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REVIEW ARTICLE

Magnetic resonance imaging of the quadriceps tendon autograft in anterior cruciate ligament reconstruction

Christopher P. Emerson [1] · Jessica M. Bernstein [1] · Fong Nham [2] · Spencer Barnhill [1] · Michael G. Baraga [1] · Eric Bogner [3] · Jean Jose [4]

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Abstract

Background Quadriceps tendon (QT) autograft is emerging as a popular technique for primary anterior cruciate ligament (ACL) reconstruction. Studies have shown that it has comparable outcomes to bone-patellar tendon-bone (BPTB) and hamstring tendon (HT) autografts while mitigating post-operative complications associated with these grafts.

Purpose To provide a literature summary of the important pre- and post-operative magnetic resonance imaging (MRI) findings of the quadriceps tendon and pertinent postoperative complications associated with the QT harvest. Radiologists should be familiar with MR findings after autologous graft harvest of the quadriceps tendon for reconstruction of the ACL.

Level of evidence Level IV.

Keywords ACL reconstruction · ACLR · Quadriceps tendon autograft · QT · MRI

Introduction

Over the past decade, there has been an increase in the use of the quadriceps tendon (QT) autograft for primary reconstruction of a torn anterior cruciate ligament (ACL). A poll at the American Academy of Orthopedic Surgeons (AAOS) published in 2010 reported that only 1% of orthopedic surgeons were using quadriceps tendon as a graft for ACL reconstruction [1]. During a 2014 international summit on ACL reconstruction, 10.6% of surgeons reported using the quadriceps tendon autograft as their preferred graft choice in ACL reconstruction. Furthermore, the survey reported that 11% of all ACL reconstructions, performed by the surgeons polled, utilized the QT autograft [2]. These trends suggest continued future increases in QT autograft for primary ACL reconstruction [3].

Radiologists play an important role in diagnosing ACL injuries and providing surgeons with detailed imaging reports before and after surgery. To date, no study has highlighted the diversity of findings of the QT autograft on magnetic resonance imaging (MRI); therefore, the purpose of this article is to (1) review the biomechanical and clinical studies that support the use of QT autograft for ACL reconstruction; (2) illustrate the anatomic features of the quadriceps tendon and surrounding region; (3) highlight the importance of pre-operative MRI evaluation; (4) summarize the intraoperative harvesting and surgical technique; (5) illustrate the normal post-operative magnetic resonance (MR) image changes at both the harvest site and the ACL reconstruction graft; and (6) illustrate the postoperative complications after ACL reconstruction unique to the QT autograft.

✉ Christopher P. Emerson
cpe16@miami.edu

1 The University of Miami Sports Medicine Institute, Department of Orthopaedic Surgery, The University of Miami Miller School of Medicine, Coral Gables, FL, USA

2 Herbert Wertheim College of Medicine, Florida International University, Miami, FL, USA

3 Department of Radiology, Hospital for Special Surgery, New York, NY, USA

4 Department of Radiology, University of Miami Miller School of Medicine, Jackson Memorial Hospital, Miami, FL, USA

Advantages of the QT graft

Biomechanical studies

Biomechanical studies have shown that the quadriceps tendon provides a large amount of tissue to create a graft with excellent tensile strength and ultimate load to failure [4–6]. From these studies, the ideal QT graft measures 70–90 mm in length, 8–10 mm wide, and 8–10 mm thick. Cadaveric biomechanical studies have demonstrated that the harvested QT graft is 1.8 times thicker and has a 1.36 times higher maximum load to tendon failure than a similar-sized bone-patellar tendon-bone (BPTB) graft [5]. Lippe et al. reported that when harvesting the QT proximally from the patella's medial edge, a surgeon will be able to routinely harvest a graft 10 mm wide [7]; furthermore, the cross-sectional area of the QT graft (91.2 mm ± 10 mm) is nearly twice that of the BPTB (48.4 mm ± 8 mm). Additionally, on histological examination the QT graft has approximately 20% more collagen than the BPTB graft of the same thickness providing it with greater tensile strength [8]. Although graft harvesting weakens the donor site, the post-operative strength of the remaining quadriceps tendon is stronger (2430 N ± 680 N) than the native patellar tendon (1920 N ± 330 N) [4]. Ultimate load to failure is also significantly higher when compared to the BPTB graft [6]. Although BPTB has earlier graft integration when compared to QT and HT autografts as evidenced by stronger pullout strength 3 weeks after surgery, at 6 weeks post-op there was no significant difference in pullout strength between the grafts [9]. When compared to hamstring tendon (HT) autografts, a cadaveric study showed no difference between QT and HT grafts under any experimental condition [10].

Clinical outcomes

Autografts for ACL surgery include BPTB, HT, and QT, and have similar improvements in clinical outcomes, which include patient reported outcomes, instrumented mean-side-to-side difference of anterior knee laxity, Lachman test, pivot-shift test, and graft failure rates [11, 12]. Often times, graft selection is based on lifestyle, consideration of associated comorbidities, and surgical experience.

Increased utilization of the QT autograft for primary ACL reconstruction can be attributed to several studies that have demonstrated in post-operative comparisons that the quadriceps tendon with bone block (QTB) has less anterior knee pain, anterior knee numbness, and harvest site pain when compared to BPTB [13, 14]. These comorbidities are associated in part with intraoperative injury to the infrapatellar branches of the saphenous nerve, while harvesting the BPTB [15], as well as location of the infrapatellar harvest incision. Harvesting QT grafts mitigates this issue as a suprapatellar incision, as small as 2 cm in length, avoids injury to any significant cutaneous nerves. A more concerning complication is patellar fracture, a possibility arising from BPTB and QTB harvesting [16], and has led to the development of the all-soft tissue QT autograft, which avoids weakening the patella and subjecting the patient to increased risk for fracture. Geib et al. reported that the QTB and QT autografts have similar clinical outcomes [17] and Schulz et al. reported that the QT autograft has excellent clinical outcomes at a mean 29.5 months follow-up [18].

