Sonography of the Medial and Lateral Tendons and Ligaments of the Knee: The Use of Bony Landmarks as an Easy Method for Identification

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OBJECTIVE. Our purpose was to describe the use of bony landmarks in the evaluation of the medial and lateral ligaments and tendons of the knee on sonography and to evaluate the value of this approach in healthy volunteers.

MATERIALS AND METHODS. Anatomic slices obtained in cadaveric specimens were inspected for the presence of bony landmarks on the medial and lateral aspects of the knee. Then sonography was performed on 40 knees of 20 healthy volunteers by two musculoskeletal radiologists who independently rated the visualization of bony landmarks and adjacent ligaments and tendons on a 5-point grading scale.

RESULTS. Bony landmarks on the lateral aspect of the knee include Gerdy's tubercle on the tibia and the sulcus for the popliteal tendon on the femur. Landmarks on the medial aspect of the knee include the medial epicondyle on the femur and the sulcus for the semimembranosus tendon on the tibia. Visualization of all landmarks was rated in the good to excellent range, and agreement between observers ranged from 92.5% to 100%.

CONCLUSION. Bony landmarks can be identified in healthy adults on the medial and lateral aspects of the knee and may serve as reference points for identification of most medial and lateral tendons and ligaments.

Sonography is increasingly used in the assessment of superficially located soft-tissue structures of the musculoskeletal system [1–3]. Previous reports have addressed the use of sonography in the assessment of abnormal conditions of the knee [2–4], although emphasis was often placed on fluid-containing lesions such as joint effusions, Baker's cysts, and meniscal cysts. Few studies have addressed the assessment of the tendons and ligaments of the knee using sonography [5–7]. Even the experienced radiologist may find it difficult to identify the medial and lateral ligaments and tendons on sonography in every patient. Precise identification of ligaments and tendons is essential to identifying and locating abnormalities relative to these structures.

During knee trauma, the medial collateral ligament may be affected; tears in this ligament can be diagnosed on sonography [6]. Other abnormal conditions on the medial side of the knee that may be diagnosed using sonography include meniscal cysts, pes anserinus bursitis, and semimembranosus bursitis [4, 8, 9]. On the lateral aspect of the knee, the iliotibial band is affected in patients with iliotibial band friction syndrome [10, 11]. Injuries of the posterolateral structures include tears of the popliteal tendon, lateral collateral ligament, and biceps tendon [12, 13].

We developed a systematic approach to the sonographic imaging of the medial and lateral sides of the knee that is based on our observations of structures in cadaveric slices. Our approach makes use of the presence of bony landmarks on the distal femur and the proximal tibia. The bony landmarks on the lateral aspect of the knee include a small protuberance of the cortex—designated "Gerdy's tubercle"—on the tibia and the sulcus for the popliteal tendon on the femur. The landmarks on the medial side of the knee include the femoral epicondyle on the femur and the sulcus for the semimembranosus tendon on the posteromedial aspect of the tibia. Once the sonography transducer is placed at the bony landmark, identification of the various ligaments and tendons can be made almost automatically (Fig. 1). In our study, the first aim was to identify the bony landmarks on anatomic slices of the knee and to indirectly cor-

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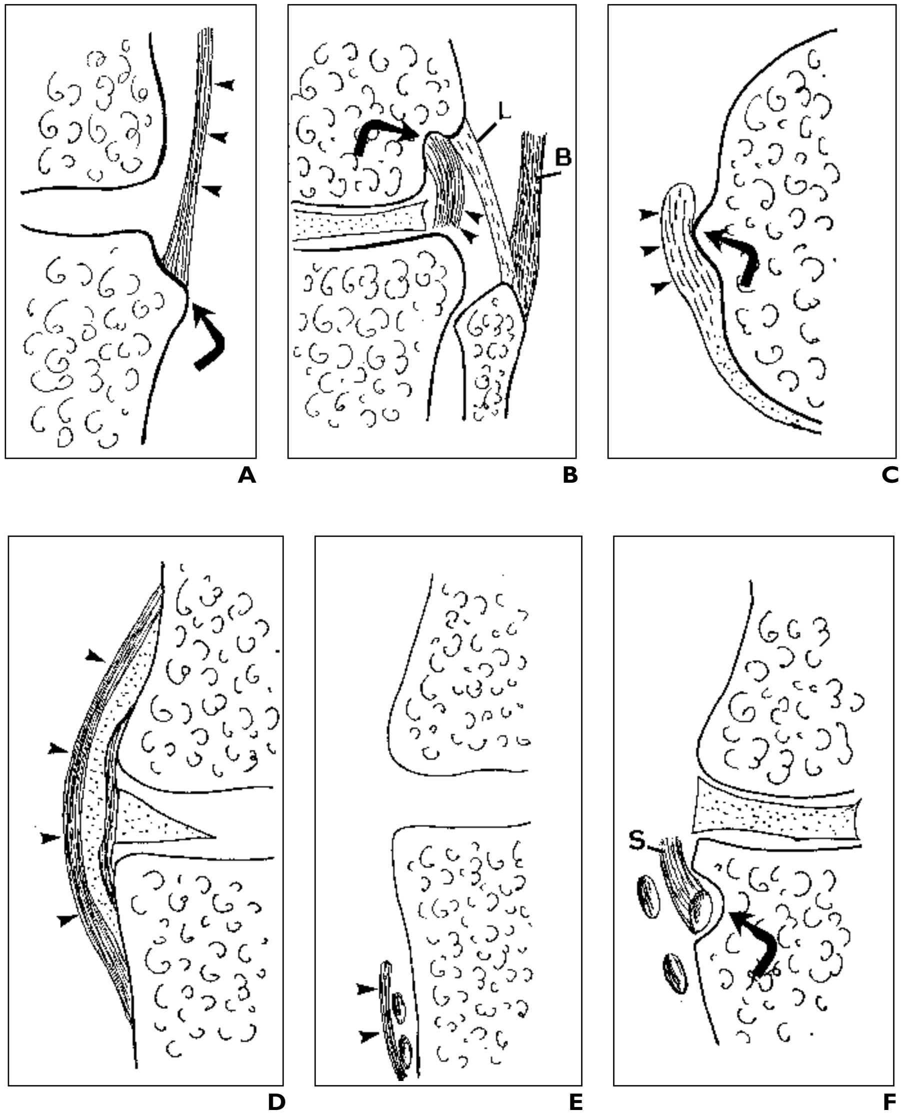


