Ultrasound of the Thigh: Focal, Compartmental, or Comprehensive Examination?

Ricardo Augusto Lutterbach-Penna[1]
Monica Kalume-Brigido
Yoav Morag
Tracy Boon
Jon Arthur Jacobson
David Paul Fessell

OBJECTIVE. Ultrasound of the thigh presents unique challenges because of the size and length of multiple structures, including tendons, muscles, nerves, and vessels. Those performing ultrasound can use a focal approach, a comprehensive approach, or a compartmental and flexible approach.

CONCLUSION. This article illustrates and summarizes our approach to ultrasound of the thigh, including unique anatomy, artifacts, and common abnormalities, with an emphasis on the advantages of performing a compartment-based and flexible ultrasound examination.

Ultrasound and MRI are the two major diagnostic imaging modalities for evaluating the soft tissues of the thigh. Advances in ultrasound technology, including higher-frequency transducers, allow diagnosis of many types of musculoskeletal abnormalities, in many cases with an accuracy similar to that of MRI [1–4].

Ultrasound has additional advantages compared with MRI, such as lower cost and real-time dynamic evaluation [1–3, 5]. Ultrasound also provides a quick comparison with the opposite extremity, offers the use of color Doppler imaging, allows rapid differentiation between fluid and solid tissue, has a flexible FOV, is portable, and can guide therapeutic interventions [1, 3, 5–7]. Ultrasound cannot, however, image deeply to the cortex of the bone or evaluate bone marrow abnormalities. An additional limitation of ultrasound is operator dependency. As with other body parts, performing a systematic and comprehensive examination can help address the issue of operator dependency.

Depending on the indication and the patient's history and symptoms during the ultrasound examination, a complete ultrasound examination, including the anterior, medial, and posterior thigh, can be performed with special attention to the area of maximum symptoms. A limited and much more focused ultrasound examination of a specific site of concern, such as the rectus femoris, optimizes efficiency and is a response to the increasing push for efficiency in health care [8]. A compartmental and flexible approach examines a minimum of one entire compartment. Additional compartments can be examined depending on the clinical symptoms and ultrasound findings. We also use a checklist to help ensure that all structures within a compartment are evaluated. When scanning the large area of the thigh, which includes multiple tendons, neurovascular structures, and potential fluid collections, should the examination be complete, focal, or compartmental and flexible?

This article illustrates and summarizes our approach to ultrasound of thigh abnormalities, including unique anatomy, artifacts, and common abnormalities, with our perspective on performing a compartmental and flexible ultrasound examination.

General Considerations

The appropriate transducer is important for the optimal examination. Typically, a 10- to 17-MHz linear array transducer is used, and, for a larger body habitus, a lower-frequency transducer (5–7 MHz) is helpful. Lower-frequency transducers are also important to ensure that the deeper soft tissues and surface of the femur are adequately assessed as an important component of any ultrasound examination. Curved transducers are usually used for examination of the hip only when deeper penetration is needed. In general, for the long muscles of the quadriceps and hamstrings, we first scan in the transverse plane. This aids orientation and localization and is followed by longitudinal scanning. When needed, a trapezoidal for-

Keywords: muscle, scanning, technique, tendon, thigh, trauma, ultrasound

DOI:10.2214/AJR.13.12286

Received November 23, 2013; accepted after revision February 24, 2014.

[1]All authors: Division of Musculoskeletal Radiology, University of Michigan Health System, 1500 E Medical Center Dr, SPC 5030, Ann Arbor, MI 48109. Address correspondence to D. P. Fessell (fessell@umich.edu).

AJR 2014; 203:1085–1092

0361–803X/14/2035–1085

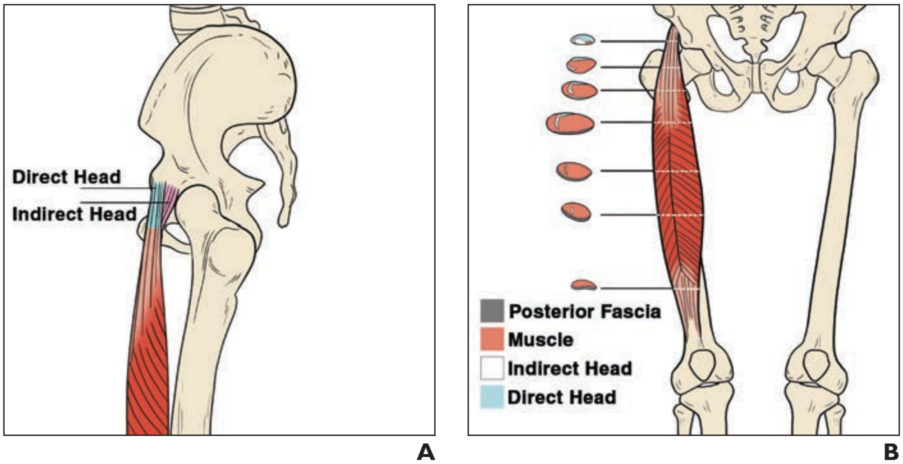


Fig. 1—Muscle and tendon anatomy of thigh. (Illustrations by Nowak C)
A, Illustration in sagittal plane shows rectus femoris direct head origin at anterior inferior iliac spine (AIIS) and indirect head more posteriorly at acetabular ridge.
B, Illustration shows rectus femoris origin at AIIS and insertion on patellar in coronal plane. Corresponding axial illustrations show central tendon posterior fascia and indirect and direct heads.

