

Sonography of Traumatic Quadriceps Tendon Tears With Surgical Correlation

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Objectives—Using surgical correlation as the reference standard, the purpose of this study was to assess the ability of sonography to detect quadriceps tendon tears that require surgical treatment (high-grade partial tears and complete ruptures).

Methods—Two hundred thirty-nine consecutive sonographic reports of the knee (May 2001 to October 2008) with subsequent surgical correlation were retrospectively reviewed for surgical intervention on the quadriceps tendon. All sonograms were blindly and retrospectively reviewed. Surgical findings were compared with results from the consensus review. Results from the original sonographic reports (nonretrospective interpretation) were also compared with the surgical findings.

Results—On the retrospective consensus review, the sensitivity (23 of 23), specificity (16 of 16), and accuracy (39 of 39) were 100% for identifying high-grade partial tears or complete ruptures versus a normal quadriceps tendon. For the original, nonretrospective sonographic reports, 22 of 23 high-grade partial tears or complete ruptures (96%) were correctly diagnosed.

Conclusions—Sonography is an effective tool for identifying quadriceps tendon tears that require surgical treatment (high-grade partial tears and complete ruptures).

Key Words—knee sonography; musculoskeletal ultrasound; quadriceps tendon injury; sonography; traumatic quadriceps tendon tears

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Abbreviations

MRI, magnetic resonance imaging

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Among injuries to the knee, quadriceps femoris tendon tears are relatively uncommon but important injuries, with a reported incidence of complete rupture of 1.37 per 100,000 per year.¹ Prompt diagnosis and treatment facilitate improved functional outcomes for quadriceps tendon rupture, thereby avoiding tendon retraction and quadriceps atrophy that may occur with delayed repair.^{2,3} Clinical examination in some cases is sufficient for diagnosis. The presentation can, however, be highly variable. Neubauer et al⁴ reported that bilateral quadriceps tendon rupture was correctly detected in only 17 of 28 cases (61%) by history and physical examination alone. Soft tissue swelling and hematoma may hinder palpation of a tendon gap in the acute setting.² Although most patients will report an inability to extend the knee, partial tears or those with an intact extensor retinaculum may show some degree of extension, further complicating the diagnosis.⁵

When diagnostic uncertainty remains, imaging can help ensure an accurate and timely diagnosis. Using surgical correlation as the reference standard, small studies have suggested that sonography can be valuable for the diagnosis of quadriceps tendon tears.^{6,7} Normal tendons have a well-defined, linear, fibrillar, echogenic appearance on sonography. A quadriceps tendon tear is a discontinuity of the linear echo texture and is usually hypoechoic or anechoic.^{6,7} In the setting of a suspected quadriceps tendon tear, magnetic resonance imaging (MRI) can aid in the detection of quadriceps injury and assess for additional intra-articular injuries. McKinney et al⁸ reported an incidence of associated intra-articular injury of only 9.6%, suggesting that MRI can be reserved for select cases with strong clinical suspicion for injuries involving more than the quadriceps tendon.

Sonography offers several advantages over MRI that make it particularly useful for evaluation of the quadriceps tendon. The improved spatial resolution, ease of contralateral comparison, direct correlation with the site of pain, and ability to perform a dynamic evaluation all add additional diagnostic information in the diagnosis of quadriceps tendon injury (Figure 1).⁹ A consensus paper from the European Society of Musculoskeletal Radiology recommended that sonography be the initial imaging modality for suspected quadriceps tendon injury and noted that additional techniques rarely provide additional information.¹⁰

The purpose of this study was to determine the accuracy of sonography for diagnosing high-grade partial quadriceps tendon tears and complete rupture using surgical findings as the reference standard. Such cases benefit from prompt diagnosis and surgical repair.^{2,3} Lesser degrees of quadriceps injury (low-grade partial tears) are more commonly treated with nonsurgical management.^{2,5}

Materials and Methods

Institutional Review Board approval was obtained for this study. Two hundred thirty-nine consecutive sonographic reports of the knee (May 2001 to October 2008) with subsequent surgical correlation were retrospectively reviewed for quadriceps tendon repair.