Fig. 1.—Schematic line drawings illustrate landmark approach to correctly identifying medial and lateral tendons and ligaments of knee.
A, With sonography transducer placed in coronal plane at anterolateral aspect of tibia, Gerdy's tubercle (*arrow*) and iliotibial band (*arrowheads*) can be seen.
B, With transducer placed in coronal plane at posterolateral aspect of femur, sulcus for popliteal tendon (*arrow*) can be detected as well as popliteal tendon (*arrowheads*), lateral collateral ligament (L), and biceps tendon (B).
C, Transverse sonographic section obtained at medial femoral condyle allows identification of femoral epicondyle (*arrow*) and adjacent medial collateral ligament (*arrowheads*).
D, With transducer then turned back in coronal plane, medial collateral ligament (*arrowheads*) is shown in its long axis.
E, When transducer is moved anteroinferiorly, pes anserinus (*arrowheads*) is visualized at its insertion.
F, Sonographic section obtained along posteromedial aspect of knee shows sulcus for semimembranosus tendon (*arrow*) and tendon itself (S).

relate the findings from these slices with those on MR images and sonograms. The second aim was to investigate the detection of bony landmarks and soft-tissue structures in healthy volunteers.

Materials and Methods

From the department of anatomy at one of our institutions, we obtained anatomic slices of the knee from six cadaveric specimens. These specimens had been used in a previous imaging project; correlating MR images for these slices were also available [14]. The slices had been prepared by sectioning deep-frozen cadaveric knees into 3-mm-thick slices with a band saw (NSV, Modena, Italy). Representative slices depicting the bony landmarks were selected by the principal investigator and then photographed. The medial side of an additional cadaveric specimen obtained from an elderly subject was dissected to show the location of the insertions of the pes anserinus tendons relative to the medial collateral ligament.

Two musculoskeletal radiologists independently evaluated both knees of 20 asymptomatic volunteers (14 men and six women) using sonography. The age of the volunteers ranged from 18 to 53 years (mean age, 31 years). They had no clinical symptoms related to the knee at the time of the examination and did not recall any previous episode of knee trauma that required a surgical or arthroscopic procedure. All examinations were performed on a clinical sonography system (Prosound 5500; Aloka, Tokyo, Japan) using a 10-MHz transducer. The transducer was first placed over the expected location of the bony landmark, and the visualization of the landmark was graded on a 5-point scale (1, not visualized; 2, moderate visualization; 3, good visualization; 4, very good visualization; and 5, excellent visualization).

As the transducer was positioned over each landmark, the observers systematically recorded the visualization of the ligaments and tendons (Figs. 1 and 2). The iliotibial band was evaluated at the level of Gerdy's tubercle on the lateral aspect of the tibia. At the popliteal sulcus level, the popliteal tendon, lateral collateral ligament, and biceps tendon were investigated. At the level of the medial femoral epicondyle, the superficial and deep medial collateral ligaments (femoral and tibial extensions) and the pes anserinus were evaluated. When the transducer was placed along the superficial medial collateral ligament in the coronal plane, the pes anserinus could be visualized by moving the transducer inferiorly and slightly anteriorly over the medial tibial cortex. At the level of the semimembranosus sulcus, the semimembranosus, gracilis, and semitendinosus tendons were studied, as well as the posteromedial aspect of the meniscus.

Using the same grading scale as they used for the landmarks, the observers rated the visualization of each ligament and tendon. A mean score for each landmark and soft-tissue structure was calculated for each investigator separately. Agreement between the grades assigned by both observers was also calculated (overall percentage of agreement). For this calculation, agreement was considered to be present when the scores from both observers were the same or only one grade apart.

