General

Time-Sensitive Injuries for the Sports Medicine Surgeon – "Sports Medicine Trauma", Part 2: Lower Extremity

Reece M Rosenthal, MD[1], Joseph Featherall, MD[1], Daniel C Lewis, MD[1], Chad W Parkes, MD[1], Rebecca L Sanderson, MD[1], Robert M Putko, MD[2], Patrick J McGlone, MD[2], Scott M Feeley, MD[2], Nicholas M Panarello, MD[2], Brendan M Lilley, BS[3], Sarah Rabin, MD[2], Robert A Waltz, MD[4], Justin J Ernat, MD, MHA[1]

[1] Orthopaedic Surgery, University of Utah, [2] Walter Reed National Military Medical Center, [3] Quinnipiac University, [4] United States Naval Academy

Keywords: Sports Medicine, Trauma, Orthopaedic Surgery, Lower Extremity

https://doi.org/10.52965/001c.126707

Orthopedic Reviews

Vol. 16, 2024

Skeletal fractures are traumatic injuries that are widely accepted as requiring acute treatment to avoid long-term disability and dysfunction. There are a number of soft-tissue injuries or non-traditional fractures, frequently treated by sports medicine surgeons, which additionally require treatment in an expedited fashion in order to optimize healing and function. Sports medicine injuries of the lower extremity requiring acute treatment include, but are not limited to, multiligamentous knee injuries, proximal hamstring ruptures, quadriceps tendon ruptures, patellar sleeve avulsions, patellar tendon ruptures, tibial spine avulsions, posterior cruciate ligament avulsions, bucket handle meniscus tears, and achilles tendon ruptures. The purpose of this manuscript is to review the sports medicine injuries of the lower extremity which require acute/urgent management to facilitate optimal treatment.

1.0 - INTRODUCTION

Orthopedic sports medicine surgery is often considered elective in nature with the vast of majority of procedures lacking threat to life or limb and having a relatively low impact risk profile when compared to other orthopedic subspecialties such as trauma, spine, oncology, and arthroplasty.[1,2] What is often overlooked, however, is the threat on quality of life that sports medicine injuries pose, and how many of these injuries can potentially lead to more long-term joint/musculoskeletal deterioration and/or dysfunction.[3,4] While most sports medicine injuries can be treated on a non-urgent or elective basis, there are select pathologies in which more urgent intervention can prevent long-term joint/musculoskeletal deterioration and/or dysfunction. We refer to these types of injuries collectively as "sports medicine trauma", where time is of the essence in optimizing surgical performance for short- and long-term treatment success. These procedures are universally understood to be non-elective and require timely intervention. While not exhaustive, this review will discuss common lower extremity sports medicine traumatic injuries with a specific focus on the impact of urgent treatment.

2.1 - MULTILIGAMENTOUS KNEE INJURIES AND KNEE DISLOCATIONS

EPIDEMIOLOGY

Multiligamentous knee injuries (MLKI) and knee dislocations (KD) are terms frequently used synchronously to describe any severe knee injury involving more than one knee ligament (Figure 1). However, it has been demonstrated that KD has a higher associated risk of soft tissue and neurovascular injury.[5] The incidence of these injuries is increasing due to increased participation in high risk/energy sports, increased high energy polytrauma, and increasing obesity.[6] Both pathologies can happen from high energy injuries (i.e., motor vehicle accident or motorcycle crashes), low energy injuries where the injury is isolated to the knee (sporting accidents), and very low energy injuries due to falls or missteps in the obese population.[7] In most cases, the ligamentous injury does not determine urgency as there is varying literature to suggest acute versus delayed ligament reconstruction. However, associated injuries such as vascular compromise, common peroneal nerve injury, irreducible dislocation, biceps femoris avulsion, extensor mechanism disruption, bucket handle meniscal tears, fractures/bony avulsions, loose bodies, open injuries, or the inability to maintain a concentric knee joint reduction may prompt urgent isolated sports medicine surgical intervention, or in conjunction with trauma and/or vascular surgery colleagues.[8,9]

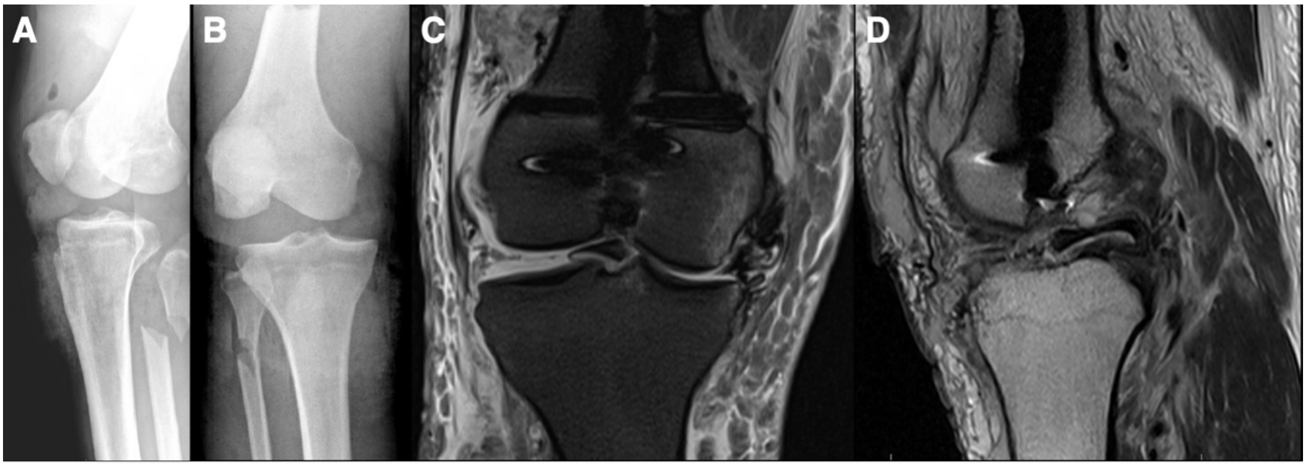

Figure 1. Representative lateral (A) and anteroposterior (B) radiographs, as well as coronal STIR (C) and sagittal proton density-weighted (D) magnetic resonance imaging of a right knee demonstrating an acute traumatic knee dislocation with associated multiligamentous injury. This patient also sustained a concomitant femur fracture treated with a retrograde intramedullary nail.

TREATMENT

Urgency of treatment hinges around the associated pathology.[8,9] Vascular repairs typically warrant external fixator application in the emergent setting, and the presence of a vascular repair impacts patient reported outcomes.[10] Transected common peroneal nerves are recommended for urgent exploration, decompression, and repair. Common peroneal nerve stretch injuries can be equally debilitating, however, common peroneal nerve injury has not demonstrated to be as impactful on patient reported outcomes as vascular injury has.[5,11] Nerve injuries are likely to be associated with biceps femoris or fibular head avulsions which may need sports medicine intervention acutely to maximize muscle function and recovery.[5,12] Open injuries, grossly unstable knees, or irreducible dislocations are all circumstances that warrant emergent or urgent sports medicine intervention, and could impact the surgeon's algorithm for surgical decision-making – i.e. acute versus delayed surgery, single- versus two-stage procedures, mobilization versus immobilization, etc.[13,14] Bucket-handle or radial meniscal tears, extensor mechanism disruptions, and loose bodies are other common concomitant pathologies in the multiligamentously-injured knee that warrant emergent/urgent sports medicine surgeon intervention, and these are discussed individually in subsequent sections of this review.[15]

2.2 - PROXIMAL HAMSTRING RUPTURES

EPIDEMIOLOGY

Complete proximal hamstring avulsion injuries, particularly those with significant retraction (>2cm), and those occurring in high demand individuals, should be identified and considered for early operative repair (Figure 2). Hamstring injuries are common in the active population, accounting for 12% to 26% of injuries occurring during sport.[16] They are associated with sports requiring repetitive kicking and aggressive sprinting such as football, soccer, and rugby, or in sports requiring forceful eccentric contraction of the hamstring complex, such as water skiing.[16] Although many hamstring injuries constitute myotendinous junction injuries or muscle strains, amenable to non-operative treatment, complete, proximal tendinous avulsions tend to benefit from operative repair.