When compared to hamstring tendon (HT) autografts, QTB has similar subjective knee scores and knee stability; however, QTB has lower donor site morbidity including lower rates of infection and lower rates of graft failure [19–21]. Magnussen et al. found that HT grafts larger than 8.5 mm thick had a 1.7% revision rate, grafts less than 8 mm had a revision rate of 6.5%, and grafts less 7.0 mm had a revision rate of 33% [22]. This becomes problematic because there is significant variability in graft size with HT harvest [23, 24] and occasionally the surgeon will need to supplement it with allograft tissue [25, 26]. Lee et al. reported that when comparing QTB to HT, there was no difference in recovery of extensor muscle strength during isokinetic testing; however, flexor muscle strength recovery was better in the QTB group at minimum 2 years follow-up [20]. Joseph et al. reported that QT patients achieve full knee extension faster than BPTB and require less post-operative pain medication than both BPTB and HT [27].

Anatomy of the quadriceps tendon

Although the quadriceps tendon anatomy is not necessarily important from a surgical planning perspective, it provides insight into the normal post-operative appearance of both the harvest site and reconstruction graft. Historically, the quadriceps femoris tendon has been described as a trilaminar structure that coalesces and inserts on the patella [28, 29]. The rectus femoris (RF) muscle comprises the most superficial tendon fibers. Tendon fibers from the vastus medialis (VM) and vastus lateralis (VL) form the intermediate layer. Lastly, tendon fibers from the vastus intermedius (VI) form the deep layer (Figs. 1 and 2) [30]. A recent study demonstrated that this classical trilaminar description is in reality a complex structure with large anatomical variation (Fig. 1) and poorly defined fascial planes [30]. Prior studies have demonstrated the highly variable anatomical nature of the quadriceps tendon, which include unilaminar, bilaminar, complex trilaminar, and even tetralaminar fiber orientations (Fig. 3) [30]. A MRI study published by Zeiss et al. revealed that only 56% of subjects had a trilaminar QT appearance, while 30% had a bilaminar appearance [31]. In a cadaver study of 20 limbs by Waligora et al., 17 quadriceps tendons had bilaminar or complex trilaminar appearances; furthermore, an oblique head of the vastus lateralis was found in 60% of the

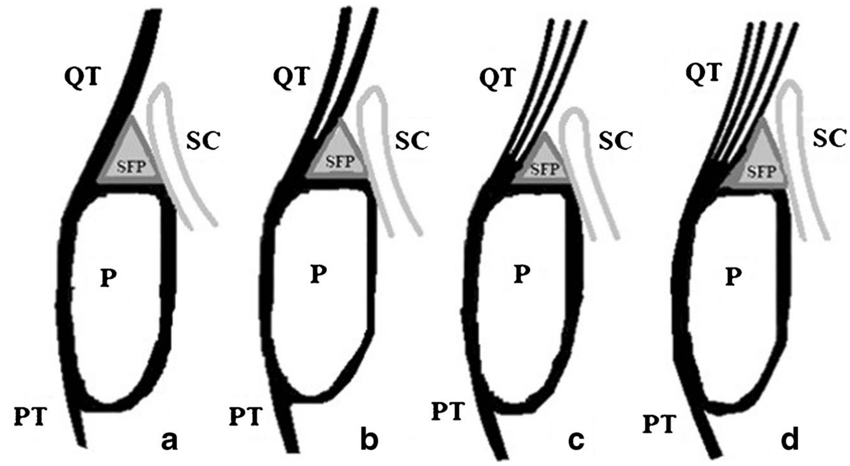

Fig. 1 Illustrations of the various laminar appearances of the quadriceps tendon: **a** unilaminar array of quadriceps tendon; **b** bilaminar array of quadriceps tendon fibers; **c** trilaminar array of quadriceps tendon fibers; **d** tetralaminar array of quadriceps tendon fibers. QT quadriceps tendon; PT patellar tendon; SC suprapatellar capsule; SFP suprapatellar (quadriceps) fat pad

specimens [30]. Other normal variations of the quadriceps anatomy include a fourth vastus muscle, known as the tensor vastus intermedius, which lies between vastus lateralis and vastus intermedius [32, 33]. This makes it important for the radiologist to know the appearance of a patient's tendon pre-operatively in order to understand the possible variability that would contribute to alterations in the post-operative appearance.

Pre-operative MRI evaluation of the quadriceps tendon

Accurate prediction of autograft size for ACL reconstruction can assist in the pre-operative planning and decision-making regarding graft choice [34]. This is particularly important in smaller stature individuals in whom a surgeon might have to harvest a full thickness QT graft. Several studies, utilizing ultrasound or MRI, have investigated the use of patient specific anthropomorphic data (age, height, and weight) as predictors of autograft size [35, 36]. Preoperative MRI is able to reliably estimate the thickness of the QT graft 3 cm proximal to the superior pole of the patella [37]. Xerogeanes et al. reported standing height to be the most important predictor of tendon length of the QT available for graft harvest on preoperative MRI. Furthermore, harvesting the QT graft results in an 87.5% greater intra-articular graft volume compared to PT, and 61.3% of native quadriceps tendon remains after harvesting, which was significantly greater than 56.6% for the native patellar tendon [36], which allows for partial thickness harvest of the QT graft, whereas for individuals with