To provide a correlation between MR images and sonograms, we recruited a volunteer (not included in the numeric analysis) to undergo both

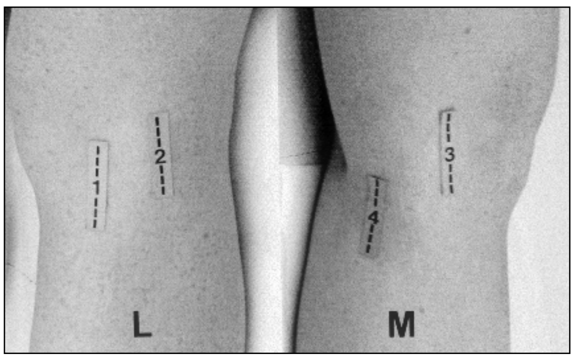


Fig. 2.—Photograph of lateral (L) and medial (M) aspects of knee of 34-year-old man shows transducer positions 1–4 for obtaining principal coronal sections illustrated in Figure 1.

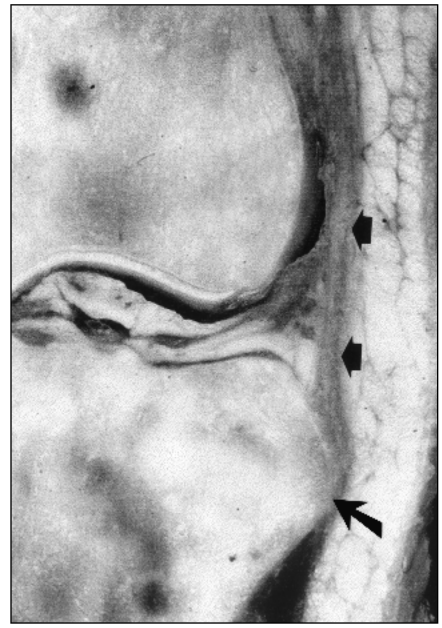


Fig. 3.—Photograph of anatomic section from cadaver shows Gerdy's tubercle (*long arrow*) and iliotibial band (*short arrows*).

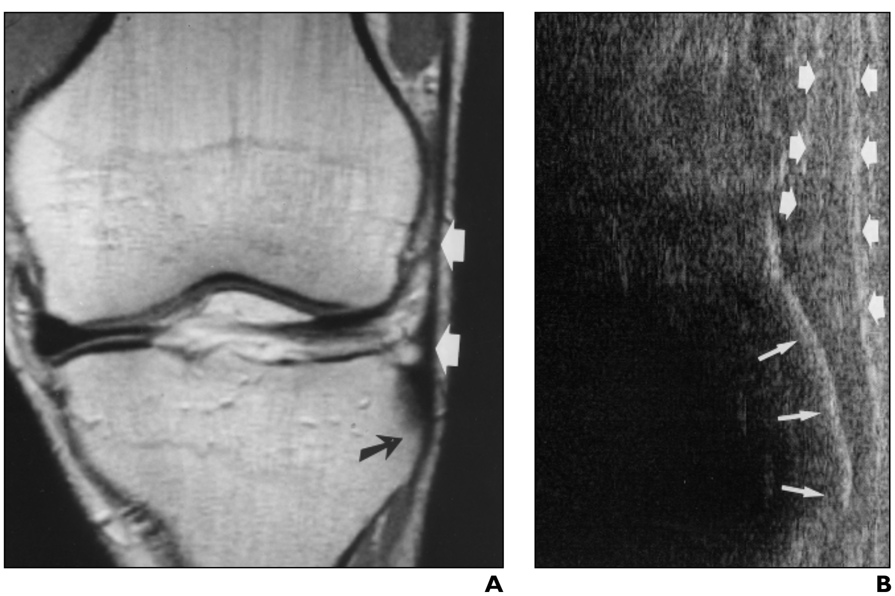


Fig. 4.—Gerdy's tubercle in 34-year-old man.
A, Coronal MR image (TR/TE, 2900/15) shows Gerdy's tubercle (*black arrow*) and iliotibial band (*white arrows*).
B, Sonogram corresponding to **A** reveals Gerdy's tubercle (*long arrows*) and iliotibial band (*short arrows*).

Fig. 5.—Photograph of anatomic slice from cadaver shows sulcus for popliteal tendon (*arrowheads*), lateral collateral ligament (*arrows*), and popliteus tendon (*star*).