TREATMENT

Regarding partial and complete hamstring avulsions, bony avulsion injuries, and complete retracted hamstring avulsions, non-operative treatment is associated with decreased strength and subjective functional deficits.[17,18] Operative repair of the proximal hamstring avulsion injury is thus preferred in active patients and is associated with greater functional improvement and strength.[17,19]

Expedient treatment of these injuries is of substantial importance. Acute operative repair of proximal hamstring avulsion injuries is associated with reduced perioperative pain, faster return to activity, and reduced rates of recurrence.[20] In both partial and complete proximal hamstring avulsion injuries, shorter time to repair is associated with greater improvement in functional status, greater strength, and greater likelihood of returning to preoperative level of activity.[19,21] Delayed or chronic repair allows time for tendon retraction, fibrous adhesions, scar formation, muscle atrophy, and development of sciatic nerve irritation, making the surgery more technically demanding, increasing operative time and rate of sciatic nerve injury, and decreasing attainable functional improvement.[19,22] Some authors have reported rates of postoperative sciatic nerve paresthesia rates of up to 30% in chronic repairs.[23] Overall, proximal hamstring avulsion repairs have a high rate of return to sport (93.8%) with 83.5% of patients returning to their preinjury level of activity.[24] Early surgical intervention may

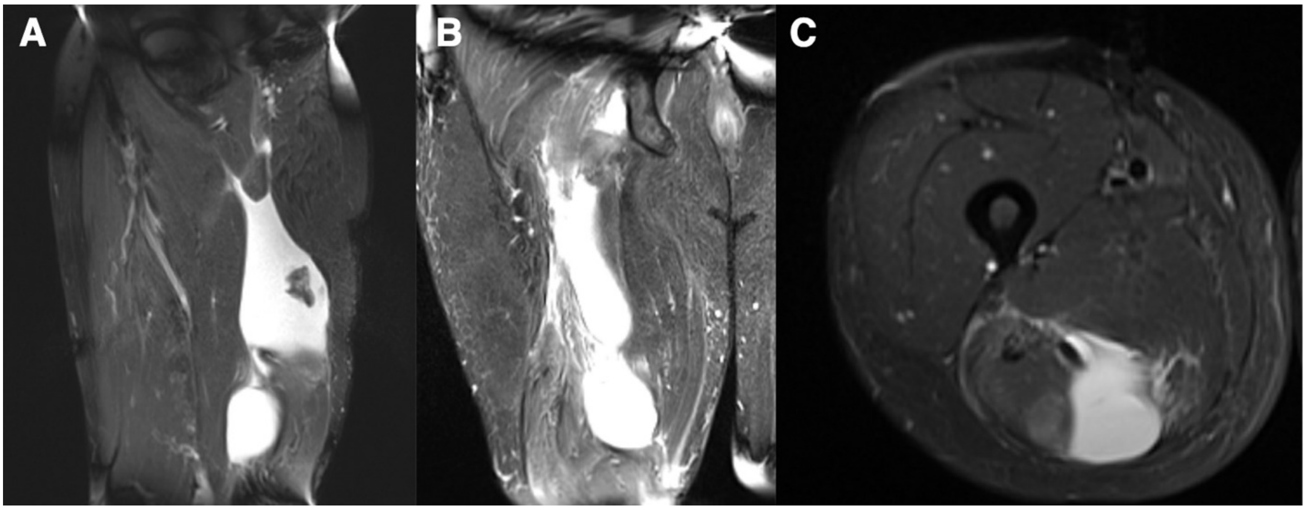

Figure 2. STIR magnetic resonance imaging of a right thigh in the coronal (A), sagittal (B), and axial (C) planes demonstrating a proximal hamstring rupture with corresponding intramuscular edema and fluid-signal intensity.

also contribute to a more rapid return to sport, however the data on this issue is not definitive.

2.3 - QUADRICEPS TENDON RUPTURES

EPIDEMIOLOGY

Quadriceps tendon ruptures are usually caused by eccentric loading of the knee extensor mechanism which can occur when landing from a jump, changing direction, a fall with forced knee flexion or other trauma. Patients commonly report feeling a pop or tear and inability to bear weight or extend the knee. Quadriceps tendon ruptures are relatively uncommon with an incidence rate of 1.37/100,000.[25] Ruptures are more common in males, patients over 40 years of age and in patients with systemic diseases such as diabetes mellitus, chronic kidney disease, obesity, rheumatoid arthritis, gout, hyperparathyroidism, and history of steroid or fluoroquinolone use.[26] Quadriceps tendon ruptures can occur at the myotendinous junction, midtendinous area, or tendon bone junction and can be classified as partial or complete. On evaluation patients may have swelling, an effusion, weak knee extension, extensor lag, and a palpable defect in the quadriceps tendon proximal to the insertion on the patella. In a complete rupture, the extensor mechanism is disrupted and patients are unable to perform a straight leg raise or actively extend the knee. In some partial ruptures, the extensor mechanism and ability to perform a straight leg raise are intact and nonoperative treatment can be considered. Radiographs may show patella baja. Diagnosis can be confirmed with ultrasound or MRI (Figure 3).

TREATMENT

Complete quadriceps tendon ruptures or partial tears without an intact extensor mechanism benefit from urgent operative repair. Nonoperative treatment of complete quadriceps tendon ruptures results in quadriceps weakness/atrophy and long term disability including buckling of the knee, difficulty with stair climbing and walking on an incline.[27] Early surgical repair of complete quadriceps tendon ruptures has been shown to have better outcomes with increased knee flexion and quadriceps strength, decreased quadriceps atrophy and need for ambulatory aids, less risk of extensor lag, and increased patient satisfaction.[28,29] The precise time period from injury to repair for optimal outcomes has not been declared. Scuderi recommended repair within 48-72 hours of the injury to obtain better outcomes.[5] Siwek et al. showed that immediate surgical repair of the quadriceps tendon (within two weeks of injury) resulted in all patients having good or excellent outcomes with at least 0-120 degrees of range of motion and at least 4/5 quadriceps strength, while delayed repair resulted in 50% of patients with unsatisfactory outcomes with range of motion less than 0-90 degrees and persistent quadriceps weakness and atrophy.[27] Rougraff et al. showed that patients treated within one week of injury had higher satisfaction scores, better functional results, and higher isokinetic data for both the injured and noninjured extremities.[29] There was no difference noted in range of motion or extensor power between the groups treated with early versus delayed repair. On the other hand, Konrath et al. did not show a statistically significant difference between time from injury to surgery in isokinetic testing and Tegner and Lysholm scores.[7] In a systematic review by Ciriello et al., it was determined that delay in surgical repair over three weeks from injury resulted in decreased functional and clinical outcomes.[30,31] Another review by Elattar et al. recommended acute repair be performed within 2-3 weeks after injury to optimize results.