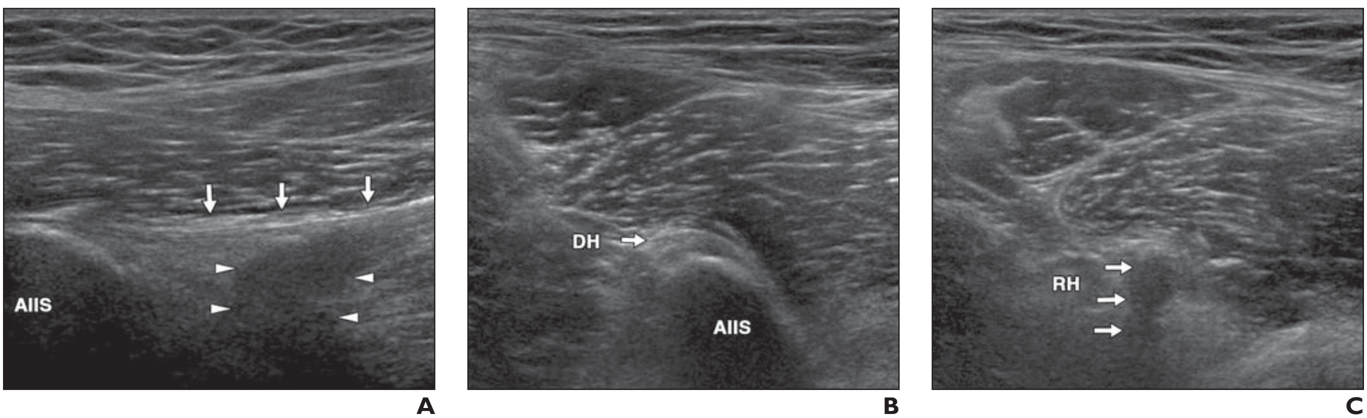


Fig. 2—31-year-old man with normal sonogram of rectus femoris.
A, Longitudinal sonogram at level of anterior inferior iliac spine (AIIS) shows normal hyperechoic fibrillar appearance of more superficial rectus femoris direct head (*arrows*). Posterior acoustic shadowing (*arrowheads*) corresponds to oblique course of rectus femoris indirect (reflected) head as it attaches at acetabular ridge.
B and **C,** Transverse sonograms show direct head (DH) (*arrow*, **B**) at AIIS and indirect (reflected) head (RH, **C**) with posterior acoustic shadowing (*arrows*, **C**) due to its oblique course.

mat can be used to provide a slightly wider FOV. Extended FOV sonography is a useful technique for musculoskeletal ultrasound, especially in cases of fluid collections, retracted tendon tears, and masses [5]. Extended FOV images can provide additional information regarding spatial relationships, is helpful for communicating with clinicians, and allows an accurate measurement over relatively long distances, such as is commonly needed in the thigh [5, 9].

Anterior Thigh Compartment: Special Anatomy, Scan Tips, and Artifacts

The rectus femoris has two heads, direct and reflected (indirect), with origins from the anterior inferior iliac spine and anterolateral acetabulum, respectively [10–12] (Fig. 1A). The direct head forms the anterior and more superficial tendon, and the reflected head forms the central tendon, also known as the central aponeurosis [10, 11] (Fig. 1B).

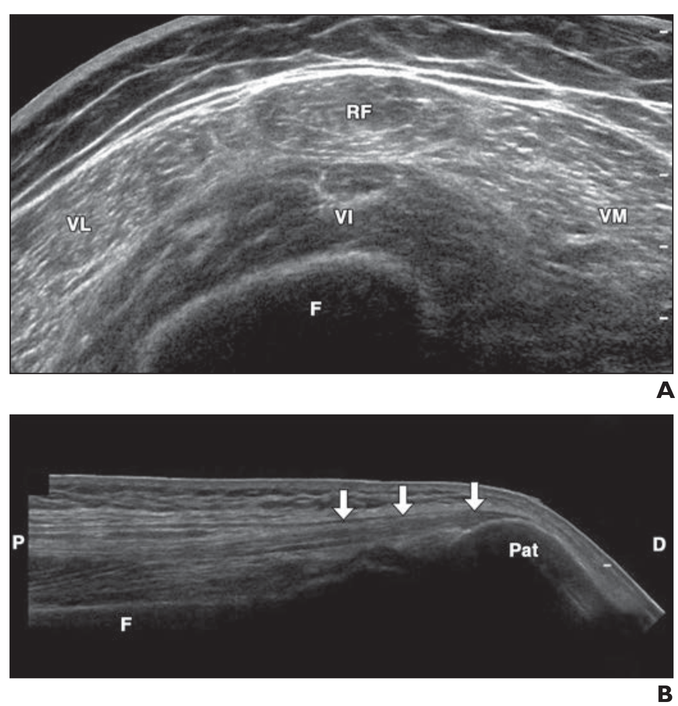


Fig. 3—31-year-old man with normal anterior thigh.
A, Extended FOV transverse sonogram of anterior thigh shows rectus femoris (RF), vastus lateralis (VL), vastus intermedius (VI), and vastus medialis (VM) muscles anterior to femur (F).
B, Longitudinal sonogram shows quadriceps tendon (*arrows*) inserting on patella (Pat). D = distal, P = proximal.

The anterior inferior iliac spine is used as an osseous landmark for the origin of the direct head. The shadowing just distal and medial to the origin of the direct head corresponds to the oblique course of the indirect (reflected) head and its origin at the acetabular ridge (Figs. 2A and 2B). Awareness of this artifact is needed to help prevent misdiagnosis as tendon abnormalities.

The quadriceps femoris is formed by the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis muscles. The rectus femoris and vastus muscles are evaluated from their origins to their insertions at the patella, first in the axial plane and then in the longitudinal plane. Because of the size and length of the thigh muscles, extended FOV sonography can be especially helpful to show the full extent of muscle or tendon abnormalities (Fig. 3).

Anterior Compartment Abnormalities

The rectus femoris muscle is the most frequently injured of the quadriceps muscles [2, 11]. Both partial tears, which usually involve the more superficial components of the quadriceps femoris, and complete tears can occur. Here, the term "partial tear" indicates a partial-width or -thickness tear, and a "complete tear" indicates tendon rupture (full thickness or full width).

Rectus Femoris

Injury of the rectus femoris is highly related to sports activity. It is particularly common when the athlete performs a kick [11–14]. The long fusiform shape of the rectus femoris, the predominance of type 2 fibers, a tendency for eccentric muscle contraction, and an anatomy spanning two joints (hip and knee) all increase its susceptibility to injury [2, 12, 13]. Proximal rectus femoris injuries can also be a cause of groin pain [15, 16].

