A**

Fig. 6 Coronal T1-weighted MR image (**A**) and the gross anatomic specimen (**B**), from the same knee, illustrate the vertical course of the MCL (*arrows*)

With MR imaging, the non-contrast axial images allowed for visualization of the POL, MCL, semimembranosus tendon, and layers of the capsule (Fig. 4). Addition of intra-articular contrast material optimized visualization of the POL and the capsule (Fig. 5). The appearance of the MCL remained distinct.

The coronal MR images demonstrated the length and vertical course of the MCL (Fig. 6) and the POL was seen in segments. Conversely, the coronal oblique plane demonstrated the length of the POL and its distal attachments to best advantage, and the MCL was seen in segments (Figs. 7, 8). The capsular layers could be seen on both the coronal and oblique coronal images. The semimembranosus tendon and its attachments were poorly seen in all coronal and oblique coronal images when compared with the axial images.

The contrast-enhanced coronal and coronal oblique images allowed for improved visualization of the capsular layers and the POL. None of the images demonstrated the fifth arm of the semimembranosus tendon.

Discussion

Medial compartment injuries are classified into anterior, medial, and posterior third injuries by Hughston and Eilers [1]. Posterior third structures include the POL, the semimembranosus tendon and its aponeurosis, and the

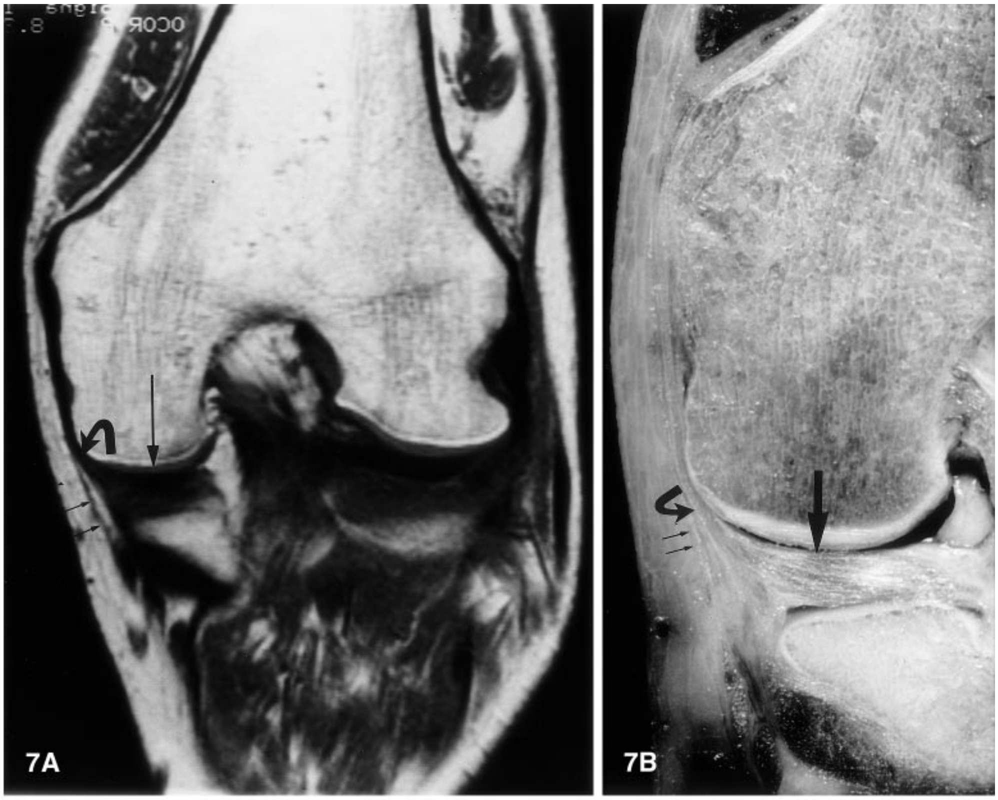

Fig. 7 Oblique coronal T1-weighted MR image (**A**) and the gross anatomic specimen (**B**), from the same knee, demonstrate the POL (*curved arrow*) and its principal distal attachment to the medial meniscus (*straight arrow*). The capsular layer I is shown (*small arrows*)