Chronic tendon ruptures and delayed repair can result in lack of tendon apposition due to retraction of the quadriceps tendon proximally and patella distally, degeneration of tendon quality, and scar tissue formation. Quadriceps tendon repair has shown a 92% patient satisfaction rate

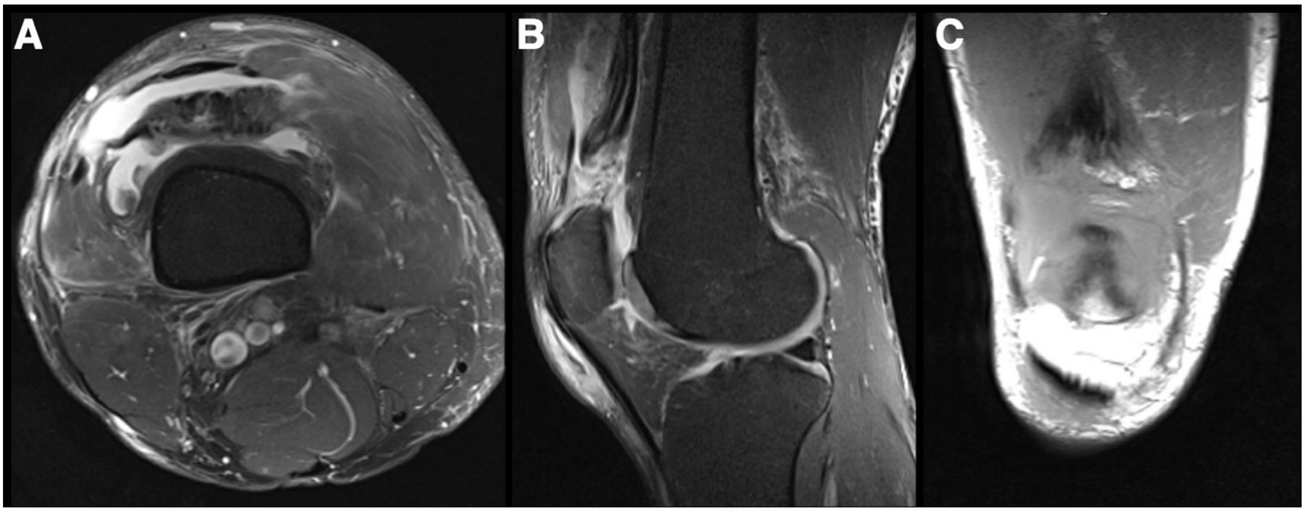

Figure 3. Proton density-weighted fat suppressed axial (A), sagittal (B), and T1 coronal (C) magnetic resonance imaging of a right knee demonstrating a quadriceps tendon rupture.

and return to previous occupation rate of 84%.[26,32] A recent systematic review by Haskel et al. showed that the rate of return to play after quadriceps tendon repair was 89.8%, with 70.0% of patients returning to same level of play.[33] To improve patient subjective and objective outcomes including return to play/occupation rates, knee range of motion, quadriceps strength, and to prevent quadriceps atrophy and extensor lag, surgical repair of quadriceps tendon ruptures should be performed expeditiously - within 2-3 weeks after injury.

2.4 - PATELLAR SLEEVE AVULSIONS

EPIDEMIOLOGY

In pediatric patients, patellar sleeve avulsion fractures are the most common patellar fracture type and result from indirect tension forces.[34] The majority of patellar sleeve fractures are avulsions of the inferior pole; superior pole patellar sleeve avulsion fractures are extremely rare.[35] In these fractures it is an important consideration that a majority of the damage occurs through the cartilage and periosteum of the patella; while there is often a small bony fragment that can be seen on plain film radiographs, the only radiographic sign of patellar sleeve avulsion fractures may be patella alta. Evaluation with ultrasound or MRI may be warranted.[34]

TREATMENT

Minimally displaced (<3mm) patellar sleeve avulsion fractures can be managed nonoperatively with immobilization followed by physical therapy and progressive range of motion. Nonoperatively managed patellar sleeve avulsion fractures have excellent clinical outcomes (mean IKDC score 96.4) and low rates of fracture displacement (1/18 patients, with only 2mm displacement).[36] Patellar sleeve avulsion fractures that require operative intervention can generally be managed with suture repair. Outcomes are generally good, with very high rates of healing, but there is a high rate of decreased knee flexion (28%) especially in patients immobilized longer than 3 weeks.[37] In both operative and nonoperative management, prompt identification and early treatment of patella sleeve avulsion fractures is essential.[34,36]

2.5 - PATELLAR TENDON RUPTURES

EPIDEMIOLOGY

Patellar tendon ruptures are commonly caused by eccentric contraction of the quadriceps tendon with the knee in flexion during an athletic activity such as when landing from a jump, cutting, and running upstairs. Patients often report feeling a pop or knee buckling, and difficulty with weight bearing and knee extension. Patella tendon ruptures are rare with an incidence rate of 0.68/100,000.[25] Ruptures are more common in males, in active patients in the 3rd or 4th decade of life, and in patients with systemic diseases such as systemic lupus erythematosus, rheumatoid arthritis, chronic kidney disease, diabetes mellitus, and history of steroid or fluoroquinolone use.[38,39] Ruptures most commonly occur as an avulsion off the inferior pole of patella, but can also occur mid-tendinous or at the attachment on the tibial tubercle. On exam, patients may have swelling/effusion, weak knee extension, extensor lag, and a palpable defect in the patella tendon. Radiographs may show patella alta or avulsion fracture. Diagnosis can be confirmed with ultrasound or MRI (Figure 4).

TREATMENT

Early surgical repair of complete patellar tendon ruptures has been shown to result in improved outcomes in increased knee flexion and quadriceps strength, and decreased quadriceps atrophy.[27,38] Chronic or neglected patellar tendon rupture will cause extension weakness, difficulty with ambulation, instability with single leg stance,

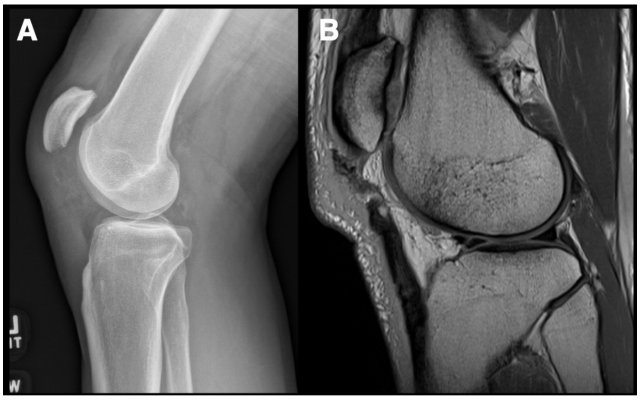

Figure 4. Lateral radiograph (A) and sagittal proton density-weighted fat suppressed MRI (B) of a left knee demonstrating a patellar tendon rupture.