Most injuries to the rectus femoris muscle are located at the proximal musculotendinous junction and distal insertion and affect the central tendon [13, 17]. The normal sonographic appearance of the central tendon is an echogenic well-defined linear structure. When acutely injured, the central tendon appears ill defined, thickened, and heterogeneous. Acute lesions normally present without central tendon retraction. Fluid around the central tendon can also be seen as a bull's-eye appearance on ultrasound

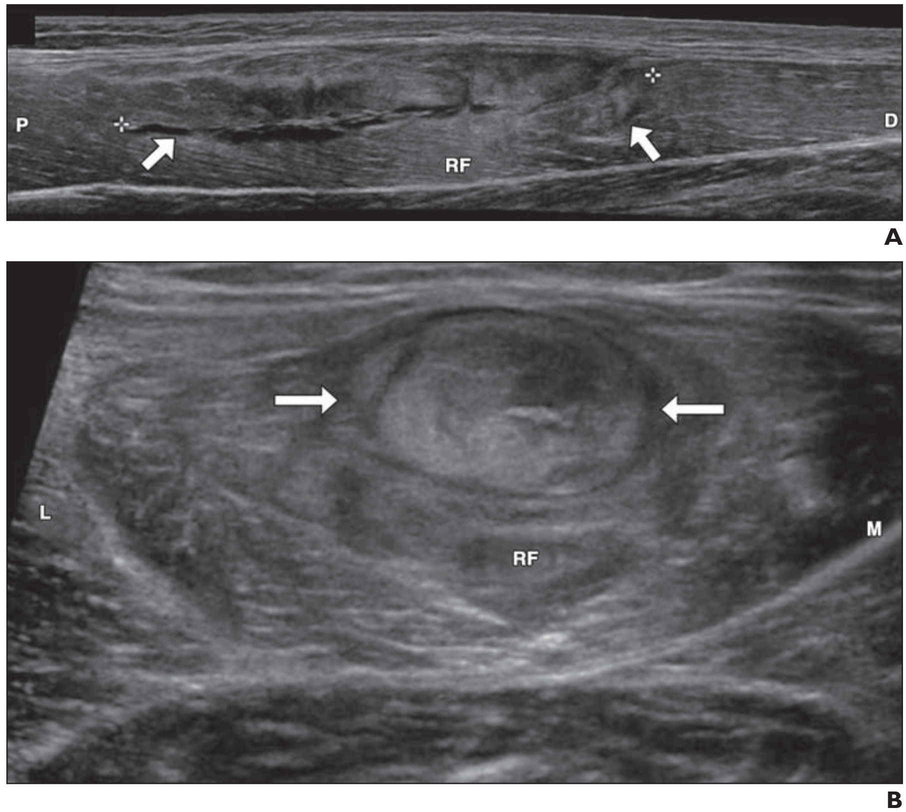


Fig. 4—18-year-old woman with rectus femoris central tendon tear and palpable abnormality.
A, Longitudinal extended FOV sonogram shows discontinuous rectus femoris (RF) fibers with fluid filling muscle defect (*arrows*). Calipers denote rectus femoris tear. D = distal, P = proximal.
B, Transverse sonogram shows abnormal increased echogenicity around central tendon (*arrows*), described as bull's-eye appearance. L = lateral, M = medial.

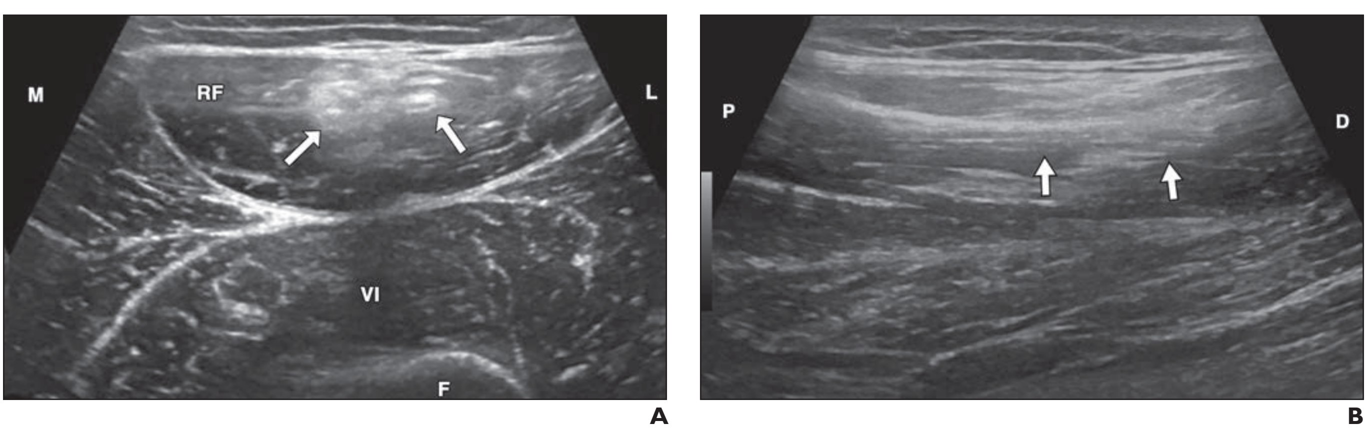
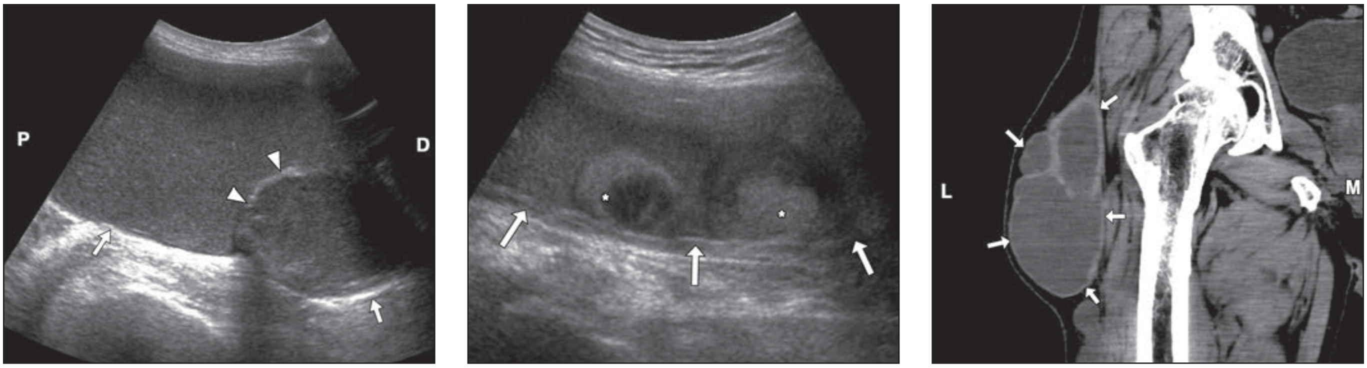