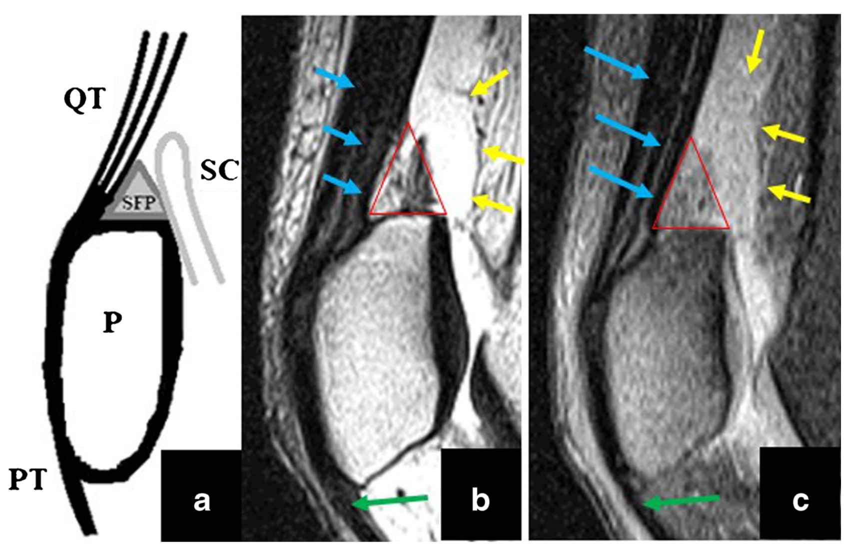

Fig. 2 Normal trilaminar appearance of quadriceps tendon. **a** Illustration of the trilaminar quadriceps tendon with important surrounding anatomical structures. **b** Sagittal proton density and **c** proton density fat saturation MRI demonstrate the normal trilaminar appearance of the quadriceps tendon. Rectus femoris (top blue arrow) is the most superficial layer. Vastus lateralis and vastus medialis combine, form the middle layer (middle blue arrow). Vastus intermedius (bottom blue arrow) forms the deepest layer. QT quadriceps tendon (blue arrows); PT patellar tendon (green arrow); SFP suprapatellar (quadriceps) fat pad (red triangle); SC suprapatellar capsule (yellow arrows)

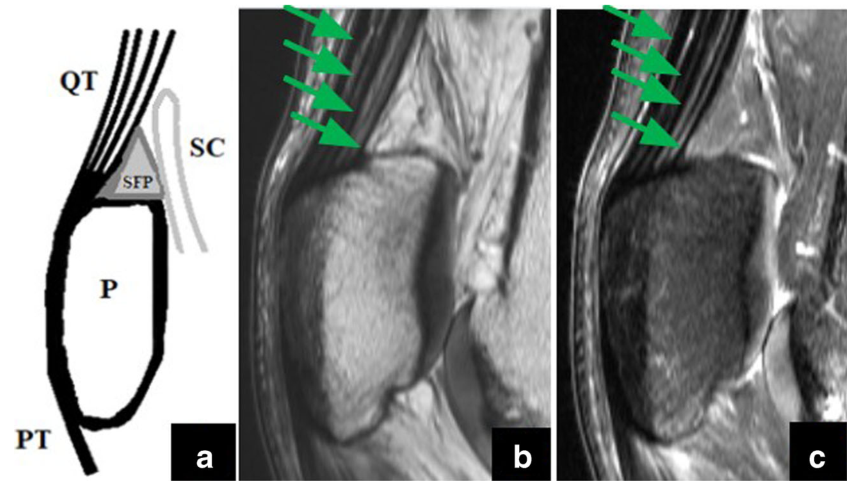

Fig. 3 Normal tetralaminar appearance of the quadriceps tendon. **a** Illustration of the tetralaminar quadriceps tendon. **b** Sagittal proton density MRI and **c** sagittal proton density fat saturation MRI demonstrate the normal tetralaminar (green arrows) appearance of the quadriceps tendon

small tendons, full thickness grafts are procured, especially when thickness is less than 7 mm. A retrospective study of 62 patients after ACL surgery found that pre-operative MR images of the quadriceps, patellar, and hamstring tendons are reliable and consistent with intra-operative measurements of the resulting autograft indicating that these images can be useful for graft selection [38]. Ashford et al. reported that on 3D MRI of 54 knees, the quadriceps tendon has a larger cross-sectional area than a pre-operative extrapolated measurement of the predicted quadrupled hamstring tendon (QHT) autograft, 84.4 mm^2 vs 47.2 mm^2, respectively. Additionally, 17% of the QHT patients had anatomy that resulted in insufficient graft size (less than 8.0 mm thick), yet these patients still had robust QT size available for autograft [39]. Preoperative MRI also assesses the quality of the quadriceps tendon and adjacent structures such as the suprapatellar fat pad and suprapatellar capsule. The native quadriceps should be inspected for tears, tendinosis, enthesopathy, muscle atrophy, and laminar appearance of the tendon. Radiologists should also review the appearance of the superior pole of the patella to assess for bone tumors, cysts, and osteopenia. Enthesopathic spurs may be present on the quadriceps muscle (Fig. 4) and are not typically removed from the graft during harvesting; therefore, they might be seen on the reconstructed ACL on post-operative MRI.

Intraoperative harvesting surgical technique

Currently, there is a variety of operative techniques for QT autograft harvesting, making it essential for the radiologist to be aware of the diverse spectrum of MRI findings to differentiate between normal post-operative findings from pathology. The three types of grafts that can be harvested from the quadriceps tendon include partial-thickness, full-thickness, either with or without bone block from the superior pole of the patella. Harvesting the QT autograft was first described by Marshall et al. in 1979 as a substitution graft for revision ACL reconstruction with a construct of "quadriceps tendon-prepatellar retinaculum-patellar tendon," which has not been adopted in modern-day protocols given its high failure rates [40]. Blauth first described harvesting the central portion of the QT tendon with bone block [41], which Fulkerson and Langeland in 1995 introduced to the United States [42] (Fig. 5). In 2003, Theut et al. then described harvesting the central quadriceps tendon without bone block [43]. Fink et al. described a minimally invasive procedure to harvest the QT with or without a bone block through a 2.5 cm incision over the superior border of the patella. This generates a graft that is 9–10 mm wide and 8 mm thick with a 20 mm bone block

Fig. 4 Lateral plain radiograph showing enthesophyte at the distal end of the quadriceps tendon (yellow arrow)