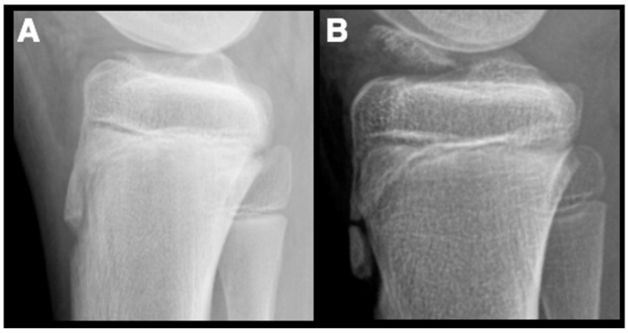

Figure 5. Representative radiographs of two right knees demonstrating Meyers and McKeever Type II (panel A) and Type III (panel B) tibial spine avulsion injuries.

difficulty with stair climbing and rising from a chair.[38] Siwek showed that repair within two weeks of injury resulted in over 80% of patients having excellent outcomes with full range motion and normal quadriceps strength. Delayed repair of the patellar tendon rupture resulted in 33% of patients with excellent outcomes, 50% of patients with good outcomes, and 17% with unsatisfactory outcomes which was described as range of motion less than 0-90 degrees and quadriceps weakness.[27] Patients who underwent repair more than 2 weeks after injury are less likely to be able to undergo primary repair and more likely to need repair augmentation with graft.[27,38] The longer the amount of time that has elapsed since the injury, the higher the likelihood of contraction of the quadriceps, proximal migration of the patella, tendon degeneration, scarring, and calcification.[38] If repair is delayed more than 6 weeks, it is often impossible to mobilize tissue enough to obtain a primary repair, necessitating V-Y advancement, quadriceps turndown or augmentation/reconstruction.[38,40] With prompt treatment, the overall return to play rate is 88.9% for patellar tendon repairs with 80.8% return to the same level of play.[33]

2.6 - TIBIAL SPINE AVULSION

EPIDEMIOLOGY

Tibial spine avulsions are a bony variant of traumatic anterior cruciate ligament (ACL) injury (Figure 5). These injuries are defined by avulsion of the intercondylar tibial eminence at the ACL insertion point and are categorized according to the Meyers and McKeever method, which classifies avulsions as non-displaced (Type I), minimally displaced with hinge (Type II), fully displaced (Type III) and comminuted (Type IV) (Figure 6).[41] They occur at a rate of less than 3 per 100,000 and occur at a higher incidence in children < 14 years old (73%) due to relative weakness of the bony epiphysis compared to the ACL in this population.[41,42] The mechanism of injury in children is most commonly a sports-associated pivot and/or hyperextension of the knee whereas in adults the injury is more likely to be associated with high-energy trauma.[41,43] The activities that are associated with tibial spine avulsion mirror those that are most often associated with ACL ligamentous injury – contact sports or those that require pivoting and twisting, such as football, skiing, cycling, baseball, and soccer.[41] These injuries are also commonly associated with concomitant soft tissue injuries (32 - 59%), specifically meniscal injuries which may be present in up to 22% of patients presenting with tibial spine avulsions.[43,44]

TREATMENT

Type I tibial spine avulsion fractures are generally treated non-operatively, with cast or splint immobilization representing the mainstay of treatment. While type II fractures may also be treated non-operatively with closed reduction and immobilization, recent evidence has emerged suggesting that for type II fractures, especially those with > 5 mm displacement, functional outcomes are improved with arthroscopic or open reduction and internal fixation.[43,45] Type III and IV fractures are managed surgically, with evidence supporting the use of arthroscopic internal fixation over open techniques.

Timely treatment is important in the repair of tibial spine avulsions, as substantially delayed or inadequate treatment increases the risk of non-union.[46] It is well-reported that delayed treatment of pediatric ACL injury results in worsened meniscal injury and inferior outcomes; however, there is comparatively less literature on the subject of delay in tibial spine avulsion treatment. The existing literature suggests that, in patients with delayed (> 21 days) treatment of tibial spine avulsions, there is a significantly higher risk of meniscal injury.[47] Additionally, those with delayed treatment were shown to be more likely to require > 2.5 hours of operative time and, additionally, had a much higher risk of developing arthrofibrosis.[47] This risk of arthrofibrosis remains with even smaller delays in treatment, with an elevated risk being found after a 7 day delay from injury to surgery.[48] Therefore, prompt treatment is preferred in the management of tibial spine avulsion injuries.

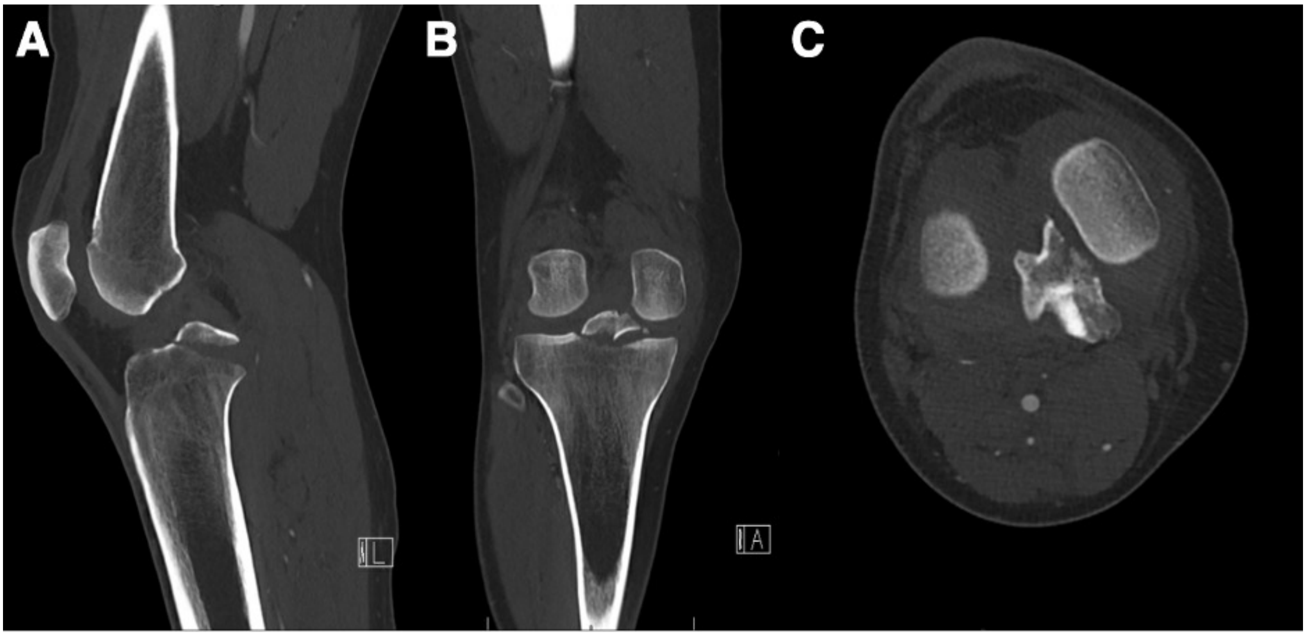

Figure 6. Representative computer tomography in the sagittal (A), coronal (B), and axial (C) planes demonstrating a PCL avulsion injury.

2.7 - POSTERIOR CRUCIATE LIGAMENT AVULSION

EPIDEMIOLOGY

Posterior cruciate ligament (PCL) injuries are relatively uncommon, accounting for 3% to 23% of knee injuries, and PCL avulsion injuries are a rare presentation of this injury (Figure 6).[49,50] Thus, the true incidence of PCL avulsion injuries is difficult to assess. These injuries may also be more common in regions where motorcycle accidents are prevalent.[51] Mechanisms include falls resulting in twisting injury to the knee and motor vehicle accidents resulting in a blow to the anterior tibia with a flexed knee.[52]

TREATMENT

Operative fixation of these injuries is preferred as nonoperative treatment often results in nonunion, posterior instability of the knee, and functional disability.[53,54] Even minimally displaced fragments may go on to nonunion, thus, reduction and screw or high-performance suture fixation is recommended. Both open and arthroscopically assisted reduction and fixation have been described with good outcomes.[51,55] These injuries are considered sports trauma as acute repair has shown improved outcomes when compared to delayed fixation in a small case series.[51,56] Delayed treatment may also make surgical intervention more difficult with formation of fracture callus, scar and fibrous tissue about the avulsion fragment.