There were no cases of sonographically normal quadriceps tendons with surgical correlation. Therefore, the same sonographic database was reviewed for sonographically normal quadriceps tendons with normal MRI findings (by report) within 20 days from the sonographic examinations. Such cases were included as “normal quadriceps tendons.” The MRI examinations were completed as part of routine patient care on 1.5- or 3.0-T MRI systems.

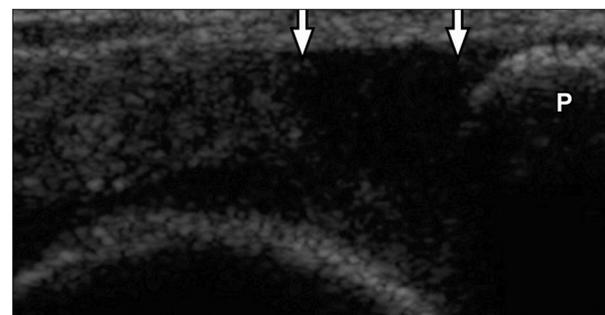
Protocols varied but generally included axial and sagittal proton density images with fat saturation for evaluation of the quadriceps tendon.

All sonograms (including both static and dynamic imaging) available in the radiology archive from the surgical patient group and normal quadriceps tendons were blindly reviewed in consensus by 2 fellowship-trained musculoskeletal radiologists with 15 and 8 years of experience in musculoskeletal sonography. One reviewer had no previous knowledge of the sonographic cases, and the other had not viewed any of the cases for at least 6 months. Cases were reviewed in a randomized order. Since both high-grade partial tears and complete tears are usually treated with surgical repair, cases were assessed as either normal tendons or high-grade tear/complete tears. High-grade partial tears were defined as those with a tear of greater than 50% of the tendon.¹¹ Complete tears were defined as disruption of the entire tendon (no intact tendon fibers). Surgical findings were compared with the findings from the consensus review. Sensitivity, specificity, and accuracy were determined for normal tendons versus the combined category of high-grade partial/complete tears.

Since the original, nonretrospective interpreters of the sonograms were often afforded additional information, including supplemental patient histories when scanning and real-time imaging while scanning, the results from the original sonographic reports were also compared with the surgical findings. Patient records were also reviewed with respect to other imaging findings.

The original sonographic examinations were performed by 1 of 10 musculoskeletal radiologists as part of routine patient care. Their experience with musculoskeletal sonography ranged from less than 1 year to 11 years. Exclusion criteria were an interval between sonography

Figure 1. Image from a 46-year-old man with complete quadriceps rupture after a slip and fall, which was confirmed at surgery. Longitudinal sonogram of the distal quadriceps tendon shows a torn tendon end separated from the patella (P) by a 1.0-cm hypoechoic gap (between arrows).



and surgery of greater than 20 days (1 case excluded) and insufficient sonograms for diagnosis (1 case excluded). Scans were performed with one of several commercially available scanners (iU22; Philips Healthcare, Bothell, WA; 7–4- or 12–5-MHz linear array transducer; Voluson E9; GE Healthcare, Milwaukee, WI; 10- or 14-MHz linear array transducer; and Acuson Sequoia 512; Siemens Medical Solutions, Mountain View, CA; 10-MHz linear array transducer) in the transverse and longitudinal planes with the knee at rest in a supine or sitting position. Dynamic scanning was performed in several cases during flexion and extension of the knee as clinically indicated by the sonographer.

Results

The group of quadriceps cases that went to surgery consisted of 23 quadriceps tendons in 20 patients (18 male and 2 female) with an average age of 54.5 years (range, 33–75 years). All 23 quadriceps tendons were found to have high-grade or complete tears at subsequent surgery. Most tears (17 of 23 [74%]) had the mechanism of a slip and fall. Six of the 20 patients had a predisposing underlying systemic disorder (diabetes, renal disease, or gout). One of 3 patients with bilateral tears had gout. Overall, systemic diseases were identified in 7 of 23 cases (30%). The group of normal quadriceps cases on MRI consisted of 16 quadriceps tendons in 15 patients (10 male and 5 female) with an average age of 37.7 years (range, 12–62 years).