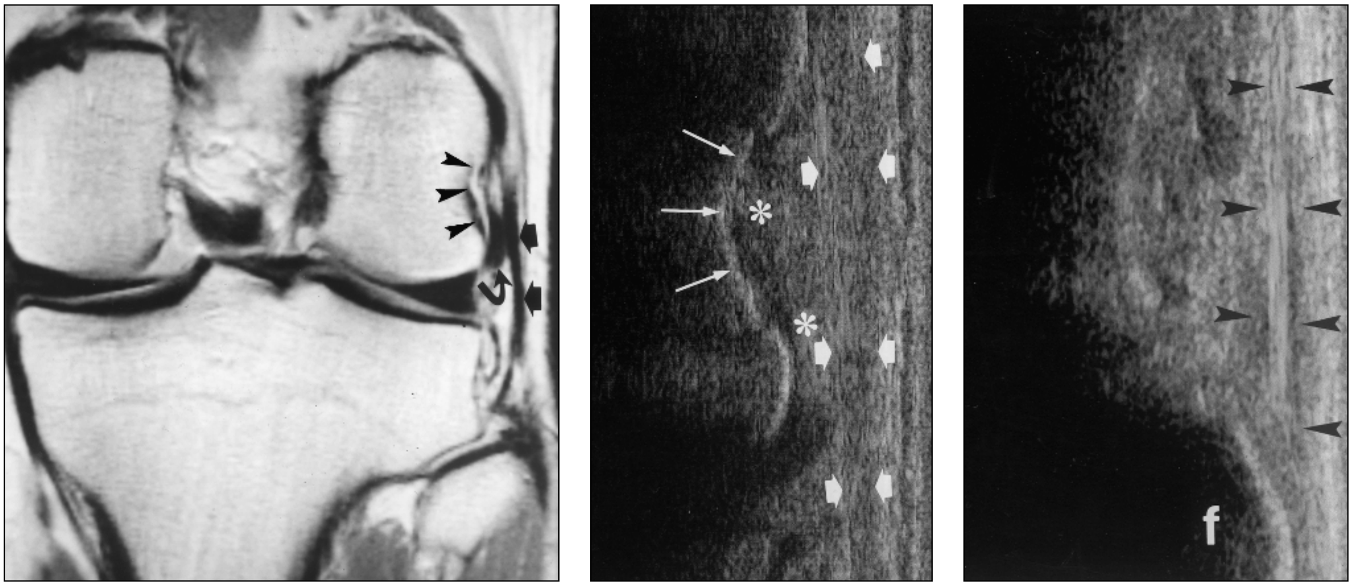


Fig. 6.—Sulcus for popliteal tendon in 34-year-old man.
A, Coronal MR image (TR/TE, 2900/15) reveals sulcus for popliteal tendon (*arrowheads*), lateral collateral ligament (*straight arrows*), and popliteal tendon (*curved arrow*).
B, Corresponding sonogram shows sulcus for popliteal tendon (*long arrows*), popliteal tendon (*asterisks*), and proximal portion of lateral collateral ligament (*short arrows*).
C, Corresponding sonogram shows distal portion of lateral collateral ligament (*arrowheads*) adjacent to fibular head (f).

MR imaging and sonography of his right knee. Proton density–weighted MR images were obtained in the coronal and transverse planes on a 1.5-T clinical system (Vision; Siemens, Erlangen, Germany). The MR imaging parameters were TR/TE, 2900/15; signals averaged, 2; section thickness, 3 mm; matrix size, 252 × 512; and field of view, 150 × 240. Sonography was performed with a 12-MHz transducer. The MR images and sonograms obtained in this volunteer were compared with respect to visualization of landmarks and soft-tissue structures.

Fig. 7.—Photograph of transverse anatomic slice from cadaver shows femoral epicondyle (*arrow*) as well as adjacent medial collateral ligament (*arrowheads*).

Results

On the coronal anatomic slices, Gerdy's tubercle was easily recognizable as a protuberance along the anterolateral aspect of the tibia. The iliotibial tract, which on the anatomic slices consisted of two separate layers, was found to terminate on this bony protuberance (Figs. 3 and 4). Also on coronal anatomic slices of the knee, a sulcus was evident at the posterolateral femoral condyle. The popliteal tendon originated from this sulcus and then penetrated the meniscus through the popliteal hiatus. Along the superficial aspect of the popliteal tendon, the lateral collateral ligament was revealed as a 3-mm-thick white bandlike structure coursing in an oblique direction from the anterosuperior to the posteroinferior position (Figs. 5 and 6).

On the transverse anatomic slices, the medial femoral epicondyle could be identified as a small bony protuberance along the middle third of the medial aspect of the femoral condyle. This protuberance was less well recognized on coronal slices, however. The location of the insertion of the femoral portion of the superficial medial collateral ligament was observed to be on the medial epicondyle. The anterior edge of the medial collateral ligament was sharply demarcated from fatty tissue (Figs. 7–9). At anatomic dissection, the pes anserinus tendons were observed to insert onto the tibia anteroinferiorly to the tibial attachment of the superficial medial collateral ligament (Figs. 9 and 10). On the coronal anatomic slices obtained along the posterior third of the medial side of the knee, the anterior termination of the semimembranosus tendon was found in a large sulcus in the tibial cortex. More superficially and inferiorly, the gracilis and semitendinosus tendons could be recognized, whereas superiorly the posterior horn of the medial meniscus was easily distinguished from adjacent fatty tissue (Figs. 11 and 12).

The visualization scores for landmarks, ligaments, and tendons are summarized in Table 1. The visualization scores for all four landmarks were in the very good to excellent range. Visualizations of the superficial medial collateral ligament, pes anserinus, semimembranosus tendon, iliotibial band, popliteal tendon, and biceps tendon also were rated in the very good to excellent range. Visualizations of the meniscofemoral ligament, gracilis tendon, posteromedial meniscus, and lateral collateral ligament were rated in the good to very good range, whereas scores for visualizations of the meniscotibial ligament and semitendinosus tendon were in the moderate to good range.