2.8 - BUCKET HANDLE MENISCAL TEAR

EPIDEMIOLOGY

Bucket handle meniscal tears (BHMT) are peripheral, vertical/longitudinal tears of the meniscus that occur most commonly in young, active patients (<40 years of age), typically due to a torsional mechanism.[57,58] A BHMT may occur in isolation, with reported rates of ~9% in ligamentously stable knees.[57] Additionally, they may occur in the setting of anterior cruciate ligament (ACL) injury, with lateral BHMTs typically presenting concomitantly with acute ACL injury and medial BHMTs presenting with chronic ACL insufficiency.[59] In up 43% of cases, a patient with a BHMT may present acutely with a “locked knee” due to the displaced torn meniscal fragment preventing full extension of the knee.[60,61] Clinical work up includes performing a thorough history and clinical examination followed by obtaining magnetic resonance imaging (MRI) to evaluate for potential causes for locking and to differentiate between true mechanical locking from pseudo-locking (muscle spasm inhibiting knee movement due to pain) (Figure 7).[62,63]

TREATMENT

A displaced BHMT is at risk for further tear propagation and could ultimately lead to extension into the avascular zone of the meniscus or avulsion of the fragment, which may render the meniscus unrepairable.[64] With the critical role the meniscus plays in knee function with load transmission, shock absorption, and knee stability, preservation of the meniscus with meniscal repair is recommended when possible, especially in the setting of a BHMT, given the large volume of meniscus involved.[65,66] The ability for the sports medicine surgeon to successfully reduce and repair a

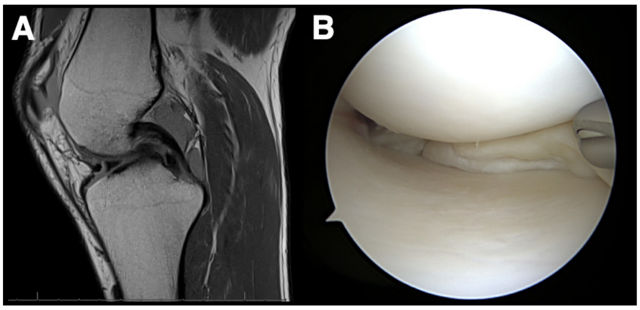

Figure 7. Proton density-weighted fat suppressed sagittal MRI (A) and arthroscopic image (B) of a right knee demonstrating a bucket handle meniscus tear.

displaced BHMT is related to the time elapsed from injury to surgery, with displaced BHMTs undergoing surgery within 6 weeks of injury possessing a higher rate of successful repair.[67]

The reported success rate of BHMT repair has been widely variable with a recent systematic review and meta-analysis reporting a failure rate of 14.8%. Failure rates of the included studies ranged from 0-75%, with the majority of failures occurring within 2 years of meniscal repair.[68] At second look arthroscopy at an average of 2 years, 82% complete healing rate has been reported when performed in conjunction with ACL reconstruction.[69] These healing rates have been shown to decrease with long clinical follow-up of patients < 18 years of age, with 75% success rate at 2 years post-operatively and 59% success rate at an average 8-year follow-up.[70] Given their complexity, BHMT repairs portend a lower success rate than simple meniscal tear repairs.[70]

2.9 - ACHILLES TENDON RUPTURES

EPIDEMIOLOGY

Achilles tendon ruptures (ATRs) present as a sudden sharp pain to the posterior aspect of the ankle, and typically the injury occurs at a level between 2 and 4 cm above the insertion point of the Achilles tendon on the calcaneus.[71, 72] They most often affect male individuals between 30 – 50 years of age and the injury most commonly occurs during athletic activity in individuals who only intermittently participate in sport.[71] The incidence of ATR has been reported as between 7 and 40 per 100,000 person-years.[72] While the mechanism of injury is typically an acute, forced plantarflexion and/or pronation of the foot (imparting an oblique force on the contracted tendon), it is largely thought that chronic degenerative changes to the Achilles tendon brought upon by age, microtrauma, and systemic disease contribute to the susceptibility of tendon to rupture.[71] ATRs are associated with activities that require sudden "push-off" force, such as cycling, running, tennis, or basketball. Diagnosis is often clinical in nature with confirmation via MRI or ultrasound modalities (Figure 8).

TREATMENT

Treatment of an ATR can be performed both non-operatively or operatively with surgical repair of the tendon using non-absorbable, high-strength suture to bridge the rupture site. There is limited literature regarding the timeliness of surgery; however, a retrospective study of 65 patients found no difference in isokinetic strength or functional outcomes in patients repaired in less than 24 hours, between 24 and 48 hours, and 48 hours to 1 week after injury.[73] A meta-analysis by He et al, however, demonstrated that despite similar functional outcomes, delayed treatment of an ATR was associated with a higher rate of post-operative complications.[74] Treatment delay in ATR can lead to difficulty opposing tendon edges in the primary repair setting, necessitating secondary tissue reconstruction or further surgery.[75] In a cohort study by Svedman et al, treatment of ATR within 48 hours led to improved functional outcomes compared to those undergoing surgical repair after 72 hours had elapsed since initial injury.[76]

Generally, treatment for ATR leads to positive functional outcomes, with studies suggesting that at long term follow-up, 96% of patients received a "good to excellent" Boyden outcome score and 71% of patients returned to pre-injury functional status.[77] Tarantino et al reports long-term limitations in calf muscle strength (with 10 – 30% decreases in strength and endurance) may follow an ATR in some patients.[78] A systematic review by Zellers et al reports an 80% return to sport rate following ATR, with a mean return to sport time of 6.0 months.[79] Post-operative complications include a partial or complete retear of the tendon, as well as stiffness and superficial/deep surgical site infection.[72]

3.0 - CONCLUSION

The orthopedic sports medicine surgeon is often responsible for the management of bony and soft tissue injuries that optimize performance and maintain quality of life through patient engagement in activities. Some common injuries require urgent intervention to not only accomplish these higher-level goals, but to also preserve function for activities of daily living (summarized in Table 1). Recognizing the impact of expeditious treatment of sports medicine trauma is critical in optimizing care for these patients and athletes.

AUTHOR CONTRIBUTIONS

RR manuscript authoring: JF manuscript authoring; RP manuscript authoring; PM manuscript authoring; SF manuscript authoring; NP manuscript authoring; BL manuscript authoring; SR manuscript authoring; DL manuscript authoring; CP manuscript authoring; RS manuscript authoring; RW manuscript authoring; JE manuscript authoring/corresponding author