Fig. 5—25-year-old man with prior right rectus femoris muscle tear.
A and **B,** Transverse (**A**) and longitudinal (**B**) sonograms show increased echogenicity in central tendon with posterior acoustic shadowing consistent with remote tear and scarring (*arrows*). Note lack of fluid at site of scar consistent with remote injury. D = distal, F = femur, L = lateral, M = medial, P = proximal, RF = rectus femoris, VI = vastus intermedius.



A B C

Fig. 6—79-year-old man with Morel-Lavallée lesion.
A and **B**, Longitudinal sonograms show complex fluid collection located between deep subcutaneous fat and gluteus muscle fascia (*arrows*, **A** and **B**), consistent with Morel-Lavallée lesion. Note internal heterogeneity, lobulations, and reactive pseudocapsule (*arrowheads*, **A**; *asterisks*, **B**). D = distal, P = proximal.
C, Corresponding coronal CT shows complex fluid collection with reactive pseudocapsule (*arrows*) at level of greater trochanter consistent with Morel-Lavallée lesion. L = lateral, M = medial.

and MRI [13, 14] (Fig. 4). A chronic central tendon tear has increased echogenicity due to scar tissue, which can produce posterior acoustic shadowing (Fig. 5). Correlation with a radiograph can evaluate for calcification, ossification, radiopaque foreign bodies, or other causes of shadowing.

Some rectus femoris injuries can lead to intramuscular bleeding and hematoma [13]. Hematomas can present with variable echogenicity depending on the chronicity of the injury. Rectus femoris muscle injuries can also be associated with detachment of the muscle from the fascia, leading to a hematoma at the posterior aspect of the muscle. Because rectus femoris injuries may present with a palpable mass, they can mimic a tumor with associated concern and patient distress [18]. In such cases, ultrasound can make a rapid, efficient, and inexpensive diagnosis.

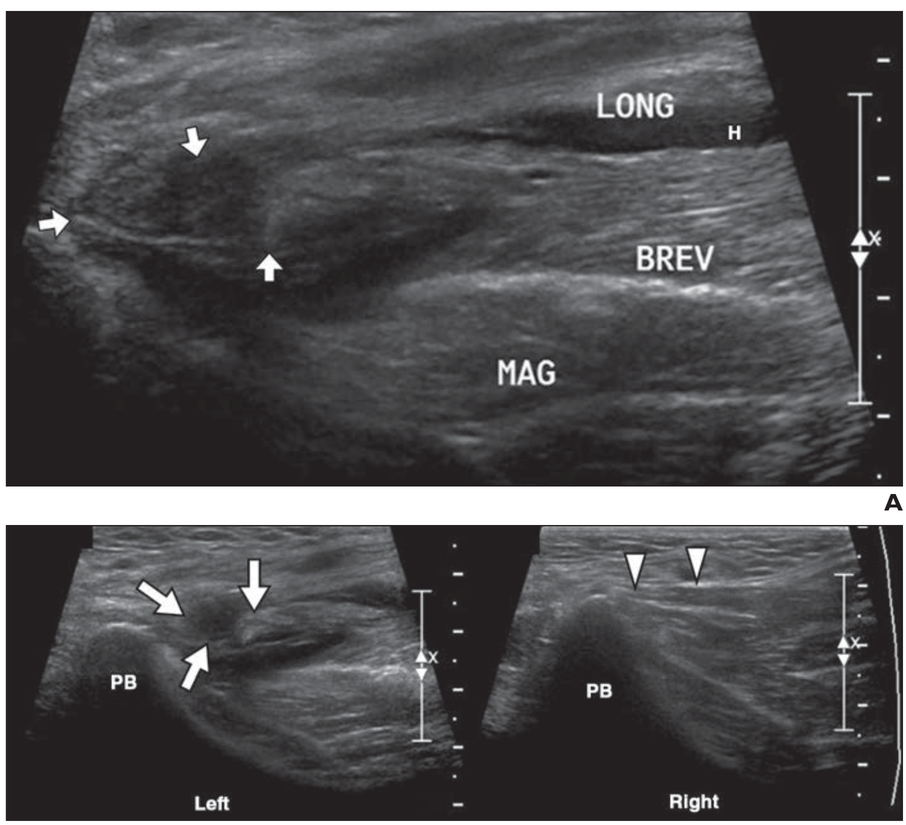
Morel-Lavallée Lesion

A Morel-Lavallée lesion is a posttraumatic soft-tissue degloving injury that separates the subcutaneous tissue from the muscle fascia with accumulation of lymph, blood, fat, or debris [19, 20]. It most commonly affects the greater trochanteric region and the proximal thigh. It has a tendency to recur and can be a source of chronic pain and potentially infection [20].

Ultrasound is a helpful tool to evaluate a Morel-Lavallée lesion, not only because it is less expensive and time consuming than MRI, but also because dynamic assessment with gentle transducer pressure can produce swirling of fluid to aid confirmation of a cystic structure [19]. Sonographically, a Morel-Lavallée lesion is seen as an anechoic or hyperechoic fluid collection at the interface between the deep subcutaneous fat and muscle fascia [19]. Long-standing lesions can develop a reactive pseudocapsule with a heterogeneous appearance, which can be mistaken for a neoplasm if a Morel-Lavallée lesion is not considered and correlation made with the history [20–22] (Fig. 6).

