Three Layers of the Medial Capsular and Supporting Structures of the Knee: MR Imaging–Anatomic Correlation

Michel De Maeseneer, MD • Frans Van Roy, RA • Leon Lenchik, MD
Eric Barbaix, MD • Filip De Ridder, RA • Michel Osteaux, MD

The authors used a three-layer approach to correlate the appearance of the capsule and ligaments of the medial side of the knee on magnetic resonance (MR) images with corresponding anatomic slices. MR images of six fresh cadaveric specimens were obtained by using a proton-density–weighted fast spin-echo sequence with a 256 × 512 matrix. Specimens were frozen and sliced with a band saw into 3.0-mm-thick sections that corresponded to the MR images. Three layers were depicted on both anatomic slices and MR images. Layer 1 consisted of the deep crural fascia; layer 2, the superficial portion of the medial collateral ligament (MCL); and layer 3, the capsule, the deep portion of the MCL, the meniscofemoral and meniscotibial extensions of the deep portion of the MCL, and the patellomeniscal ligament. Along the anterior aspect of the medial side of the knee, layer 1 was fused with layer 2; along the posterior aspect of the knee, layer 2 was fused with layer 3.

Abbreviation: MCL = medial collateral ligament

Index terms: Knee, anatomy • Knee, ligaments, menisci, and cartilage, 452.13 • Knee, MR, 452.1214 • Ligaments, MR, 452.1214

RadioGraphics 2000; 20:S83–S89

1From the Departments of Radiology (M.D.M., F.D.R., M.O.) and Experimental Anatomy (F.V.R., E.B.), Vrije Universiteit Brussel, Laarbeeklaan 101, 1090 Jette, Belgium; and the Department of Radiology, Bowman Gray School of Medicine, Winston-Salem, NC (L.L.). Presented as a scientific exhibit at the 1999 RSNA scientific assembly. Received February 2, 2000; revision requested March 9 and received April 3; accepted April 19.

Address correspondence to M.D.M. (e-mail: midema@village.uunet.be).

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Introduction

The knee is the joint most commonly examined at magnetic resonance (MR) imaging. Although the medial collateral ligament (MCL) is frequently injured, descriptions of the appearance of the medial capsular and supporting structures of the knee at MR imaging are often not very detailed (1). Existing classifications of MCL lesions do not address involvement of the superficial and deep portions of the MCL or involvement of the anterior vertical and posterior oblique portions. This may explain why classifications of MCL injuries with MR imaging have been considered inaccurate (2). Because various pathologic conditions may involve the medial aspect of the knee, a more accurate description of pathologic changes with regard to these layers may help accurately define the injured components and the precise extent of the lesions. Certain conditions may be located in or between specific layers, and precise localization of the condition with regard to these layers may help make the differential diagnosis. With this approach, MCL bursitis, meniscal cysts, pes anserinus bursitis, and semimembranosus and semitendinosus bursitis could be differentiated with MR imaging. The purpose of this study was to correlate high-spatial-resolution MR images with anatomic slices by using a three-layer approach. Particular emphasis was placed on identification of all three layers on both anatomic slices and MR images.

Anatomic Considerations

The superficial layer (layer 1) on the medial side of the knee consists of the deep crural fascia (Figs 1, 2) (3). Anterosuperiorly, this fascia is continuous with the fascia overlying the vastus medialis muscle, whereas posteriorly it is continuous with the sartorius muscle. Anteriorly, layer 1 joins layer 2 to form the medial patellar retinaculum (4). Along the middle third of the medial side of the knee, the fascia is separated from the superficial portion of the MCL by a variable amount of fatty tissue. Posteriorly, the fascia is located superficial to the tendons of the semimembranosus, semitendinosus, and gracilis muscles. The tendons of the gracilis and semitendinosus muscles may blend with the fascia or the MCL at their insertion on the tibia (5).