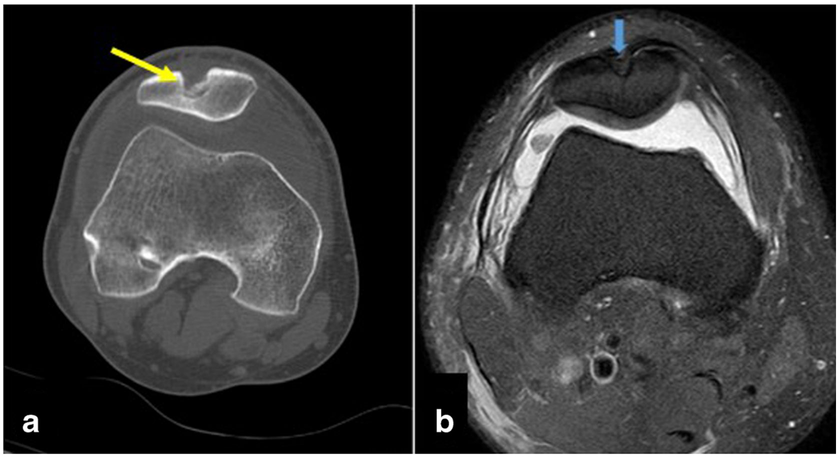

Fig. 5 Image of QTB graft harvesting: **a** axial CT image showing central tendon quadriceps harvesting with bone block; **b** T2 proton density fat saturation MRI axial image showing a groove over the patella indicating the patella bone block harvest site (blue arrow). Image **a** was provided courtesy of Dr. Steven Rabuck at the University of Pittsburgh Medical Center, Department of Orthopedic Surgery, Division of Sports Medicine, whereas image **b** was reproduced with permission by Dr. Vivek Pandey and BMJ Copyright

and to the surgeons desired length (70–90 mm) [44]. Advancements in surgical instrumentation for minimally invasive QT graft harvesting have allowed for improvements and modifications in ACL reconstruction with this autograft. Crall et al. described the surgical technique for an all-soft tissue QT autograft with the anatomic all-inside ACL reconstruction technique. This results in a shorter graft length of 65–70 mm with benefits of bone preservation, less postoperative pain, and independent anatomic socket drilling [45] (Fig. 6).

Harvesting of the QT can be achieved with or without a bone block [46, 47]. Both harvesting techniques (QTB or all-soft tissue QT) have shown comparable clinical outcomes to BPTB [17]. Unlike the QTB, the QT harvest will not have a risk of patella fracture; furthermore, the surgeon can harvest a partial-thickness or full-thickness quadriceps tendon autograft and should only remove the amount of tissue necessary for a robust graft [48]. Therefore, the all-soft tissue technique allows for minimum removal of graft tissue from the harvest site; theoretically this might result in

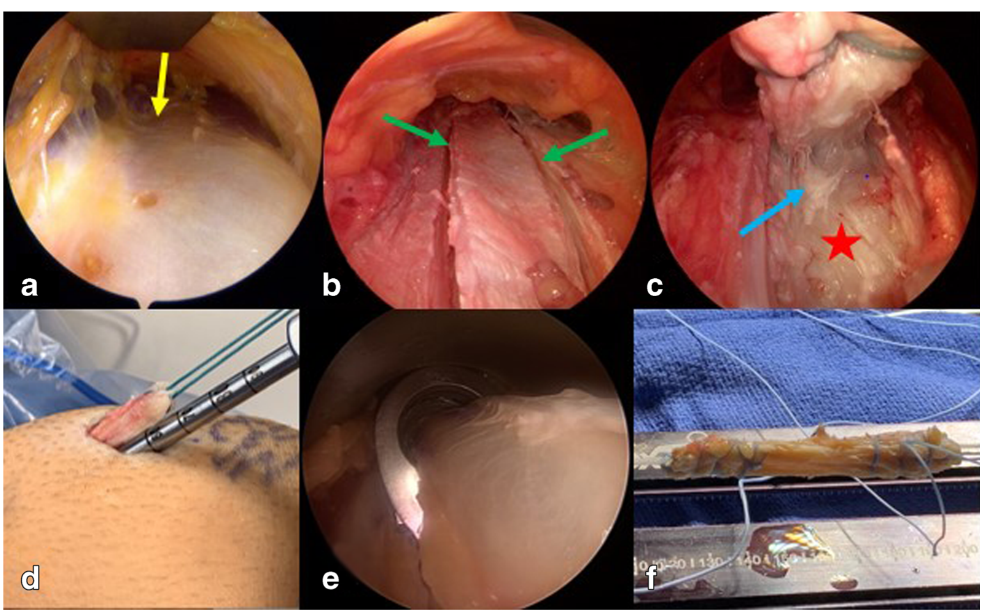

Fig. 6 Partial thickness quadriceps graft harvesting without bone block. **a** Arthroscopic appearance of the normal quadriceps tendon prior to harvesting. **b** Parallel incisions in the central third portion of the quadriceps tendon. **c** Securing distal free end of QT graft. Deep quadriceps tendon layer (vastus intermedius) is visualized (red star). **d** Measuring length of the graft with a calibrated harvesting tool. Smaller length graft harvests are less likely to violate the proximal myotendinous junction. **e** Calibrated quadriceps graft harvester is used to truncate the proximal graft end. **f** All soft tissue quadriceps tendon graft whipstitched on operative table in preparation for reconstruction of the ACL

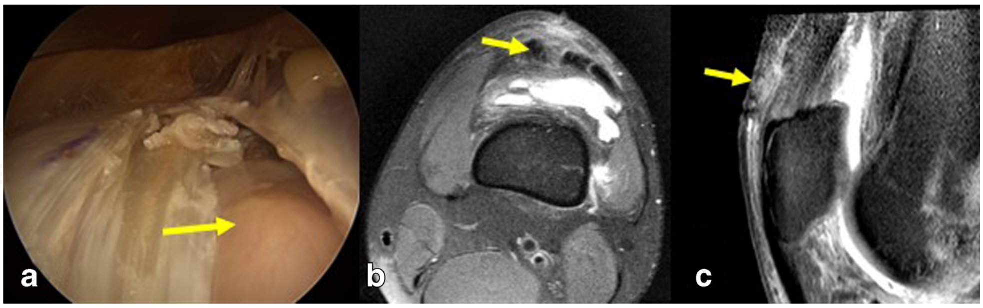

Fig. 7 Normal postop appearance of full thickness all-soft tissue graft harvesting without closure. **a** Arthroscopic image of the post-harvest quadriceps tendon with visualization of the suprapatellar fat pad (yellow arrow); **b** axial and **c** sagittal MRI proton density fat saturation that demonstrates full thickness soft tissue graft without violation of the suprapatellar pouch. This was a medial-central harvest where the tendon is slightly thicker and avoids the lateral vascular anastomosis. Edema pattern and scar tissue formation is around the harvest site (yellow arrows)