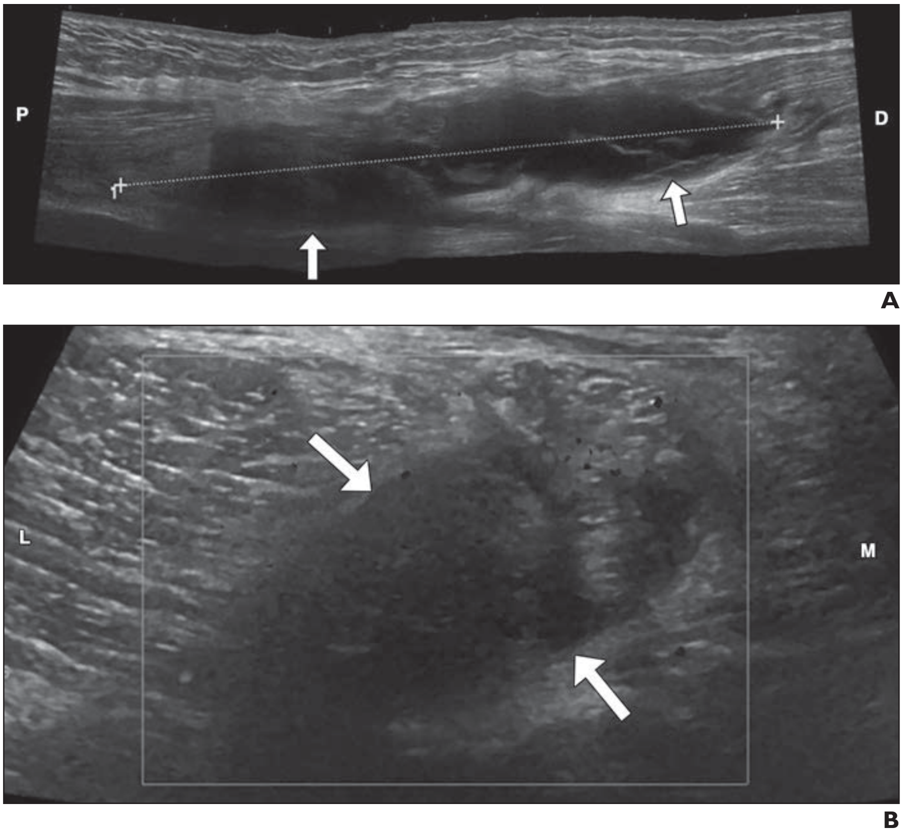
Medial Thigh Compartment: Special Anatomy, Scan Tips, and Artifacts

The adductor muscles include three muscles: adductor longus, brevis, and magnus [7]. The adductors have their origin at the pubis and ischium. The graci-



A B

Fig. 7—49-year-old man with adductor longus and brevis tear.
A, Longitudinal sonogram shows discontinuity of adductor longus (LONG) and brevis (BREV) muscles fibers (*arrows*) with anechoic fluid filling defect. H = hematoma, MAG = adductor magnus muscle.
B, Split-screen transverse sonogram shows discontinuity of adductor longus and brevis muscles fibers (*arrows*, left) and comparison with contralateral normal side (*arrowheads*, right). PB = pubic bone.



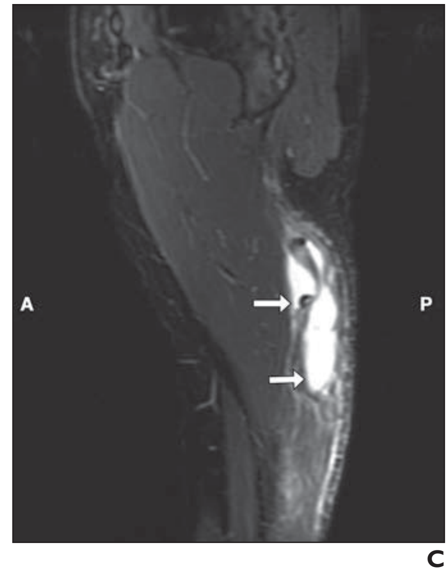


Fig. 8—53-year-old man with semimembranosus tear. **A** and **B,** Longitudinal extended FOV (**A**) and transverse (**B**) sonograms show complete tear of proximal semimembranosus muscle and tendon retraction filled with hematoma (*arrows*). Calipers and dotted line (**A**) denote fluid-hematoma at site of tendon tear. D = distal, L = lateral, M = medial, P = proximal.
C, Corresponding sagittal MRI confirms semimembranosus tear with tendon retraction and hematoma (*arrows*). A = anterior, P = posterior.

lis has its origin at the anterior margin of the lower half of the symphysis pubis and the upper half of the pubic arch. The ultrasound is performed with the patient in a supine position, with the thigh in external rotation and 45° of knee flexion [7]. With the transducer in the axial position at the level of the pelvic brim, the adductors and gracilis are examined in axial and then in longitudinal planes.

Medial Compartment Abnormalities: Adductors and Gracilis

Adductor muscles injuries are commonly associated with sports, by either chronic overuse or acute trauma, and can lead to complete or partial tears. An acute adductor longus muscle tear may cause a hematoma, which can be seen with sonography as discontinuity of the normal muscle fibers with associated fluid in the acute or subacute setting (Fig. 7).

Chronic groin pain, especially associated with sports that involve repeated kicking and rapid change of direction, has a large differential diagnosis, which includes adductor muscle dysfunction [1, 23]. Chronic pain secondary to adductor muscle dysfunction originates from chronic myotendinous strain. Of the medial tendons, the gracilis and adductor longus tendon are more susceptible to injury [23].

The gracilis is normally very thin, especially proximally near its origin. Awareness of its normal size and correlation with symptoms during scanning helps prevent mistaking it for a partial tear. Pain with hip adduction should raise suspicion for gracilis injury. Most are partial tears occurring at the proximal-to-middle third junction at the musculotendinous junction. Ultrasound has been shown to be useful in assessing gracilis injuries [24].