STUDY APPROVAL

Not required - Review Article

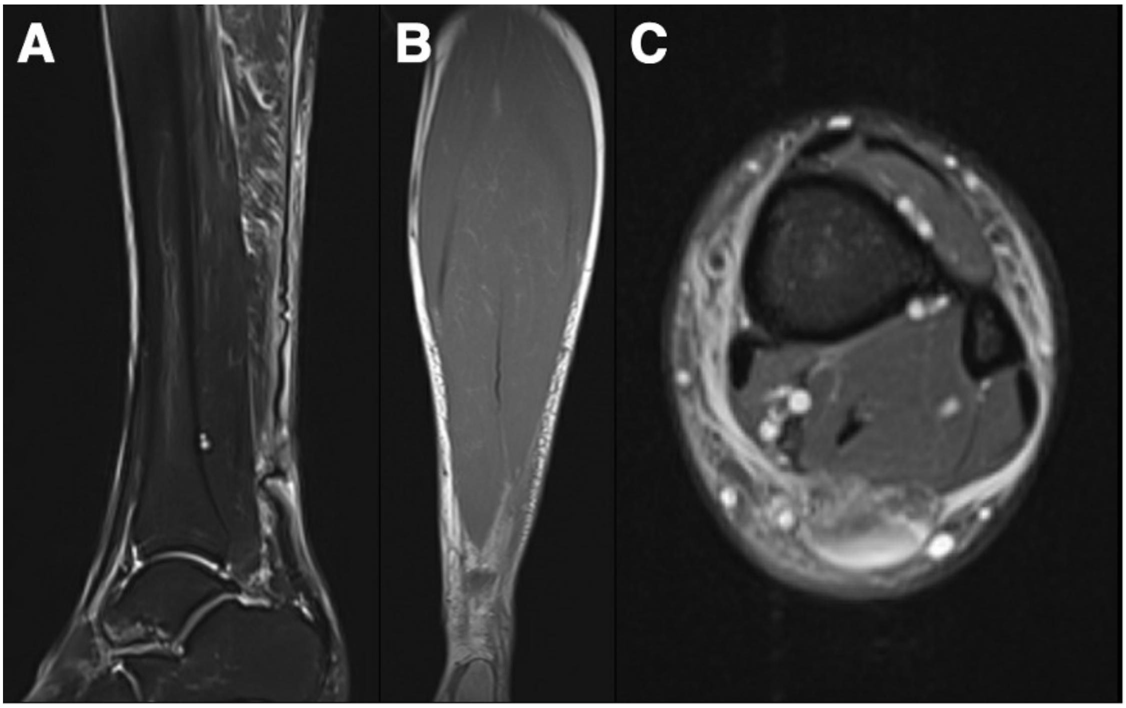

Figure 8. Representative fat suppressed T2 sagittal (A), T1 coronal (B), and proton density-weighted fat suppressed axial (C) magnetic resonance imaging of a left ankle demonstrating an acute Achilles tendon rupture.

STUDY FUNDING

No funding was obtained for the completion of this study.

COLOR PUBLICATION

The figures in this manuscript DO require publication in color.

RESULTS PRESENTATION

This review article has not been previously presented or published elsewhere

Submitted: October 22, 2024 EST, Accepted: November 15, 2024 EST

REFERENCES

1. Blom AW, Donovan RL, Beswick AD, Whitehouse MR, Kunutsor SK. Common elective orthopaedic procedures and their clinical effectiveness: umbrella review of level 1 evidence. *BMJ*. 2021;374(1):1511. doi:10.1136/BMJ.N1511

2. Hinckel BB, Baumann CA, Ejnisman L, et al. Evidence-based Risk Stratification for Sport Medicine Procedures During the COVID-19 Pandemic. *J Am Acad Orthop Surg Glob Res Rev*. 2020;4(10). doi:10.5435/JAAOSGLOBAL-D-20-00083

3. Boneti Moreira N, Cristina Vagetti G, de Oliveira V, de Campos W. Association between injury and quality of life in athletes: A systematic review, 1980–2013. *Apunts Sports Medicine*. Published online 2014. doi:10.1016/j.apunts.2014.06.003

4. Houston MN, Hoch JM, van Lunen BL, Hoch MC. The Impact of Injury on Health-Related Quality of Life in College Athletes. *J Sport Rehabil*. 2017;26(5):365-375. doi:10.1123/JSR.2016-0011

5. Kahan JB, Schneble CA, Li D, et al. Increased Neurovascular Morbidity Is Seen in Documented Knee Dislocation Versus Multiligamentous Knee Injury. *J Bone Joint Surg Am*. 2021;103(10):921-930. doi:10.2106/JBJS.20.01151

6. Ockuly AC, Imada AO, Richter DL, Treme GP, Wascher DC, Schenck RC. Initial Evaluation and Classification of Knee Dislocations. *Sports Med Arthrosc Rev*. 2020;28(3):87-93. doi:10.1097/JSA.0000000000000271

7. Levy BA, Fanelli GC, Whelan DB, et al. Controversies in the treatment of knee dislocations and multiligament reconstruction. *J Am Acad Orthop Surg*. 2009;17(4):197-206. doi:10.5435/00124635-200904000-00001

8. Fanelli GC. Multiple Ligament Injured Knee: Initial Assessment and Treatment. *Clin Sports Med*. 2019;38(2):193-198. doi:10.1016/J.CSM.2018.11.004

9. Woodmass JM, Johnson NR, Mohan R, Krych AJ, Levy BA, Stuart MJ. Poly-traumatic multi-ligament knee injuries: is the knee the limiting factor? *Knee Surg Sports Traumatol Arthrosc*. 2018;26(9):2865-2871. doi:10.1007/S00167-017-4784-3

10. Sanders TL, Johnson NR, Levy NM, et al. Effect of Vascular Injury on Functional Outcome in Knees with Multi-Ligament Injury: A Matched-Cohort Analysis. *J Bone Joint Surg Am*. 2017;99(18):1565-1571. doi:10.2106/JBJS.16.01540

11. Kahan JB, Li D, Schneble CA, et al. The Pathoanatomy of Posterolateral Corner Ligamentous Disruption in Multiligament Knee Injuries Is Predictive of Peroneal Nerve Injury. *Am J Sports Med*. 2020;48(14):3541-3548. doi:10.1177/0363546520962503

12. Peskun CJ, Chahal J, Steinfeld ZY, Whelan DB. Risk factors for peroneal nerve injury and recovery in knee dislocation. *Clin Orthop Relat Res*. 2012;470(3):774-778. doi:10.1007/S11999-011-1981-0

13. Marder RS, Poonawala H, Pincay JI, et al. Acute Versus Delayed Surgical Intervention in Multiligament Knee Injuries: A Systematic Review. *Orthop J Sports Med*. 2021;9(10). doi:10.1177/23259671211027855

14. Jiang W, Yao J, He Y, Sun W, Huang Y, Kong D. The timing of surgical treatment of knee dislocations: a systematic review. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(10):3108-3113. doi:10.1007/S00167-014-3435-1

15. Kim SH, Park YB, Kim BS, Lee DH, Pujol N. Incidence of Associated Lesions of Multiligament Knee Injuries: A Systematic Review and Meta-analysis. *Orthop J Sports Med*. 2021;9(6). doi:10.1177/23259671211010409

16. Kayani B, Ayuob A, Begum F, Khan N, Haddad FS. Surgical Management of Chronic Incomplete Proximal Hamstring Avulsion Injuries. *Am J Sports Med*. 2020;48(5):1160-1167. doi:10.1177/0363546520908819

17. Shambaugh BC, Olsen JR, Lacerte E, Kellum E, Miller SL. A Comparison of Nonoperative and Operative Treatment of Complete Proximal Hamstring Ruptures. *Orthop J Sports Med*. 2017;5(11). doi:10.1177/2325967117738551

18. Hofmann KJ, Paggi A, Connors D, Miller SL. Complete Avulsion of the Proximal Hamstring Insertion: Functional Outcomes After Nonsurgical Treatment. *J Bone Joint Surg Am*. 2014;96(12):1022-1025. doi:10.2106/JBJS.M.01074

19. Wood D, French SR, Munir S, Kaila R. The surgical repair of proximal hamstring avulsions: Does the timing of surgery or injury classification influence long-term patient outcomes? *Bone and Joint Journal*. 2020;102(10):1419-1427. doi:10.1302/0301-620X.102B10.BJJ-2019-1112.R1/LETTERTOEDITOR