Agreement between observers ranged from 92.5% to 100% for the bony landmarks (Table 2). Agreement was more than or equal to 90% for visualizations of the medial collateral ligament, pes anserinus, semimembranosus tendon, iliotibial tract, popliteal tendon, and biceps tendon. Agreement was equal to or more than 70% for visualizations of the meniscofemoral extension, gracilis tendon, posteromedial meniscus, and lateral collateral ligament. Agreement was 55% for visualizations of the meniscotibial extension, and 47.5% for visualizations of the semitendinosus tendon. The bony landmarks as visualized on the MR images of the “benchmark” volunteer correlated well with findings on sonography.

Discussion

At our institutions, a typical sonographic examination of the knee is accomplished in three phases. The examination starts with the patient in a supine position with the foot on the examination table and the knee flexed at a 30° angle. The anterior aspect of the knee is examined in the sagittal and transverse planes, with an emphasis on the quadriceps and patellar tendon. The suprapatellar recess also is examined with the knee in this position. This portion of the examination usually presents little difficulty, even to the inexperienced radiologist. For the second phase of the examination, the patient remains in a supine position, but the leg is placed on the table with the knee fully extended. In this position, the medial and lateral aspects of the knee are examined using the landmark approach that is the subject of this article. This part of the examination generally is more difficult, and we developed the landmark approach in an attempt to systematize and simplify this phase of the examination. Finally, the patient is placed in a prone position, and the posteromedial aspect of the knee is examined for the presence of a Baker’s cyst.

When the sonography transducer is placed in the coronal plane at the anterolateral aspect of the tibia, Gerdy’s tubercle is easily depicted, as shown by our observations in the volunteers. The iliotibial band inserts directly onto Gerdy’s tubercle and is depicted on sonograms as a hyperechoic 3-mm-thick bandlike structure. The iliotibial band con-