On the retrospective consensus review of the 39 cases, the 23 surgically confirmed high-grade partial tears or complete ruptures were correctly distinguished from the normal tendons (Figure 1). All 16 normal quadriceps tendons on MRI were correctly diagnosed during the consensus review. The sensitivity (23 of 23), specificity (16 of 16), and accuracy (39 of 39) were 100% for identifying high-grade partial tears/complete ruptures versus a normal quadriceps tendon.

Results of the original 23 sonographic reports were also compared with the surgical findings. Using sonography, 22 of 23 cases (96%) were correctly classified as “surgical” cases: ie, high-grade partial tear or complete rupture. One high-grade partial tear at surgery was not described at initial sonography. At surgery, this patient was noted to have a large hematoma that likely complicated the sonographic interpretation (Figure 2). The original sonographic report detailed the hematoma but determined that the integrity of the quadriceps tendon was difficult to ascertain. Follow-up sonography 2 days later suggested that a partial tear of the quadriceps tendon was likely but again limited in the evaluation. Subsequent MRI 9 days after the initial

sonographic examination showed a near-complete tear of the quadriceps tendon, which was confirmed at surgery (Figure 2). Four of the 23 surgically confirmed high-grade partial tears or complete ruptures had preoperative MRI, all within 13 days of the sonographic examinations. None of the 4 cases with preoperative MRI had additional intra-articular injuries noted on MRI.

Dynamic scanning during flexion and extension of the knee was performed in 11 of the 39 cases at the discretion of the sonographer. In all 11 cases, the dynamic images were subjectively thought to be useful in making a diagnosis on the retrospective consensus review (Figure 3).

Discussion

The quadriceps femoris tendon represents a confluence of the 4 muscle bellies that constitute the quadriceps muscle: the vastus medialis, vastus intermedius, vastus lateralis, and rectus femoris. All muscles originate from the femoral shaft except for the rectus femoris, which originates from the anterior inferior iliac spine and adjacent to the acetabulum. The normal quadriceps tendon has a layered structure, with the superficial layer formed by the rectus femoris, middle layer by the vastus lateralis and medialis, and deep layer by the vastus intermedius.¹² The result is a common trilaminar tendon, which inserts on the superior pole of the patella. The superficial quadriceps fibers extend over the patella to insert on the tibial tuberosity as part of the patellar tendon.¹³

The vascular supply to the quadriceps tendon originates from the medial, lateral, and peripatellar arcades with a hypovascular zone located 1 to 2 cm superior to the patella, where most spontaneous ruptures occur.^{2,14} Due to the tensile strength of the normal quadriceps tendon, it is generally accepted that most ruptures occur in the setting of preexisting degenerative changes or microtrauma.^{2,15} Steroid and fluoroquinolone use along with several systemic diseases, including renal disease, diabetes, gout, rheumatoid arthritis, and hyperparathyroidism, have been implicated as potential contributory factors leading to weakening the tendon and accelerating pathologic degeneration, thereby increasing the risk of quadriceps tendon rupture.^{5,16}

Although many high-grade partial and complete quadriceps tendon tears are diagnosed on the basis of clinical examination, diagnosis can be missed in up to 50% of cases in the acute setting.¹⁷ Radiographic findings of joint effusion, suprapatellar masses, osseous avulsion, and patella baja are helpful when present but are not always present or diagnostic.¹⁸ Because quadriceps tendon tears have the