less post-operative pain and quicker rehabilitation. The graft can be fixated using an aperture fixation with either interference screws or a cortical suspensory device. If a bone block is used with the graft, there is no consensus as to whether it should be placed in the femoral or tibial tunnel. When harvesting, surgeons use caution to avoid violating the suprapatellar capsule or proximal quadriceps myotendinous junction. Disruption of the suprapatellar capsule occurs more frequently when full-thickness quadriceps tendon grafts are harvested, resulting in extravasation of joint fluid and possibly limiting the ability to perform arthroscopy after graft harvesting. If this occurs, superior capsular repair should be performed prior to arthroscopy. Surgical changes can be seen on post-operative MRI (Fig. 7). If there was violation of proximal myotendinous junction, a hematoma may be seen proximal to the harvest site and can be distinguished from a hematoma that would be concerning regarding tendon rupture [49]. This may not be seen on conventional knee MRI, as it would occur proximal to the routinely imaged area.

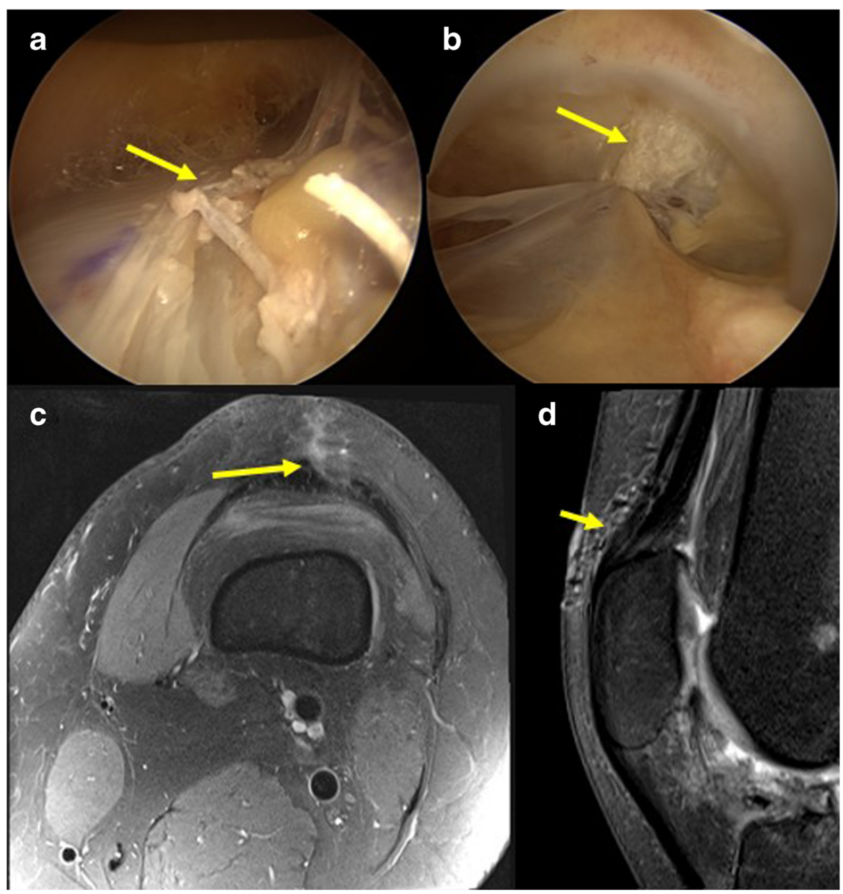

Fig. 8 Post-op appearance of full thickness quadriceps tendon harvest with defect closure. **a** Extra-articular and **b** intra-articular arthroscopic views of harvest site showing quadriceps tendon with violated capsule. **c** Axial and **d** sagittal proton density fat saturation images demonstrating normal post-surgical changes. Post-surgical scarring and suture material (yellow arrow) informs the radiologist that suture repair of the harvest site occurred and results in restoration of the trilaminar appearance of the quadriceps tendon

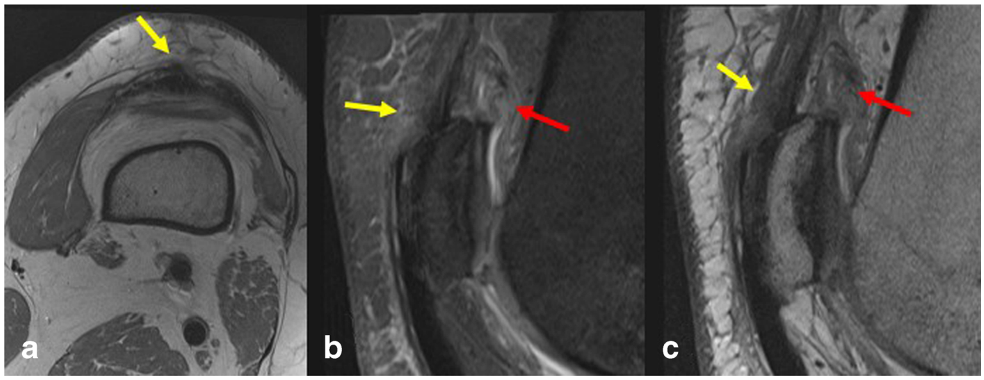

Fig. 9 Full thickness graft harvest with defect closure and capsular repair. **a** Axial proton density, **b** sagittal proton density fat saturation MRI, and **c** sagittal proton density MRI demonstrating scar changes (yellow arrows) at the quadriceps tendon donor site with evidence of capsular rupture repair (red arrows)

Normal post-operative appearance of harvest site

The normal postoperative appearance of the QT autograft donor site depends on the harvest technique used. The radiologist should be able to understand the post-operative findings at the quadriceps and patellar harvest sites, the suprapatellar fat pad, the joint capsule, and the reconstructed ACL. A radiologist should be able to appreciate the different expected post-operative findings of a partial thickness versus full thickness graft harvest site as well as between QT and QTB; however, no appreciable difference in the graft itself between a partial thickness and full thickness harvest will be noticeable on imaging.