Posterior Thigh Compartment: Special Anatomy, Scan Tips, and Artifacts

The patient is placed in the prone position, and the ischial tuberosity is used as a landmark. The hamstrings are evaluated from their origin at the ischial tuberosity to their insertions at the knee in both transverse and longitudinal planes. Proximally, the sciatic nerve is noted adjacent to the semitendinosus and biceps femoris. The sciatic nerve and the hamstring tendons are linear echogenic structures. On ultrasound, nerves are seen as hypoechoic fascicles separated by hyperechoic epineurium and can look similar to tendons. Compared with tendons fibers, however, nerve fibers are less tightly packed and show less anisotropy [4]. Knowledge of the anatomic relationship between the sciatic nerve and the hamstring tendons is important to avoid mistaking tendon for nerve. In addition, imaging in the transverse plane is helpful because this will accentuate the honeycomb appearance of the sciatic nerve.

Posterior Compartment Abnormalities

Hamstring Tendinosis and Tear

Acute injury of the hamstring muscle complex is most commonly sports related. Chronic repetitive overuse and microtrauma can lead to tendinosis and small partial tears. The proximal portions of the hamstring muscles are susceptible to injury and abnormalities, including strains and partial or complete ruptures [25]. Hamstring tendinosis is commonly seen in athletes, secondary to overuse and repetitive trauma. It most frequently involves the origin of the hamstring, at the ischial tuberosity. Thickening and hypoechogenicity are common findings on ultrasound. Hyperemia on color Doppler imaging and calcifications can also be seen [26].

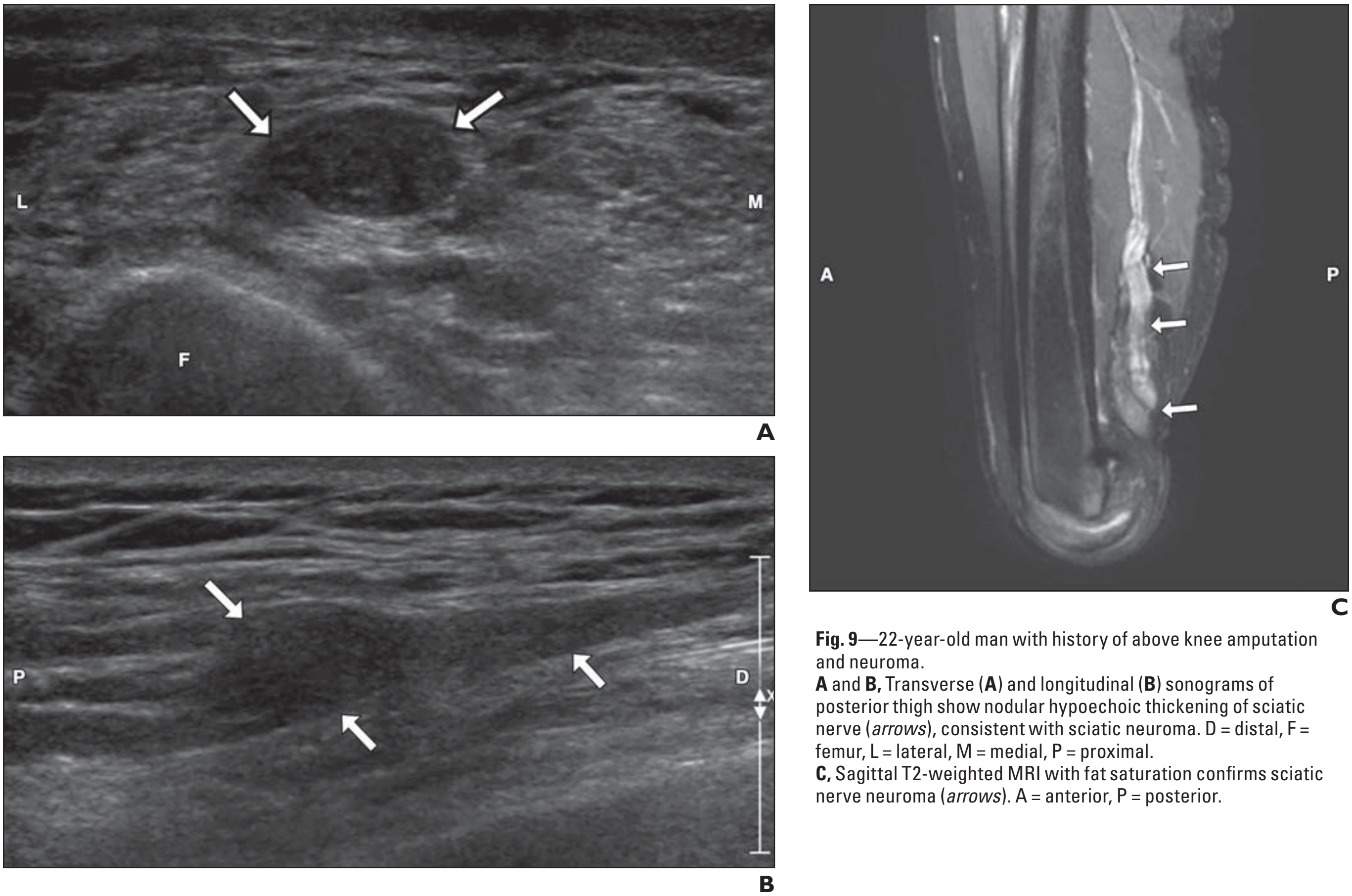


Fig. 9—22-year-old man with history of above knee amputation and neuroma.
A and **B,** Transverse (**A**) and longitudinal (**B**) sonograms of posterior thigh show nodular hypoechoic thickening of sciatic nerve (*arrows*), consistent with sciatic neuroma. D = distal, F = femur, L = lateral, M = medial, P = proximal.
C, Sagittal T2-weighted MRI with fat saturation confirms sciatic nerve neuroma (*arrows*). A = anterior, P = posterior.

Proximal hamstring tendon rupture can be diagnosed by MRI or ultrasound [27, 28]. When less than 5% of the muscle is injured (grade I muscle injury), MRI is more sensitive than ultrasound [28]. However, such low-grade injuries would most likely undergo conservative treatment, and ultrasound is potentially less expensive than MRI [27]. For patients with a very large body habitus, evaluation by ultrasound may be difficult and MRI may be helpful. Sonographically, tears can be partial or complete, with disruption of tendon fibers noted and a tendon gap that is usually filled with fluid or hematoma in the acute or subacute setting (Fig. 8).