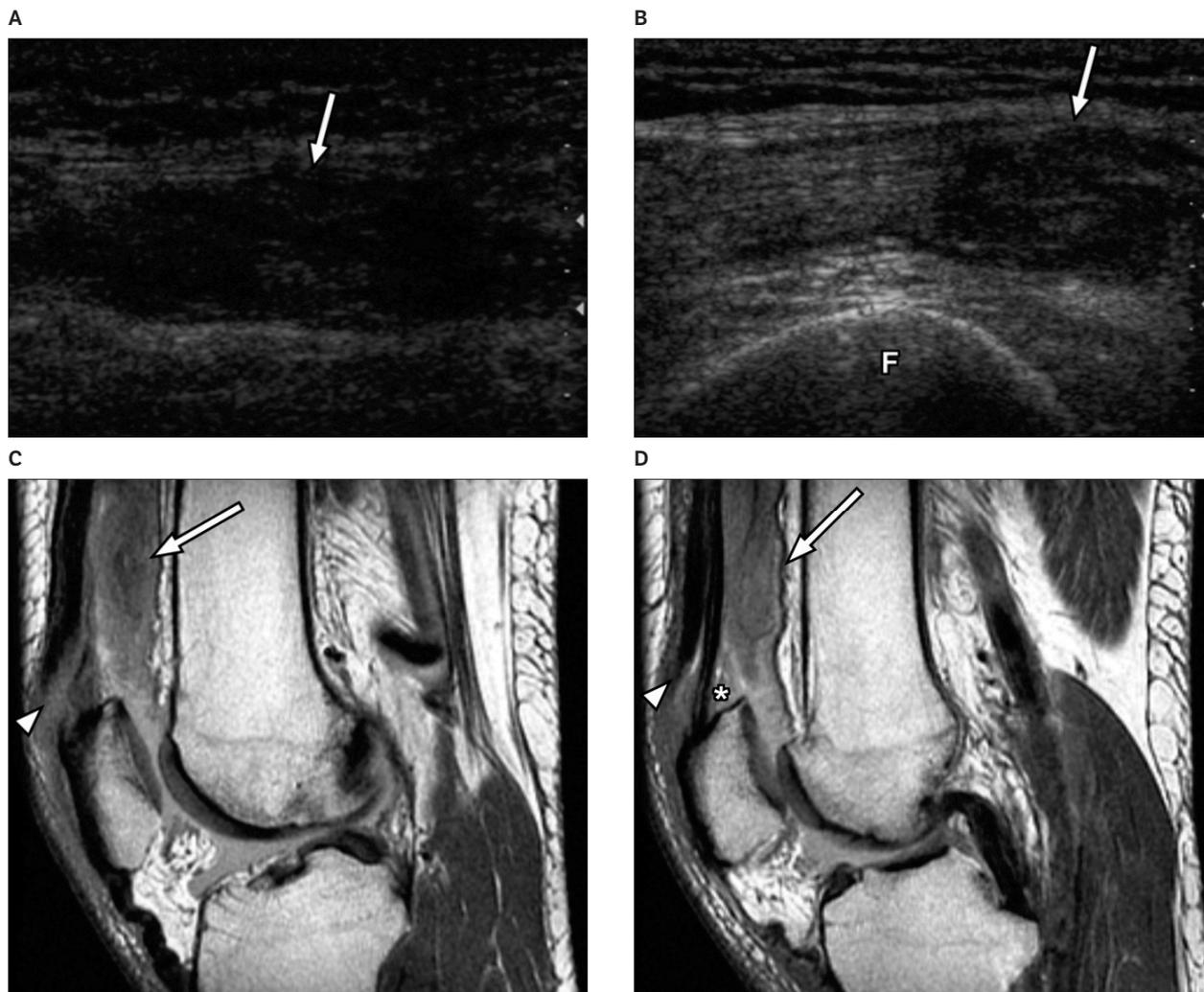
best outcomes with timely diagnosis and repair, imaging can have a direct effect on patient treatment when there is clinical ambiguity.^{2,3} Our results show that sonography can be a reliable clinical tool for rapidly identifying high-grade partial and complete quadriceps tendon tears. Such cases usually undergo prompt surgical repair.

Although sonography is generally accepted as a useful means to diagnose quadriceps tendon injury, its reliability has been questioned, particularly in obese and highly muscular patients.¹⁹ Results of our consensus review suggest that sonography can facilitate diagnosis of high-grade partial and complete quadriceps tendon ruptures with high

sensitivity, specificity, and accuracy. The findings further substantiate similar conclusions made by smaller studies using surgical correlation as the reference standard.^{6,7}

Dynamic imaging during flexion and extension was used in 11 of 23 cases, and the retrospective review suggested that it was helpful in making the diagnosis of a high-grade partial/complete rupture. Dynamic evaluation may help avoid misdiagnosis of a partial-thickness tear when hematoma is present at the site of a full-thickness tendon tear. Further study is needed to systematically assess the utility of dynamic imaging and determine its value in assessing high- and low-grade quadriceps tendon tears.