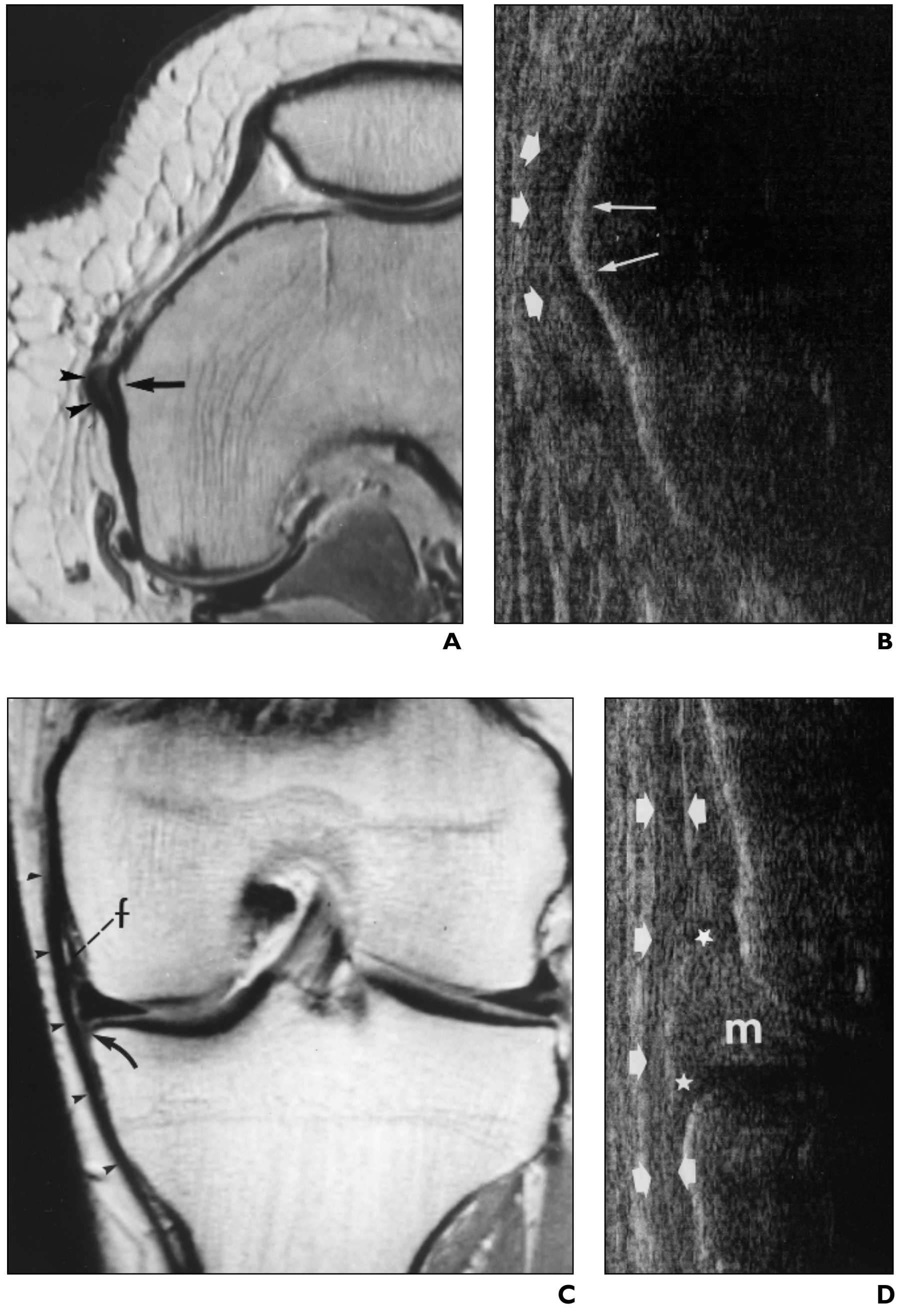


Fig. 8.—Femoral epicondyle in 34-year-old man.
A, Transverse MR image (TR/TE, 2900/15) shows femoral epicondyle (*arrow*) and medial collateral ligament (*arrowheads*).
B, Transverse sonogram corresponding to **A** shows femoral epicondyle (*long arrows*) and medial collateral ligament (*short arrows*).
C, Coronal MR image (2900/15) shows superficial medial collateral ligament (*arrowheads*) and meniscofemoral (f) and meniscotibial (*arrow*) portion of deep medial collateral ligament.
D, Sonogram corresponding to **C** shows superficial (*arrows*) and deep (*stars*) medial collateral ligament as well as meniscus (m).

sists anatomically of two layers, but these may be difficult to identify on sonography (Figs. 3 and 4). In patients with iliotibial band friction syndrome, a bursa may have formed between the femoral condyle and the iliotibial tract, or periligamentous fluid collections may be apparent [10, 11].

The popliteal tendon originates in a sulcus along the posterolateral aspect of the femur (Fig. 5). When the sonography transducer is placed in the coronal plane along the posterolateral aspect of the knee, the sulcus is easily identifiable as a depression in the femoral cortex [13]. The tendon of the popliteus muscle is located in this sulcus. Depending on the angle of the incident sonographic beam, considerable anisotropic artifact may be evident in the popliteal tendon, and thus its echogenicity may vary from hypoechoic to hyperechoic. Once the sulcus for the popliteal tendon has been identified, the lateral collateral ligament can also be recognized. The lateral collateral ligament corresponds to a hyperechoic band that is 3–4 mm thick, originating on the lateral femur and terminating on the fibular head. The lateral collateral ligament courses over the sulcus for the popliteal tendon and is located superficially in relation to the tendon. The lateral collateral ligament can be easily followed distally, where it fuses with the biceps tendon.

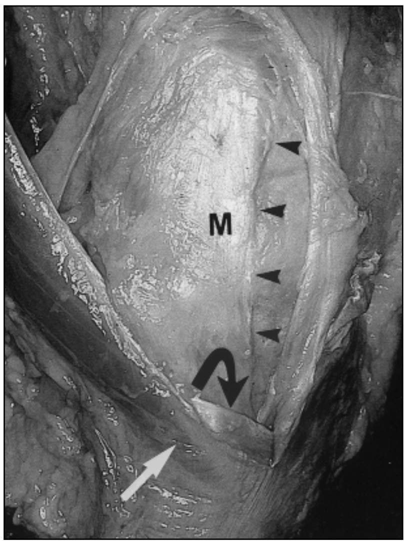


Fig. 9.—Photograph of anatomic slice of medial side of knee of cadaver shows pes anserinus adjacent to inferior aspect of medial collateral ligament (M). Anterior margin (*arrowheads*) of superficial medial collateral ligament is outlined. Gracilis (*curved arrow*) and sartorius (*straight arrow*) tendons are seen. Semitendinosus tendon is located deep in relation to the sartorius (not shown).

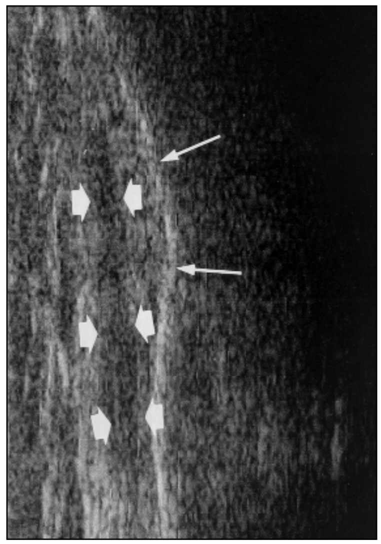


Fig. 10.—Coronal sonogram obtained in 34-year-old man through pes anserinus (*short arrows*) shows anteromedial tibial cortex (*long arrows*).