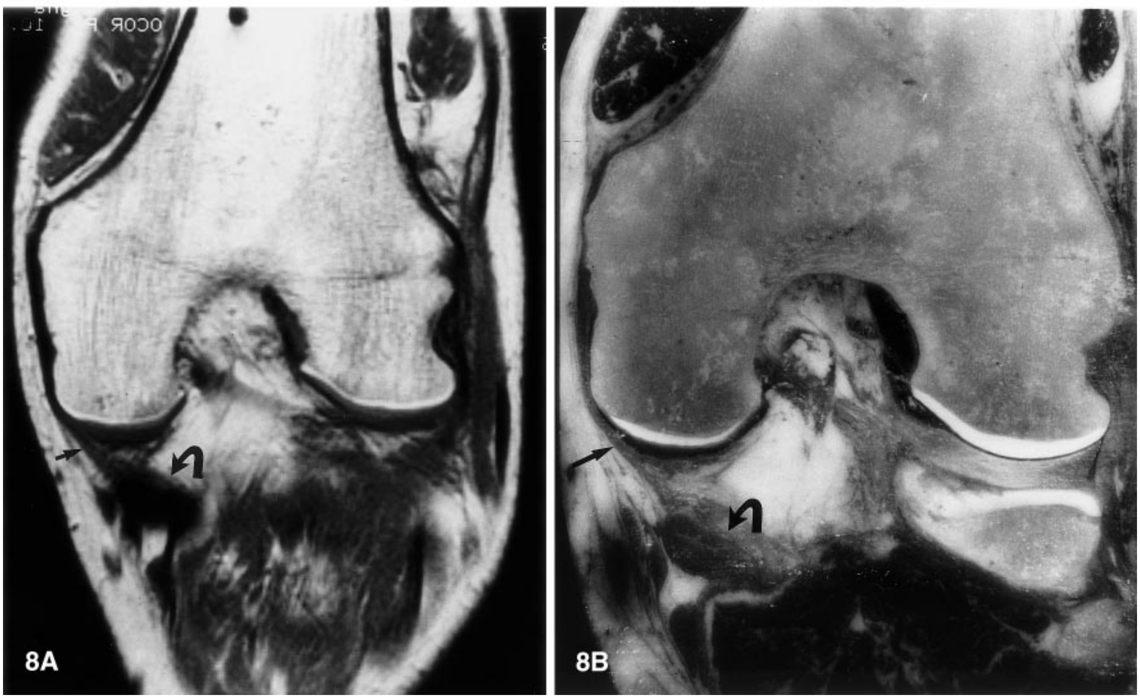

Fig. 8 Oblique coronal T1-weighted MR image (**A**) and the gross anatomic specimen (**B**), from the same knee, demonstrate the third arm of the POL (*straight arrow*) as it blends with the sheath of the semimembranosus tendon (*curved arrow*)

oblique popliteal ligament, constituting the posteromedial corner of the knee. The medial head of the gastrocnemius muscle also adds support to the posteromedial corner [4].

Hughston and Eilers [1] describe the POL as a distinct thickening or condensation of the posteromedial capsule that is firmly attached to the medial meniscus. It has been shown that the POL is a very important stabilizer of the medial side of the knee, functionally independent of the MCL. However, the importance of the POL is often disregarded. In fact, many knees are unstable at the time of skin closure following repair of acute knee ligament tears because the surgeon does not appreciate the importance of the POL. Thus, restoration of the POL is most often the key to a successful, stable repair of ligament and capsular tears in the medial compartment of the knee [1].

MR imaging is a diagnostic tool that may be used preoperatively for delineating various ligamentous and capsular injuries in order to help design the operative approach. Our anatomic-MR correlative study has demonstrated several points regarding the normal anatomic appearance of these structures. Before and following intra-articular administration of the gadolinium-containing solution, the true coronal plane and the axial plane were most useful in delineation of the MCL. The coronal plane allowed for visualization of the POL; however, the coronal oblique plane in combination with the axial plane improved the analysis of the POL. The axial images were adequate for analysis of the POL; however, the coronal oblique plane offered another perspective of the complex anatomy in this area. Addition of intra-articular contrast material optimized visualization of the POL and the capsular layers in the axial plane, most likely as a result of these structures being displaced away from the femur. The fifth arm of the semimembranosus tendon was not well seen on any of the images due to the fact that none demonstrated the extreme distal aspect of the MCL where expected blending of the fifth semimembranosus arm normally occurs.

In conclusion, learning the anatomy of the posteromedial corner of the knee is important in understanding the various types of post-traumatic knee pathology that affect this region. Assessment of the posteromedial corner of the knee with MR imaging remains difficult owing to the thin and intimate nature and intricate course of the capsular structures. Demonstration of posteromedial corner tears with MR imaging may be useful in the preoperative planning of repair and restoration of normal joint stability. However, in order to recognize pathology in this area, it is important to be familiar with the normal appearance of structures in the posteromedial corner of the knee.

Acknowledgement Supported in part by the Veterans Administration Grant SA 360.

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