The principal component of the intermediate layer (layer 2) is the superficial portion of the MCL. The superficial portion of the MCL is found along the middle third of the knee and is composed of vertically oriented fibers. It is also referred to as the vertical component of the MCL. Posteriorly with regard to the vertical component of the MCL, the posterior oblique portion of the MCL is found. This posterior oblique portion of the MCL is fused with layer 3 and closely attached to the posteromedial meniscus (1,3,4,6). This conjoined structure is also designated as the posterior oblique ligament. Along the posterior aspect of the knee, this structure receives fibers from the semimembranosus tendon and synovial sheath. It envelops the posterior aspect of the femoral condyle, and in this area it is termed the oblique popliteal ligament.

Layer 3 corresponds to the deepest capsular layer. Anteriorly, layer 3 is continuous with the capsule of the suprapatellar recess, which extends to the margin of the patella (7). Deep to the vertical component of the superficial MCL, the capsule becomes thicker, forming the deep portion of the MCL, which is located close to the meniscus. The deep portion of the MCL is composed of fibers adjacent to the meniscus and of the meniscofemoral and meniscotibial (coronary ligament) extensions. The MCL bursa is located between the superficial and deep portions of the MCL (8), along the middle third of the knee.

Materials and Methods

Six cadaveric specimens were harvested immediately after death and frozen at −30°C. All specimens were derived from elderly patients, although the precise ages of the donors were not available. The specimens were thawed at room temperature for 20 hours. MR imaging was then performed with a 1.5-T clinical system (Vision; Siemens, Erlangen, Germany). We obtained images along the coronal, transverse, and sagittal planes by using a proton-density–weighted fast spin-echo sequence with high spatial resolution (repetition time msec/echo time msec = 3,000/15, 252 × 512 or 128 × 252 matrix, 150 × 240 field of view, 3-mm-thick sections, and two signals acquired).

All specimens were frozen again, and a bandsaw (NSV, Modena, Italy) was used to cut them into 3.0-mm-thick slices along the coronal (n = 4) or transverse (n = 2) imaging plane. The slices...
were photographed, and correlation with the corresponding MR images was performed by consensus of an experienced musculoskeletal radiologist (M.D.M.) and two anatomists (F.V.R., E.B.). A binocular magnification system (Carl Zeiss, Germany) was used to inspect selected areas of the anatomic slices in detail. Selected slices were also dissected to allow better identification of anatomic structures. For image analysis, the medial side of the knee was arbitrarily divided into an anterior, middle, and posterior third. The anterior third was located anterior to the anterior edge of the vertical portion of the MCL. The middle third was located between this edge and the region where layer 2 united with layer 3. The posterior third was located posterior to the junction of layers 2 and 3.

**Figures 1, 2.** (1) Line drawing illustrates the three layers along the middle third of the medial side of the knee. The superficial layer (layer 1) corresponds to the crural fascia (C), the middle layer (layer 2) consists of the superficial portion of the MCL (mcl), and the deep layer (layer 3) consists of the deep portion of the MCL and the meniscofemoral (j) and meniscotibial (t) extensions of the deep MCL. (2) Line drawing shows a transverse section through the knee joint above the level of the joint space. Layers 1 (I) and 2 (II) are fused anteriorly (arrowheads, a), whereas layers 2 (II) and 3 (III) are fused posteriorly (arrowheads, p).

**Figure 3.** Coronal anatomic slice (a) and corresponding MR image (3,000/15) (b) obtained along the anterior third of the medial knee joint. The medial retinaculum (straight arrows) is seen as a band of low signal intensity on the MR image, although two delicate layers are seen on the anatomic slice. The joint capsule (curved arrow in a) and intraarticular gadolinium-based contrast material (+ in b) also are seen.