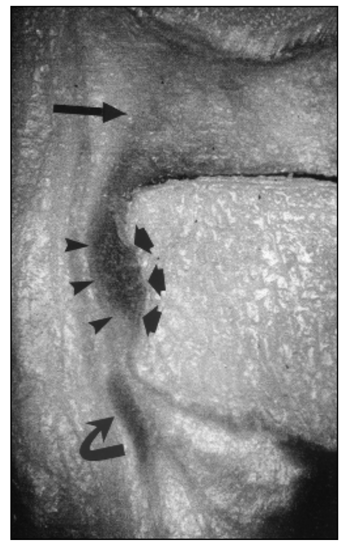
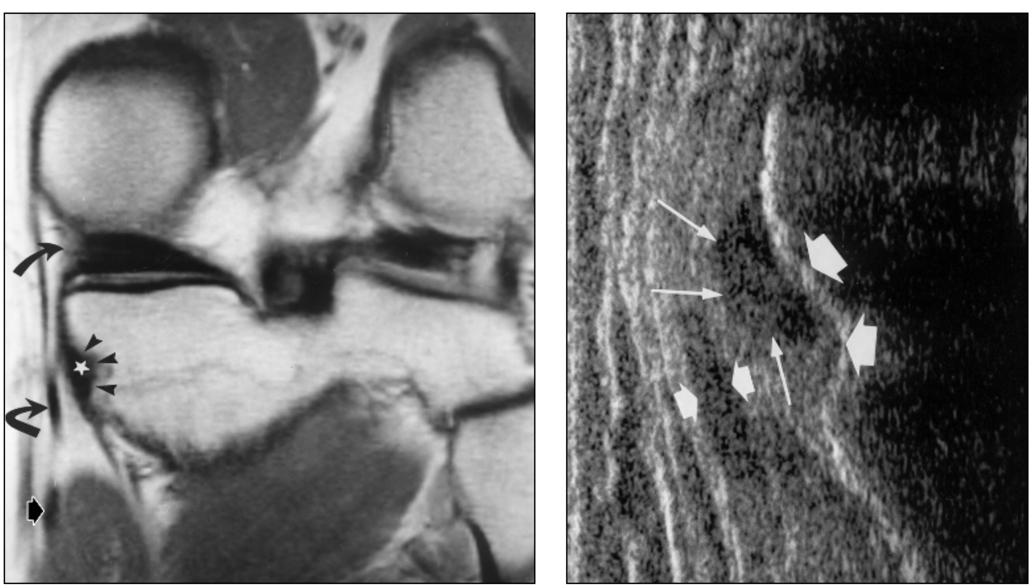


Fig. 11.—Photograph of coronal anatomic slice from cadaver shows sulcus for semimembranosus tendon (*short straight arrows*). Also note semimembranosus tendon (*arrowheads*) and gracilis tendon (*curved arrow*). Posteromedial meniscus is also visible (*long straight arrow*).



A B

Fig. 12.—Sulcus for semimembranosus in 34-year-old man.
A, MR image (TR/TE, 2900/15) reveals posteromedial meniscus (*bowed arrow*) and sulcus for semimembranosus (*arrowheads*) in addition to semimembranosus (*star*), gracilis (*curved arrow*), and semitendinosus (*short arrow*) tendons.
B, Corresponding sonogram shows semimembranosus tendon (*long arrows*) located in sulcus (*small short arrows*) as hypoechoic. Gracilis tendon (*large short arrows*) also is delineated.

TABLE 1 Mean Scores (and SD) for Visualization of Bony Landmarks and Soft-Tissue Structures on Sonography

Aspect of Knee	Bony Landmark	Observer 1	Observer 2	Associated Ligaments or Tendons	Observer 1	Observer 2
Lateral	Gerdy's tubercle	4.82 ± 0.59	4.55 ± 0.67	Iliotibial band	4.65 ± 0.48	4.65 ± 0.62
	Popliteal sulcus	4.65 ± 0.57	4.50 ± 0.75	Popliteal tendon	4.67 ± 0.52	4.75 ± 0.49
				Biceps tendon	4.35 ± 0.57	4.30 ± 0.85
				LCL	3.85 ± 0.62	4.75 ± 0.58
Medial	Medial epicondyle	4.95 ± 0.22	4.50 ± 0.59	MCL	4.27 ± 0.50	4.75 ± 0.43
				Meniscofemoral ext.	3.74 ± 0.54	3.69 ± 1.40
				Meniscotibial ext.	3.42 ± 0.81	2.30 ± 1.39
				Pes anserinus	4.55 ± 0.55	4.82 ± 0.44
	SMB sulcus	4.97 ± 0.15	4.97 ± 0.15	Semimembranosus tendon	4.27 ± 0.27	4.33 ± 0.59
				Gracilis tendon	3.77 ± 0.53	4.47 ± 0.64
				Semitendinosus tendon	3.10 ± 1.19	2.72 ± 1.75
				Posteromedial meniscus	3.86 ± 0.62	4.34 ± 1.04

Note.—LCL = lateral collateral ligament, MCL = medial collateral ligament, ext. = extension, SMB = semimembranosus.

TABLE 2 Percentage of Agreement Between Two Observers on Quality of Visualization of Bony Landmarks, Ligaments, and Tendons on Sonography

Aspect of Knee	Bony Landmark	Percentage of Agreement	Associated Ligaments or Tendons	Percentage of Agreement
Lateral	Gerdy's tubercle	92.5	Iliotibial band	97.5
	Popliteal sulcus	95.0	Popliteal tendon	95.0
			Biceps tendon	90.0
			Lateral collateral ligament	72.5
Medial	Medial epicondyle	100.0	Medial collateral ligament	100.0
			Meniscofemoral extension	77.5
			Meniscotibial extension	55.0
			Pes anserinus	100.0
	Semimembranosus sulcus	100.0	Semimembranosus tendon	90.0
			Gracilis tendon	87.5
			Semitendinosus tendon	47.5
			Posteromedial meniscus	75.0

The medial femoral epicondyle corresponds to a small protrusion on the medial aspect of the femur, located about 3 cm superior to the level of the joint space. On transverse anatomic slices, this small bony protrusion is triangular. We found that when the transducer was placed in the transverse plane along the medial aspect of the femur, the medial epicondyle could be accurately identified in most of our volunteers.