Sciatic Nerve Abnormalities

Nerve entrapment, lumbar radiculopathy, and nerve sheath tumors can affect the sciatic nerve and mimic hamstring tendon abnormalities. Hamstring tendon tears can cause tethering of the sciatic nerve, secondary to scarring around the torn tendon and adjacent nerve, and can be a cause of sciatic neurop-

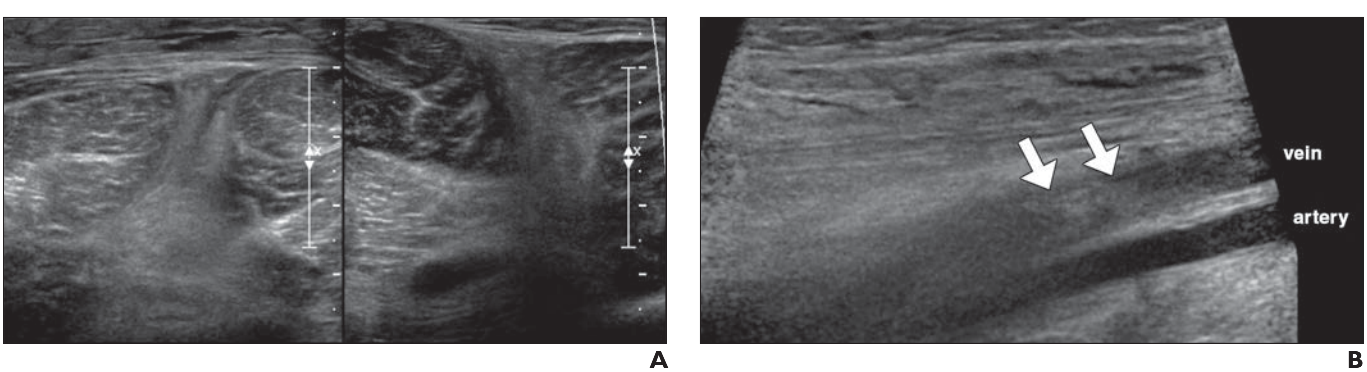


Fig. 10—36-year-old man with deep vein thrombosis simulating hamstring injury. (Republished with permission of American Institute of Ultrasound in Medicine from [6]; permission conveyed through Copyright Clearance Center, Inc.)
A, Split-screen transverse sonography of posterior aspect of bilateral thighs. Left thigh shows diffuse swelling, increased echogenicity consistent with edema, and marked skin thickening (left image). Right thigh is normal on sonography (right image).
B, Longitudinal ultrasound of left femoral vein shows increased internal echogenicity (*arrows*) due to thrombus. Pulmonary embolism CT was positive for segmental and subsegmental emboli (not shown) and patient was started on anticoagulation therapy.

TABLE 1: Thigh Ultrasound Examination Checklist

Location	Structures of Interest
Anterior thigh	Rectus femoris
	Vastus medialis
	Vastus intermedius
	Vastus lateralis
Medial thigh	Femoral artery and nerve
	Sartorius
	Gracilis
	Adductors
Posterior thigh	Semimembranosus
	Semitendinosus
	Biceps femoris
	Sciatic nerve
	Popliteal vein
Other	Along scar in postoperative patients
	Masses (including hematoma and seroma)
	Vascular findings (including aneurysm and deep venous thrombosis)

Note—Checklist was created using information published elsewhere [6, 26, 29].

athy [29]; therefore, assessment of the sciatic nerve is important in the context of hamstring injury [29]. A focal ultrasound of only the hamstrings may miss important nerve abnormalities and delay appropriate treatment.

Nerve masses can be accurately detected by sonography [4]. Neuromas are sonographically seen as ovoid hypoechoic nodules with an entering and exiting nerve (Fig. 9). Ultrasound's real-time dynamic capability gives the sonographer the opportunity to correlate the mass with the patient's symptoms by exerting gentle pressure over the mass with the transducer [30].

Vascular Abnormalities

Additional abnormalities can mimic tendon or muscle injuries. In some cases, the clinical suspicion may be that of a hamstring tear, but the abnormalities can be vascular and due to a deep venous thrombosis. In such cases, the sonographer may note a normal hamstring tendon with leg edema. The examination can then be extended to assess the popliteal vein for a deep venous thrombosis [6]. Such findings illustrate the importance of a comprehensive knowledge of the anatomy and potential abnormalities in the posterior thigh and the need for a checklist- and compartment-based application of ultrasound, including assessment of the vascular structures. In such cases, a focal examination of only the hamstrings could miss life-threatening vascular abnormalities (Fig. 10).

Other Soft-Tissue Abnormalities: Abscess and Fluid Collections

A soft-tissue abscess can occur in any of the thigh compartments and is seen as a hypoechoic or complex fluid collection, which may or may not have a thick wall surrounding it [30, 31]. Discrete fluid collections are well seen at sonography [31, 32]. Doppler evaluation shows no internal flow within an abscess but may show increased flow in the periphery and in the surrounding soft tissues [31]. The sonographic appearance cannot reliably be used to exclude infection; aspiration is needed and can be guided with sonography [30, 33].

The soft tissue around a scar, such as after a hip replacement, should be evaluated for underlying fluid collection. Not infrequently, a seroma or abscess can be found in this location [33].

Discussion

Ultrasound has value in the evaluation of a variety of pathologic conditions in the thigh. It is important for the sonographer to have a systematic approach, using a checklist with a detailed understanding of the normal anatomy and artifacts, and a thorough grounding in the various types of thigh abnormalities and associated conditions. The checklist is used to ensure a complete examination and is not meant to specify the order in which structures are scanned.

In our experience, a comprehensive examination of all soft-tissue structures in all compartments of the thigh—anterior, medial, and posterior (Table 1)—is not commonly indicated but is helpful when learning musculoskeletal ultrasound. We recommend a systematic examination that always includes at least one entire compartment, as determined by the patient's symptoms and clinical history. Additional compartments can be included depending on the ultrasound findings, history, and symptoms. Important and unsuspected diagnoses, including deep venous thrombosis and nerve abnormalities, should not be missed by an examination that is too limited and too focal.