Figure 2. Images from a 65-year-old man taking warfarin with a high-grade partial tear after a slip and fall on ice, which was confirmed at surgery. Longitudinal (A) and transverse (B) sonograms of the distal quadriceps tendon show hematoma (arrows) overlying the anterior lateral patella, limiting evaluation of tendon integrity. F indicates femur. Sagittal proton density MRI (C and D) performed 9 days later shows high-grade partial disruption of lateral fibers of the distal quadriceps tendon (arrowheads) with a few intact fibers medially (asterisk in D) and hemarthrosis (arrows).



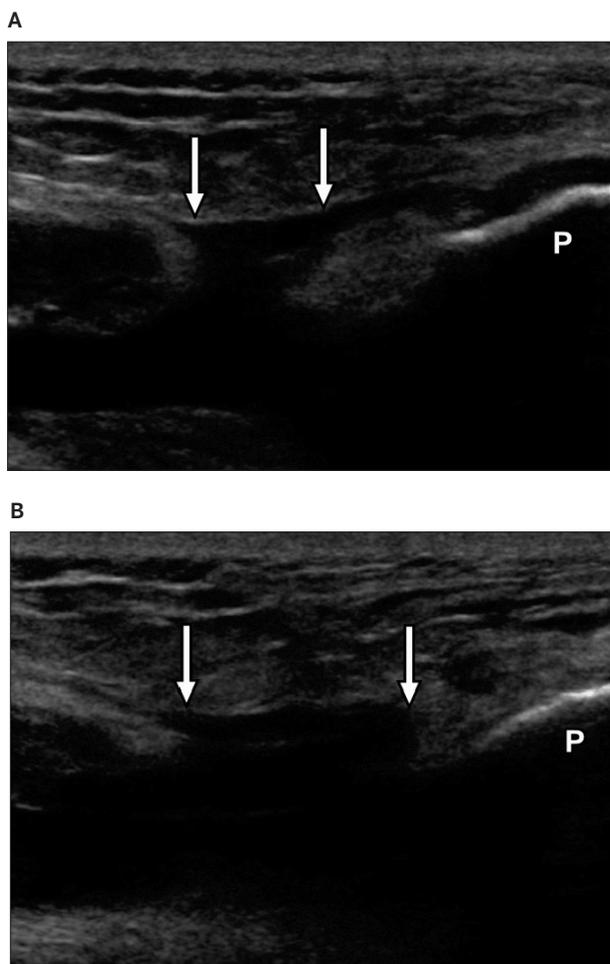
Limitations of the study included its retrospective nature and an inherent selection bias introduced because of the adherence to a reference standard of surgically proven cases of quadriceps tendon tears. Similarly, the selection method precluded any discussion of the accuracy of sonography in diagnosing low-grade partial tears or tendinosis. However, such cases are usually treated with nonsurgical management, as is tendinosis.^{2,5}

Surgical reports were somewhat limited in their description of tendon injuries. Terms such as tendon “rupture” and “avulsion” were frequently used. The surgical descriptions did, however, suggest that these terms meant

that at least the overwhelming majority of the tendon was torn in width and thickness. In cases in which a high-grade partial tear was described in the surgical reports, typically the amount of tendon that remained intact was not precisely specified. Such factors limited comparison with imaging findings. However, from the surgeon’s perspective, identifying cases that require surgical treatment (high-grade partial tears and complete tendon ruptures) is the goal, and sonography can aid in this evaluation.

In conclusion, clinical findings in cases of acute quadriceps tendon injury may be limited due to swelling, hematoma, and pain. When diagnostic uncertainty remains, sonography can be an effective tool for rapidly identifying high-grade partial tears and complete ruptures. For optimal outcomes, such cases usually undergo prompt surgical repair. Further study is needed to determine the accuracy of sonography in assessing low-grade partial quadriceps tendon tears and tendinosis.

Figure 3. Images from a 49-year-old man with a complete quadriceps tear after a slip on ice, which was confirmed at surgery. Longitudinal sonograms of the distal quadriceps tendon during extension (**A**) and flexion (**B**) shows a full-thickness tear of the distal quadriceps tendon with discontinuous movement of tendon stumps during gentle dynamic maneuvers (arrows). P indicates patella.



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