The superior part of the superficial medial collateral ligament inserts onto the femoral epicondyle. On transverse sonograms, the medial collateral ligament can appear as a bandlike structure that is slightly hypoechoic relative to adjacent fatty tissue. The anterior margin of the medial collateral ligament is sharply demarcated from the hyperechoic fatty tissue [14, 15]. The superficial medial collateral ligament fuses posteriorly with the capsule. From the transverse plane, the transducer can be turned in the coronal plane to obtain a coronal section of the medial collateral ligament. The medial collateral ligament has a three-layered aspect on sonography, with a hyperechoic superficial layer, a hypoechoic intermediate layer, and a hyperechoic deep layer (Fig. 8). The superficial layer corresponds to the superficial medial collateral ligament, the intermediate layer corresponds to fatty tissue or a fluid-filled medial collateral ligament bursa, and the deep layer corresponds to the deep medial collateral ligament, including the meniscofemoral and meniscotibial extensions [16].

The presence of anisotropy causes variable echogenicity of the superficial and deep medial collateral ligament. Our findings show that the superficial portion of the medial collateral ligament is easily recognized in most patients. Agreement and visualization scores were lower for the deep portion of the medial collateral ligament, especially for the meniscotibial portion, a finding that indicates that the latter may be more difficult to identify on sonography. When the transducer is moved from over the joint line to a more anteroinferior position along the tibial cortex, a coronal section through the pes anserinus can be obtained.

The insertion of the pes anserinus is made up of portions of the sartorius, gracilis, and semitendinosus tendons. The intermingling of tendons occurring at the insertion of the pes anserinus onto the tibia shows considerable anatomic variability [17]. Therefore, at the insertion, discernment of the different components that make up the pes anserinus can be difficult. The pes anserinus bursa, which is not usually seen in healthy adults, may be evident adjacent to the pes anserinus tendons when inflamed [18].

The semimembranosus tendon shows several terminations at the posteromedial aspect of the knee. One of the main terminations inserts into a sulcus on the posteromedial aspect of the tibia [9, 19]. When the transducer is placed in the coronal plane along the posterior third of the medial side of the knee, this sulcus can be easily identified as a focal depression of the hyperechoic cortical line (Fig. 12). The semimembranosus tendon in this sulcus is depicted on sonography as a hyperechoic structure, although the tendon may show considerable anisotropy artifact. Semimembranosus bursitis may be diagnosed in patients with a fluid effusion visible adjacent to the tendon insertion [9, 20]. More inferior in relation to the semimembranosus tendon, the gracilis and semitendinosus tendons may be depicted as oval structures. Visualization of the semitendinosus tendon, however, appears to be quite difficult on sonography in this location, as shown by our results in the volunteers. In our experience, the semitendinosus tendon is more easily visualized along the posterior aspect of the medial femoral condyle, where it is located superficially relative to the semimembranosus tendon.

Superior to the sulcus for the semimembranosus tendon, the posteromedial aspect of the meniscus is evident. This area of the meniscus is commonly involved with meniscal tears, and adjacent meniscal cysts may be identified as perimeniscal hypoechoic collections [4].

Some limitations apply to our investigation. The presence of landmarks was not systematically evaluated in a large number of cadaveric specimens. Representative examples were selected from among existing cadaveric slices. Hence, we did not take all possible anatomic variants into account. Nevertheless, sonograms obtained in our volunteers consistently showed that the landmarks were present in most individuals.

The mean age of the volunteers included in our study was 31 years, and it might be argued that the landmarks would be more difficult to identify in elderly patients with osteoarthritis. However, we believe that the mean age of our volunteers is representative of the patient population who typically undergoes sonography of the knee. In addition, we believe that the findings obtained in our population of volunteers can be extrapolated to the general adult population.

Our examinations in volunteers were performed with a 10-MHz transducer. The use of a 12-MHz transducer may have resulted in better visualization scores than those obtained in our study. We did not assess imaging of abnormal ligaments and tendons, and sonography of injured soft-tissue structures may give different results than those in our study. In our experience, however, the presence of edema and thickening in soft-tissue injuries makes detection of soft-tissue structures easier. In addition, we could not entirely exclude the possibility that some of the volunteers may have had knee abnormalities that influenced visualizations of structures because they may not have remembered previous episodes of knee trauma.

In summary, the use of four bony landmarks along the medial and lateral aspects of the knee, including Gerdy's tubercle, the sulcus for the popliteal tendon, the medial epicondyle, and the sulcus for the semimembranosus tendon, may help one to accurately identify most medial and lateral tendons and ligaments of the knee.

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