References

1. Koh ES, McNally EG. Ultrasound of skeletal muscle injury. *Semin Musculoskelet Radiol* 2007; 11:162–173
2. Jacobson JA. Ultrasound in sports medicine. *Radiol Clin North Am* 2002; 40:363–386
3. Nazarian LN. The top 10 reasons musculoskeletal sonography is an important complementary or alternative technique to MRI. *AJR* 2008; 190:1621–1626
4. Ahmed R, Nazarian LN. Overview of musculoskeletal sonography. *Ultrasound Q* 2010; 26:27–35
5. Lin EC, Middleton WD, Teefey SA. Extended field of view sonography in musculoskeletal imaging. *J Ultrasound Med* 1999; 18:147–152
6. Lutterbach-Penna RA, Kalume-Brigido M, Robertson BL, Jacobson JA, Girish G, Fessell DP. Deep vein thrombosis simulating hamstring injury on sonography. *J Ultrasound Med* 2012; 31:660–662
7. Nestorova R, Vlad V, Petranova T, et al. Ultrasonography of the hip. *Med Ultrason* 2012; 14:217–224
8. Jamadar DA, Jacobson JA, Caoili EM, et al. Musculoskeletal sonography technique: focused versus comprehensive evaluation. *AJR* 2008; 190:5–9
9. Noorkoiv M, Nosaka K, Blazevich AJ. Assessment of quadriceps muscle cross-sectional area by ultrasound extended-field-of-view imaging. *Eur J Appl Physiol* 2010; 109:631–639
10. Bianchi S, Martinoli C, Waser NP, Bianchi-Zamorani MP, Federici E, Fasel J. Central aponeurosis tears of the rectus femoris: sonographic findings. *Skeletal Radiol* 2002; 31:581–586
11. Hasselman CT, Best TM, Hughes C, Martinez S, Garrett WE. An explanation for various rectus femoris strain injuries using previously undescribed muscle architecture. *Am J Sports Med* 1995; 23:493–499
12. Ouellette H, Thomas BJ, Nelson E, Torriani M. MR imaging of rectus femoris origin injuries.

Skeletal Radiol 2006; 35:665–672

13. Douis H, Gillett M, James SL. Imaging in the diagnosis, prognostication, and management of lower limb muscle injury. *Semin Musculoskelet Radiol* 2011; 15:27–41
14. Cross TM. Acute quadriceps muscle strains: magnetic resonance imaging features and prognosis. *Am J Sports Med* 2004; 32:710–719
15. Bortolotto C, Coscia DR, Ferrozzi G. Enthesitis of the direct tendon of the rectus femoris muscle in a professional volleyball player: a case report. *J Ultrasound* 2011; 14:95–98
16. Kälebo P, Karlsson J, Swärd L, Peterson L. Ultrasonography of chronic tendon injuries in the groin. *Am J Sports Med* 1992; 20:634–639
17. Hsu JC, Fischer DA, Wright RW. Proximal rectus femoris avulsions in national football league kickers: a report of 2 cases. *Am J Sports Med* 2005; 33:1085–1087
18. Temple HT, Kuklo TR, Sweet DE, Gibbons CL, Murphey MD. Rectus femoris muscle tear appearing as a pseudotumor. *Am J Sports Med* 1998; 26:544–548
19. Goodman BS, Smith MT, Mallempati S, Nuthakki P. A comparison of ultrasound and magnetic resonance imaging findings of a Morel-Lavallée lesion of the knee. *PM R* 2013; 5:70–73
20. Neal C, Jacobson JA, Brandon C, Kalume-Brigido M, Morag Y, Girish G. Sonography of Morel-Lavallée lesions. *J Ultrasound Med* 2008; 27:1077–1081
21. Mukherjee K, Perrin SM, Hughes PM. Morel-Lavallée lesion in an adolescent with ultrasound and MRI correlation. *Skeletal Radiol* 2007; 36(suppl 1):S43–S45
22. Puig J, Pelaez I, Baños J, et al. Long-standing Morel-Lavallée lesion in the proximal thigh: ultrasound and MR findings with surgical and histopathological correlation. *Australas Radiol* 2006; 50:594–597
23. Robinson P, Barron DA, Parsons W, Grainger AJ, Schilders EM, O'Connor PJ. Adductor-related groin pain in athletes: correlation of MR imaging with clinical findings. *Skeletal Radiol* 2004; 33:451–457
24. Pedret C, Balius R, Barceló P, et al. Isolated tears of the gracilis muscle. *Am J Sports Med* 2011; 39:1077–1080
25. Davis KW. Imaging of the hamstrings. *Semin Musculoskelet Radiol* 2008; 12:28–41
26. Jacobson JA. *Fundamentals of musculoskeletal ultrasound*, 2nd ed. Philadelphia, PA: Elsevier, 2013
27. Mariani C, Caldera FE, Kim W. Ultrasound versus magnetic resonance imaging in the diagnosis of an acute hamstring tear. *PM R* 2012; 4:154–155
28. Kerkhoffs GM, van Es N, Wieldraaijer T, Sierevelt IN, Ekstrand J, van Dijk CN. Diagnosis and prognosis of acute hamstring injuries in athletes. *Knee Surg Sports Traumatol Arthrosc* 2013; 21:500–509
29. Koulouris G, Connell D. Hamstring muscle complex: an imaging review. *RadioGraphics* 2005; 25:571–586
30. Smith SE, Salanitri J, Lisle D. Ultrasound evaluation of soft tissue masses and fluid collections. *Semin Musculoskelet Radiol* 2007; 11:174–191
31. Bureau NJ, Chhem RK, Cardinal E. Musculoskeletal infections: US manifestations. *RadioGraphics* 1999; 19:1585–1592
32. Loyer EM, DuBrow RA, David CL, Coan JD, Eftekhari F. Imaging of superficial soft-tissue infections: sonographic findings in cases of cellulitis and abscess. *AJR* 1996; 166:149–152
33. Hadduck TA, van Holsbeeck MT, Girish G, et al. Value of ultrasound before joint aspiration. *AJR* 2013; 201:[web]W453–W459