The normal post-operative appearance of the harvest site of a partial thickness, all-soft tissue QT harvest is a central defect of the quadriceps tendon with edema and scar tissue formation. The deep layer of the QT, the suprapatellar (quadriceps) fat pad and the suprapatellar pouch will be intact. There is no consensus regarding routine closure of the quadriceps tendon harvest defect superficially. Partial thickness graft harvests may not undergo suture closure (Fig. 6). A full thickness graft harvest, without closure of the suprapatellar capsule, will reveal edema signal extending from the subcutaneous fat through the defect and into the suprapatellar fat pad that does not infiltrate the suprapatellar capsule (Fig. 7). The suprapatellar fat pad can be easily visualized on sagittal proton density sequences and, if it is not violated, there will be clear visualization of the joint fluid. If during full-thickness graft harvest there is violation of the suprapatellar capsule (Fig. 8), then suture material with scarring may be noted in the suprapatellar capsule, suprapatellar fat pad and quadriceps tendon (Fig. 9). Following graft harvest, the quadriceps tendon may not be re-approximated but if the surgeon needs to repair any violation to the capsule there will be a restoration of the laminar appearance of the tendon on post-operative MRI (Fig. 10). The radiologist should also review the superior edge of the patella as this is where a 20–25-mm bone block will be harvested from when using QTB graft. The normal defect on the patella will be easily visualized on CT scans and on MRI (Fig. 5).

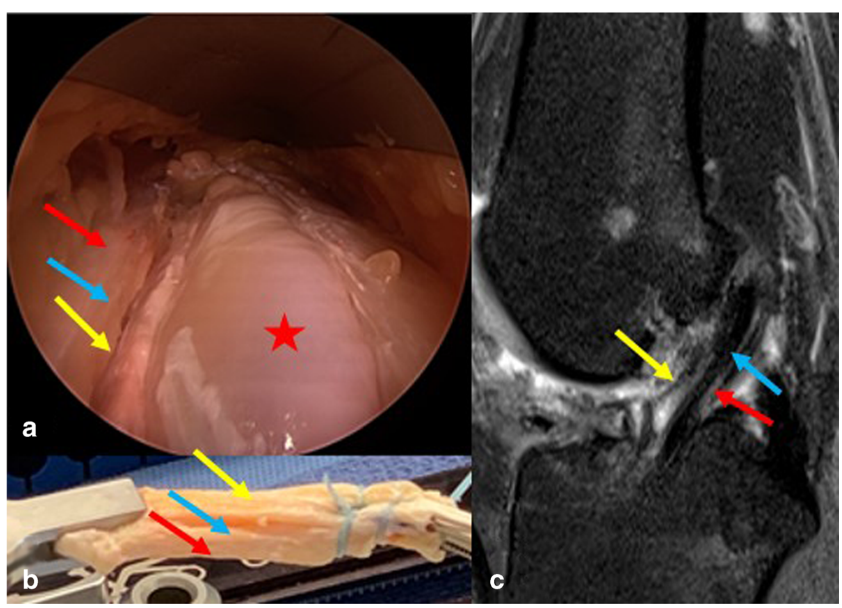

Fig. 10 Full thickness quadriceps graft harvest without violation of the capsule. **a** Arthroscope: red is superficial, blue is intermediate, yellow is deep. Suprapatellar capsule is visualized (red star). **b** Full thickness graft that has trilaminar appearance, a reflection of quadriceps tendon anatomy. Deep layer has suprapatellar fat pad tissue (yellow arrow). **c** Sagittal PD fat saturation MRI showing trilaminar appearance of the ACL graft

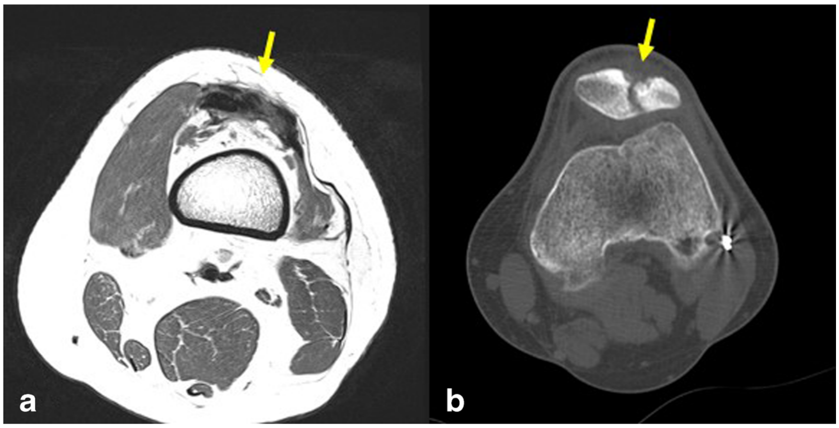

Fig. 11 Patellar fracture following QTB graft harvesting, a complication that can occur if harvesting of bone block is too deep or to lateral. **a** Axial T1 MRI showing that the harvest of the quadriceps tendon is lateral. **b** Axial CT image showing fracture of the patella after quadriceps tendon bone block harvest. Image **b** was provided courtesy of Dr. Steven Rabuck at the University of Pittsburgh Medical Center, Department of Orthopedic Surgery, Division of Sports Medicine

Normal post-operative appearance of QT ACL graft

Newly reconstructed ACLs will have an intermediate signal intensity for 4–8 months after reconstruction, which decreases over time. The increased signal from within the QT ACL graft is due to ligamentization, revascularization and synovialization and generally resolves by 12 months (Fig. 10). This is also seen in graft incorporation of BPTB and HT. Both BPTB and QT autografts are single stranded and do not have separation of the intermediate fluid signal that is normally seen in the quadrupled HT autograft [50]. Placement of the QTB bone block into the tunnel produces a signal noise on T2 fat saturation and proton density similar to BPTB.

Complications of quadriceps tendon autograft

The most significant complications unique to the use of quadriceps autograft include: quadriceps tendon rupture, myotendinous junction hematoma/rectus femoris deformity, and infection at the superior pole of the patella. Patellar fracture is not unique to quadriceps tendon harvest as it has also been described in BPTB harvest, but may occur with similar frequency.