20. Sarimo J, Lempainen L, Mattila K, Orava S. Complete proximal hamstring avulsions: a series of 41 patients with operative treatment. *Am J Sports Med*. 2008;36(6):1110-1115. doi:10.1177/0363546508314427

21. Cohen SB, Rangavajjula A, Vyas D, Bradley JP. Functional results and outcomes after repair of proximal hamstring avulsions. *Am J Sports Med*. 2012;40(9):2092-2098. doi:10.1177/0363546512456012

22. Chang JS, Kayani B, Plastow R, Singh S, Magan A, Haddad FS. Management of hamstring injuries: current concepts review. *Bone Joint J*. 2020;102-B(10):1281-1288. doi:10.1302/0301-620X.102B10.BJJ-2020-1210.R1

23. Bowman KF, Cohen SB, Bradley JP. Operative management of partial-thickness tears of the proximal hamstring muscles in athletes. *American Journal of Sports Medicine*. 2013;41(6):1363-1371. doi:10.1177/0363546513482717/SUPPL_FILE/DS_10.1177_0363546513482717.PDF

24. Belk JW, Kraeutler MJ, Mei-Dan O, Houck DA, McCarty EC, Mulcahey MK. Return to Sport After Proximal Hamstring Tendon Repair: A Systematic Review. *Orthop J Sports Med*. 2019;7(6). doi:10.1177/2325967119853218

25. Clayton RAE, Court-Brown CM. The epidemiology of musculoskeletal tendinous and ligamentous injuries. *Injury*. 2008;39(12):1338-1344. doi:10.1016/J.INJURY.2008.06.021

26. Ilan DI, Tejwani N, Keschner M, Leibman M. Quadriceps tendon rupture. *J Am Acad Orthop Surg*. 2003;11(3):192-200. doi:10.5435/00124635-200305000-00006

27. Siwek C, Rao J. Ruptures of the extensor mechanism of the knee joint. JBJS. The Journal of Bone & Joint Surgery. 1981. Accessed October 1, 2023. https://journals.lww.com/jbjsjournal/Abstract/1981/63060/Ruptures_of_the_extensor_mechanism_of_the_knee.10.aspx

28. Boublik M, Schlegel TF, Koonce RC, Genuario JW, Kinkartz JD. Quadriceps tendon injuries in national football league players. *Am J Sports Med*. 2013;41(8):1841-1846. doi:10.1177/0363546513490655

29. Rougraff B, Reeck C, Essenmacher J. Complete quadriceps tendon ruptures. *Orthopedics*. 1996;19(6):509-514.

30. Ciriello V, Gudipati S, Tosounidis T, Soucacos PN, Giannoudis PV. Clinical outcomes after repair of quadriceps tendon rupture: a systematic review. *Injury*. 2012;43(11):1931-1938. doi:10.1016/J.INJURY.2012.08.044

31. Elattar O, McBeth Z, Curry EJ, Parisien RL, Galvin JW, Li X. Management of Chronic Quadriceps Tendon Rupture: A Critical Analysis Review. *JBJS Rev*. 2021;9(5). doi:10.2106/JBJS.RVW.20.00096

32. Konrath GA, Chen D, Lock T, et al. Outcomes following repair of quadriceps tendon ruptures. *J Orthop Trauma*. 1998;12(4):273-279. doi:10.1097/00005131-199805000-00010

33. Haskel JD, Fried JW, Hurley ET, et al. High rates of return to play and work follow knee extensor tendon ruptures but low rate of return to pre-injury level of play. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(8):2695-2700. doi:10.1007/S00167-021-06537-4

34. Hunt DM, Somashekar N. A review of sleeve fractures of the patella in children. *Knee*. 2005;12(1):3-7. doi:10.1016/j.knee.2004.08.002

35. Kimball MJ, Kumar NS, Jakoi AM, Tom JA. Subacute superior patellar pole sleeve fracture. *Am J Orthop (Belle Mead NJ)*. 2014;43(1):29-32.

36. Sousa PL, Stuart MJ, Prince MR, Dahm DL. Nonoperative Management of Minimally Displaced Patellar Sleeve Fractures. *J Knee Surg*. 2021;34(3):242-246. doi:10.1055/s-0039-1694742

37. Perkins CA, Egger AC, Willimon SC. Transosseous Repair of Patellar Sleeve Fractures: A Case Series and Surgical Technique Guide. *J Knee Surg*. 2022;35(12):1326-1332. doi:10.1055/s-0041-1723013

38. Matava MJ. Patellar Tendon Ruptures. *J Am Acad Orthop Surg*. 1996;4(6):287-296. doi:10.5435/00124635-199611000-00001

39. Greis PE, Holmstrom MC, Lahav A. Surgical treatment options for patella tendon rupture, Part I: Acute. *Orthopedics*. 2005;28(7):672-679. doi:10.3928/0147-7447-20050701-15

40. Volk WR, Yagnik GP, Uribe JW. Complications in Brief: Quadriceps and Patellar Tendon Tears. *Clin Orthop Relat Res*. 2014;472(3):1050. doi:10.1007/S11999-013-3396-6

41. LaValva SM, Aoyama JT, Adams AJ, et al. THE EPIDEMIOLOGY OF TIBIAL SPINE FRACTURES IN CHILDREN: A MULTICENTER INVESTIGATION. doi:10.1177/2325967120S00172

42. DeFrancesco CJ, Tananbaum A, LeBrun DG, Fabricant PD. The Incidence of Pediatric Tibial Spine Fractures Is Greater and Peaks Later in Male Patients. *Arthrosc Sports Med Rehabil*. 2022;4(2):e639-e643. doi:10.1016/J.ASMR.2021.12.005

43. Tuca M, Bernal N, Luderowski E, Green DW. Tibial spine avulsion fractures: treatment update. *Curr Opin Pediatr*. 2019;31(1):103-111. doi:10.1097/MOP.0000000000000719

44. Callanan M, Allen J, Flutie B, et al. Suture Versus Screw Fixation of Tibial Spine Fractures in Children and Adolescents: A Comparative Study. *Orthop J Sports Med*. 2019;7(11). doi:10.1177/2325967119881961

45. Coyle C, Jagernauth S, Ramachandran M. Tibial eminence fractures in the paediatric population: a systematic review. *J Child Orthop*. 2014;8(2):149. doi:10.1007/S11832-014-0571-6

46. Kobayashi S, Harato K, Udagawa K, et al. Arthroscopic Treatment of Tibial Eminence Avulsion Fracture With Suture Tensioning Technique. *Arthrosc Tech*. 2018;7(3):e251. doi:10.1016/J.EATS.2017.08.078

47. Smith HE, Cruz AI, Mistovich RJ, et al. What Are the Causes and Consequences of Delayed Surgery for Pediatric Tibial Spine Fractures? A Multicenter Study. 2022;10(3). doi:10.1177/23259671221078333

48. Watts CD, Larson AN, Milbrandt TA. Open Versus Arthroscopic Reduction for Tibial Eminence Fracture Fixation in Children. *J Pediatr Orthop*. 2016;36(5):437-439. doi:10.1097/BPO.0000000000000476

49. Fontboté CA, Sell TC, Laudner KG, et al. Neuromuscular and Biomechanical Adaptations of Patients with Isolated Deficiency of the Posterior Cruciate Ligament. 2005;33(7):982-989. doi:10.1177/0363546504271966

50. Veltri DM, Warren RF. Isolated and Combined Posterior Cruciate Ligament Injuries. *J Am Acad Orthop Surg*. 1993;1(2):67-75. doi:10.5435/00124635-199311000-00001