**MR Imaging–Anatomic Correlation**

**Layer 1**

On anatomic slices obtained along the anterior third of the medial aspect of the knee joint, layer 1 was fused with layer 2 to make up the medial patellar retinaculum. The medial retinaculum was seen as a discrete white band extending from the vastus medialis muscle superiorly to the tibia inferiorly. In two of the six cases, two bandlike structures were apparent instead of one conjoined structure. On MR images, the medial retinaculum was seen as a low-signal-intensity structure (Fig 3).
On anatomic slices obtained along the middle third of the medial aspect of the joint, layer 1 was depicted as a separate structure from layer 2. A variable amount of fatty tissue was interposed between layers 1 and 2. On MR images, the fascia was seen as a thin, low-signal-intensity structure superficial to the superficial portion of the MCL (Fig 4).

On anatomic slices obtained along the posterior third of the medial aspect of the knee joint, layer 1 was located superficially to the gracilis and semitendinosus tendons. Superiorly, it invested the sartorius muscle and tendon, whereas inferiorly it was continuous with the superficial fascia of the lower leg (Fig 5). On MR images, layer 1 was most easily detected posteriorly as a thin, delicate structure with low signal intensity.
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Figure 6. Coronal proton-density–weighted MR image (3,000/15) (b) shows the meniscofemoral (MF) and meniscotibial (MT) extensions of the deep portion of the MCL, deep to the superficial portion of the MCL (arrows). Fat (★) is seen interposed between layers 2 and 3.

Layer 2
On anatomic slices obtained along the middle third of the medial aspect of the knee joint, layer 2 was composed of the superficial portion of the MCL, which was depicted as a white bandlike structure extending from the femoral cortex superiorly to the tibial cortex inferiorly (Fig 6). The vertical component of the MCL was separated from the meniscus by the capsular layer (layer 3), a variable amount of fatty tissue, and the MCL bursa. On MR images, the superficial MCL was seen as a low-signal-intensity structure about 12 cm long, 1–2 cm wide, and 2–4 mm thick (Fig 6). On transverse MR images, the femoral attachment of the vertical component of the MCL was identified adjacent to a small convexity on the femoral condyle termed the medial epicondyle (Figs 7, 8). Along the anterior edge of the vertical
component of the superficial MCL, a split in layer 2 was observed at the level of or slightly above the joint space (Figs 9, 10). The split was best seen on transverse MR images. In our experience, the split may simulate a tear of the anterosuperior portion of the superficial MCL on coronal MR images. Anterior to this 3–6-mm-wide split, layer 2 was fused with layer 1 to form the medial patellar retinaculum.

On anatomic slices obtained along the posterior third of the medial aspect of the knee joint, layer 2 was seen to blend with layer 3 to form the posterior oblique ligament. This ligament enveloped the posteromedial portion of the femoral condyle (Fig 8) and was close to the posterior horn of the medial meniscus.

Layer 3

On anatomic slices obtained along the anterior third of the medial aspect of the knee joint, layer 3 was continuous with the capsule along the suprapatellar recess. The patellomeniscal ligament, which was also a component of layer 3, was seen anteriorly extending from the meniscus to the patellar margin (3,7).

Along the middle third of the knee joint, the meniscofemoral extension of the deep MCL was evident as a thin bandlike structure. The meniscofemoral extension originated from the outer superior margin of the meniscus to blend either with the superficial portion of the MCL or the femoral condyle 1–2 cm above the level of the joint space (Fig 11). The use of intraarticular contrast material or the presence of joint fluid increased detection of the meniscofemoral extension. Inferiorly, the shorter meniscotibial extension originated
from the outer inferior margin of the meniscus to attach to the tibial cortex inferiorly to the joint space. The outer margin of the meniscus could not be distinguished from the capsule and deep portion of the MCL. A variable amount of fatty tissue and the MCL bursa were interposed between the superficial and deep portions of the MCL. On MR images, the meniscofemoral and meniscotibial extensions were detected as low-signal-intensity bandlike structures deep to the superficial portion of the MCL.

Conclusions

In cadaveric specimens, our findings show that a three-layered aspect may often be observed on MR images. Use of the three-layer approach may enable abnormalities involving the medial side of the knee to be described and classified in more detail (2,8). In addition, pathologic conditions may be localized with regard to these layers, limiting differential diagnostic considerations.

References