Patellar fracture

Intraoperative and postoperative patella fractures have been described when harvesting the bone block for a QTB graft (Fig. 11) [13, 16] but this is only reported with an incidence of 4 in 1,154 (0.03%) [51], similar to those rates published for BPTB autograft [16]. Techniques to avoid fracture include harvesting less than 30% of the patellar thickness and avoiding removal of bone from the lateral patella [52]. More recently in a case series of 57 QTB patients, Fu et al. reported that the incidence of

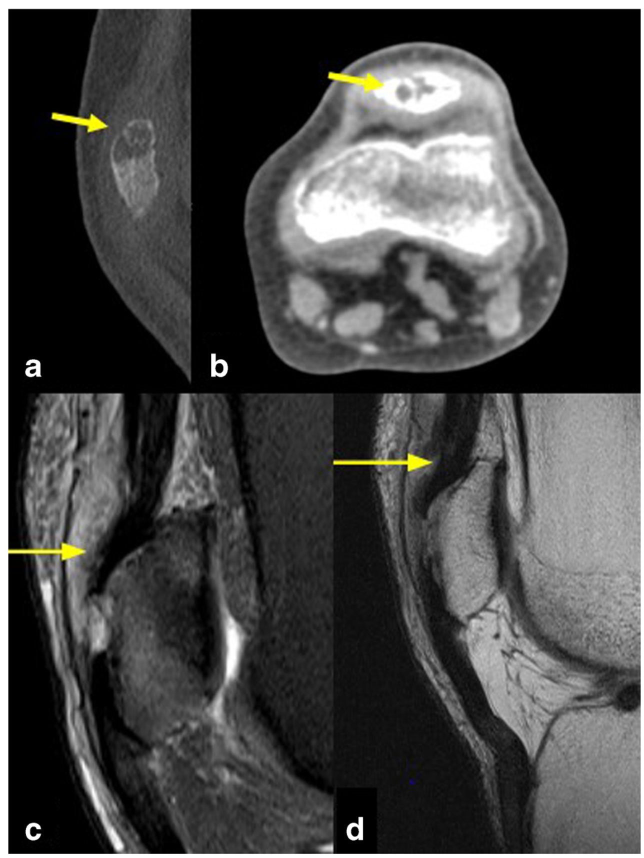

Fig. 12 Representative image of osteomyelitis in two different patients: sagittal **a** and axial **b** CT images demonstrating lytic lesion (yellow arrow) with surrounding infiltration of the adjacent soft tissue, reflecting acute osteomyelitis. **c** Sagittal proton density fat saturation and **d** sagittal proton density showing OM of the superior pole of the patella with surrounding phlegmon

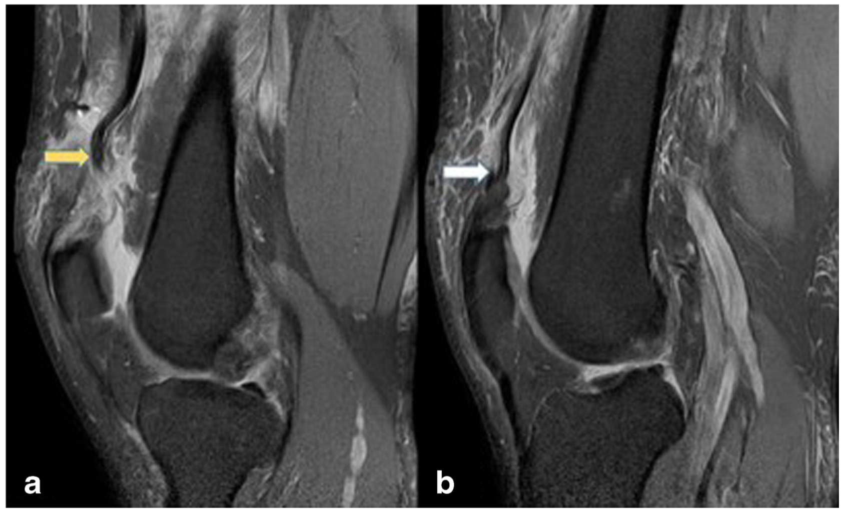

Fig. 13 Quadriceps tendon rupture after QTB harvesting. **a**–**b** Sequential sagittal proton density fat saturation MRI of the knee showing complete rupture of remnant quadriceps tendon with proximal retraction (yellow/white arrow). These figures were reproduced with permission by Dr. Vivek Pandey and BMJ CopyRight

patellar fractures was 3.5% intraoperatively and 8.8% at 2 years postoperative. This risk can be avoided by harvesting the all-soft tissue QT graft [53].

Infection/osteomyelitis

Knee joint infection is a rare but serious complication following ACL reconstruction, and can occur at either the graft donor site or graft implant site. The overall incidence ranges from 0.14 to 1.70% including all locations [54]. Graft implant site infections are particularly uncommon, and include septic arthritis [55, 56] and/or osteomyelitis of tibial [57] and/or femoral [58] bone tunnels. When compared to BPTB or QT grafts, there is an increased risk of implant site infection with the use of allograft and increased risk of donor site infection with the use of HT autograft [59]. Infection rates have been reported to be up to 66% lower in BPTB autografts when compared to HT and allografts [59]. QTB harvesting may increase the risk of osteomyelitis of the superior pole of the patella simply due to the location of harvest (Fig. 12); however, no literature has been published on infection complications risks unique to the QT harvest.

Quadriceps tendon rupture

Disruption of the knee extensor mechanism is a rare complication of harvesting either the quadriceps or patellar tendon and occurs from rupture of the weakened tendon from the patella. Benner et al. reported 13 patellar tendon ruptures from a database of 5,364 ACL reconstructions (incidence 0.24%) with BPTB [60]; prior reports of patellar tendon rupture had an incidence of (0.06–0.08%) [61, 62]. Rupture of the native quadriceps tendon after ACL graft harvesting is a rare unique potential complication of QT autograft. To date, only one such case has been reported in the literature by Pandey et al. in a patient 10-years after ACL reconstruction with QTB (Fig. 13) [63]. Rupture of the quadriceps tendon manifests on postoperative imaging as hematoma formation at the superior pole of the patella and loss of extensor mechanism function on clinical exam (Fig. 14).