51. Bali K, Prabhakar S, Saini U, Dhillon MS. Open reduction and internal fixation of isolated PCL fossa avulsion fractures. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(2):315-321. doi:10.1007/S00167-011-1618-6

52. Kim SJ, Shin SJ, Choi NH, Cho SK. Arthroscopically assisted treatment of avulsion fractures of the posterior cruciate ligament from the tibia. *J Bone Joint Surg Am*. 2001;83(5). doi:10.2106/00004623-200105000-00008

53. Meyers M. Isolated avulsion of the tibial attachment of the posterior cruciate ligament of the knee. *Journal of Bone and Joint Surgery America*. 1975;57(5):669-672. doi:10.2106/00004623-197557050-00015

54. Nicandri GT, Klineberg EO, Wahl CJ, Mills WJ. Treatment of posterior cruciate ligament tibial avulsion fractures through a modified open posterior approach: operative technique and 12- to 48-month outcomes. *J Orthop Trauma*. 2008;22(5):317-324. doi:10.1097/BOT.0B013E31817279D1

55. Hooper PO, Silko C, Malcolm TL, Farrow LD. Management of Posterior Cruciate Ligament Tibial Avulsion Injuries: A Systematic Review. *Am J Sports Med*. 2018;46(3):734-742. doi:10.1177/0363546517701911

56. Torisu T. Avulsion fracture of the tibial attachment of the posterior cruciate ligament. Indications and results of delayed repair. *Clin Orthop Relat Res*. 1979;(143):107-114. doi:10.1097/00003086-197909000-00015

57. Metcalf MH, Barrett GR. Prospective evaluation of 1485 meniscal tear patterns in patients with stable knees. *Am J Sports Med*. 2004;32(3):675-680. doi:10.1177/0095399703258743

58. Vaquero J, Vidal C, Cubillo A. Intra-articular traumatic disorders of the knee in children and adolescents. *Clin Orthop Relat Res*. 2005;432(432):97-106. doi:10.1097/01.BLO.0000156002.16750.8D

59. Hagino T, Ochiai S, Senga S, et al. Meniscal tears associated with anterior cruciate ligament injury. *Arch Orthop Trauma Surg*. 2015;135(12):1701-1706. doi:10.1007/S00402-015-2309-4

60. Smillie IS. Injuries of the Knee Joint. Edinburgh Medical School. 1946. Accessed October 1, 2023. https://era.ed.ac.uk/handle/1842/33992

61. Shakespeare DT, Rigby HS. The bucket-handle tear of the meniscus. A clinical and arthrographic study. *J Bone Joint Surg Br*. 1983;65(4):383-387. doi:10.1302/0301-620X.65B4.6874707

62. Bansal P, Deehan DJ, Gregory RJH. Diagnosing the acutely locked knee. *Injury*. 2002;33(6):495-498. doi:10.1016/S0020-1383(02)00081-5

63. McNally EG, Nasser KN, Dawson S, Goh LA. Role of magnetic resonance imaging in the clinical management of the acutely locked knee. *Skeletal Radiol*. 2002;31(10):570-573. doi:10.1007/S00256-002-0557-1/METRICS

64. Arnoczky SP, Warren RF. The microvasculature of the meniscus and its response to injury. An experimental study in the dog. *Am J Sports Med*. 1983;11(3):131-141. doi:10.1177/036354658301100305

65. Walker PS, Erkman MJ. The role of the menisci in force transmission across the knee. *Clin Orthop Relat Res*. 1975;No. 109(109):184-192. doi:10.1097/00003086-197506000-00027

66. Aagaard H, Verdonk R. Function of the normal meniscus and consequences of meniscal resection. *Scand J Med Sci Sports*. 1999;9(3):134-140. doi:10.1111/J.1600-0838.1999.TB00443.X

67. Sood A, Gonzalez-Lomas G, Gehrmann R. Influence of Health Insurance Status on the Timing of Surgery and Treatment of Bucket-Handle Meniscus Tears. *Orthop J Sports Med*. 2015;3(5):1-6. doi:10.1177/2325967115584883

68. Marchetti DC, Phelps BM, Dahl KD, et al. A Contact Pressure Analysis Comparing an All-Inside and Inside-Out Surgical Repair Technique for Bucket-Handle Medial Meniscus Tears. *Arthroscopy*. 2017;33(10):1840-1848. doi:10.1016/J.ARTHRO.2017.04.013

69. Feng H, Hong L, Geng XS, Zhang H, Wang XS, Jiang XY. Second-look arthroscopic evaluation of bucket-handle meniscus tear repairs with anterior cruciate ligament reconstruction: 67 consecutive cases. *Arthroscopy*. 2008;24(12):1358-1366. doi:10.1016/J.ARTHRO.2008.07.017

70. Krych AJ, Pitts RT, Dajani KA, Stuart MJ, Levy BA, Dahm DL. Surgical repair of meniscal tears with concomitant anterior cruciate ligament reconstruction in patients 18 years and younger. *Am J Sports Med*. 2010;38(5):976-982. doi:10.1177/0363546509354055

71. Shamrock AG, Varacallo M. Achilles Tendon Rupture. StatPearls. March 19, 2023. Accessed July 9, 2023. https://www.ncbi.nlm.nih.gov/books/NBK430844/

72. Lemme NJ, Li NY, DeFroda SF, Kleiner J, Owens BD. Epidemiology of Achilles Tendon Ruptures in the United States: Athletic and Nonathletic Injuries From 2012 to 2016. *Orthop J Sports Med*. 2018;6(11). doi:10.1177/2325967118808238

73. Park YH, Jeong SM, Choi GW, Kim HJ. How early must an acute Achilles tendon rupture be repaired? *Injury*. 2017;48(3):776-780. doi:10.1016/J.INJURY.2017.01.020

74. He SK, Liao JP, Huang FG. Higher Rate of Postoperative Complications in Delayed Achilles Tendon Repair Compared to Early Achilles Tendon Repair: A Meta-Analysis. 2020;35(1):157-163. doi:10.1080/08941939.2020.1824247

75. Den Hartog BD. Surgical strategies: Delayed diagnosis or neglected achilles' tendon ruptures. *Foot Ankle Int*. 2008;29(4):456-463. doi:10.3113/FAI.2008.0456/ASSET/IMAGES/LARGE/10.3113_FAI.2008.0456-FIG16.JPEG

76. Svedman S, Juthberg R, Edman G, Ackermann PW. Reduced Time to Surgery Improves Patient-Reported Outcome After Achilles Tendon Rupture. *American Journal of Sports Medicine*. 2018;46(12):2929-2934. doi:10.1177/0363546518793655/ASSET/IMAGES/LARGE/10.1177_0363546518793655-FIG4.JPEG

77. Strauss EJ, Ishak C, Jazrawi L, Sherman O, Rosen J, Rosen J. Operative treatment of acute Achilles tendon ruptures: An institutional review of clinical outcomes. JINJ-2987. doi:10.1016/j.injury.2006.06.005

78. Tarantino D, Palermi S, Sirico F, Corrado B. Achilles Tendon Rupture: Mechanisms of Injury, Principles of Rehabilitation and Return to Play. *J Funct Morphol Kinesiol*. 2020;5(4). doi:10.3390/JFMK5040095

79. Zellers JA, Carmont MR, Silbernagel KG. Return to Play Post Achilles Tendon Rupture: A Systematic Review and Meta-Analysis of Rate and Measures of Return to Play. *Br J Sports Med*. 2016;50(21):1325. doi:10.1136/BJSPORTS-2016-096106