Myotendinous junction hematoma

If QT graft harvest extends far lateral and proximal into the quadriceps myotendinous junction, injury to perforating vessels can cause bleeding and result in hematoma formation

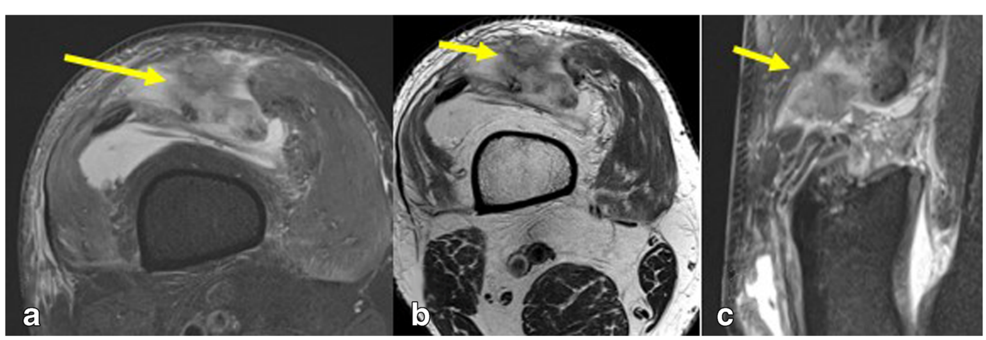

Fig. 14 Representative image of rupture of Quadriceps Tendon. Axial PD with (**a**) and without (**b**) fat saturation and sagittal proton density fat saturation (**c**) demonstrating complete rupture of the distal quadriceps tendon with a large hematoma adjacent to the superior pole of the patella (yellow arrow)

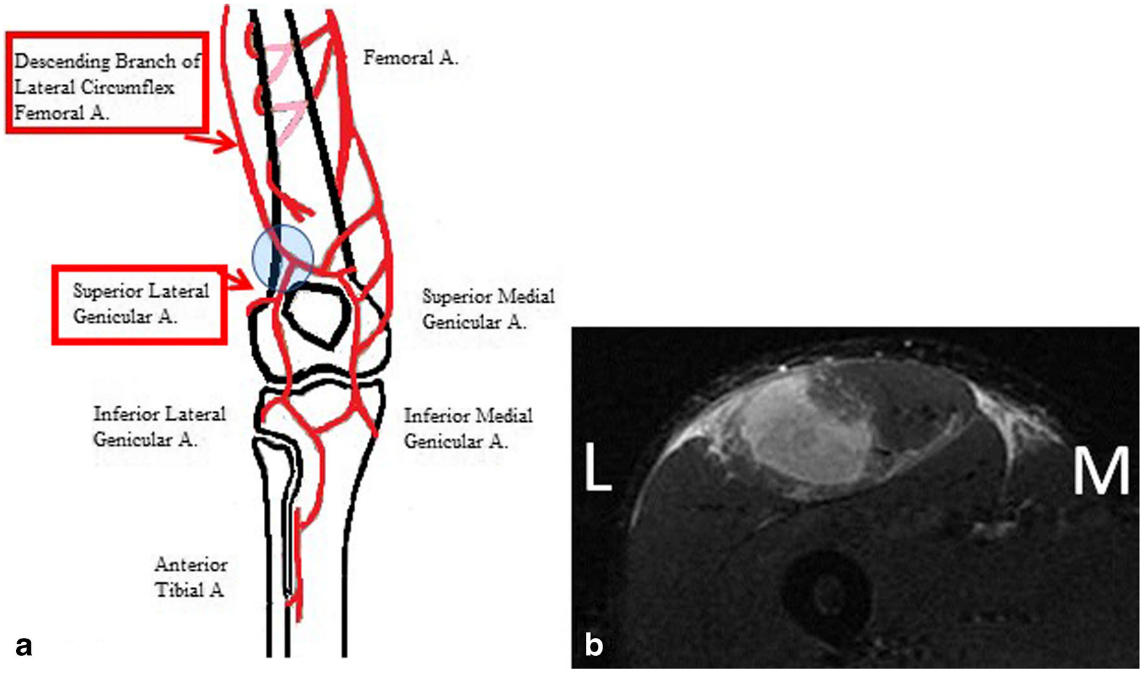

Fig. 15 **a** Illustration of vascular anatomy at the quadriceps myotendinous junction. **b** Representative image of axial T2 fat saturation MR image of hematoma formation due to violation of the myotendinous junction. L lateral; M medial

(Fig. 15) [51, 64]. Although the quadriceps myotendinous junction is often not included in the field of view of a standard knee MRI, it is important for a radiologist to appreciate this concept as a way of explaining the cause of post-operative hematoma. The presence of hematoma at the QT harvest site does not necessarily imply that the remnant quadriceps tendon has ruptured or that the patient has a coagulopathy. Hematoma from excessive lateral and proximal graft harvesting will occur at the quadriceps myotendinous junction without disruption of the quadriceps tendon at the distal harvest site (Fig. 15). In contradistinction, post-operative hematoma from quadriceps rupture typically occurs at the superior pole of the patella and will be associated with disruption of the native quadriceps tendon fibers beyond the expected post-harvest defect (Fig. 14).

Conclusions

Quadriceps tendon autograft is becoming a more popular graft option in primary ACL reconstruction. The QT autograft has favorable biomechanical properties and comparable clinical outcomes to both BPTB and HT autografts without the associated complications of these grafts such as anterior knee pain, kneeling pain, higher risk of infection, and patellar fracture. Given the biomechanical advantages of the quadriceps tendon, surgeons are able to harvest a robust graft and still preserve more native tissue when compared to BPTB and HT. Radiologists play a key role in providing pre- and post-operative imaging interpretations of the quadriceps femoris tendon donor site and the reconstructed ACL. It is important for them to have familiarity with normal post-operative MRI changes as well as an understanding of the appearance of unique post-operative complications.

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