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PICTORIAL ESSAY

Stump entrapment of the anterior cruciate ligament in late childhood and adolescence

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Abstract Displacement of a portion of the torn anterior cruciate ligament (ACL) into the intercondylar notch can cause a focal fibrotic reaction similar to that seen following ACL reconstruction. This displacement, which can result in locking or limitation of knee extension, is termed *stump entrapment* and is described in adult MR imaging literature. We present a pictorial essay of the etiology and appearance of stump entrapment on MR imaging of the knee in an older child and adolescents and review the significance of this finding.

Keywords Knee · MRI · Anterior cruciate ligament · Trauma

Introduction

Focal arthrofibrosis, more commonly referred to as the *cyclops lesion*, is a well-described complication that occurs after anterior cruciate ligament (ACL) reconstruction [1]. This nodular mass of fibrous granulation tissue forms near the anterior tibia at the site of tendon graft placement and results in mechanical obstruction to knee extension, ultimately requiring surgical resection. It has been recognized in adults that a similar lesion can form in patients who sustain tears of the ACL but who have not had ligament reconstruction [2–9]. In these patients, the distal portion of the torn ACL is displaced anteriorly into the intercondylar notch, subsequently becoming impinged between the lateral femoral condyle and the tibial plateau during extension of the knee. This repeated mechanical impediment leads to fibroproliferative changes that have similar clinical, imaging, gross arthroscopic and histological features to those of the cyclops lesion [2–10]. To our knowledge, descriptions of ACL stump entrapment on MRI have been limited to adults. We present this pictorial essay to familiarize the pediatric radiologist with the various MR imaging findings of stump entrapment identified in an older child and adolescents and review the etiology and importance of recognizing this entity.

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Cyclops lesion following ACL repair

In the acute setting, ACL tears can cause limited range of motion secondary to pain, swelling and muscle spasm. When limited extension persists beyond the acute setting, this usually is secondary to associated injuries such as meniscal or collateral ligament tears, or intra-articular loose bodies [2]. However, in the months following ACL reconstruction, persistent limited extension of the knee raises suspicion for, among other complications, the development of focal arthrofibrosis within the joint. The histology of these nodular lesions shows fibrosis and synovial elements with or without bony fragments [11, 12]. This entity has been termed a *cyclops lesion* because of its bulbous appearance at surgery that often has a focal area of discoloration resembling the solitary eye of the Greek mythical creature Cyclops [1, 12]. The cyclops lesion is located in the intercondylar notch anterior to the reconstructed graft [13]. On MR imaging, the cyclops lesion shows predominately hypointense to intermediate signal on both intermediate-weighted and T2-weighted imaging sequences [10, 11] (Fig. 1).

Fig. 1 Cyclops lesion in a 17-year-old boy who underwent right ACL reconstruction 8 months prior to MR imaging. **a** Midline sagittal fat-suppressed fast spin-echo (FSE) T2-W (TR/TE [repetition time/echo time, msec], 3,216/73) MRI shows an intact ACL graft (*white arrows*) and a focal area of heterogeneous signal within the intercondylar notch (*black arrow*), consistent with a cyclops lesion. **b** Midline sagittal FSE proton density-weighted (1,700/11) MRI shows an intact ACL graft (*white arrows*) and a focal area of heterogeneous intermediate signal within the intercondylar notch (*black arrow*). **c** Axial fat-suppressed FSE T2-W (4,316/70) MRI shows the focal cyclops lesion with heterogeneous signal intensity within the intercondylar notch (*arrows*)

Cyclops-like lesion in the non-operated knee following ACL tear: stump entrapment

In 1999, McMahon et al. [2] first reported a small series of adults with clinically diagnosed complete ACL tears and persistently decreased extension of the knee several months following injury but prior to any surgical intervention. At arthroscopy performed 9–14 weeks after injury, each patient had a focal nodular lesion near the tibial insertion of the distal segment of the torn ACL that grossly resembled the post-operative cyclops lesion. Three years later, Huang et al. [3] described the MR imaging appearance of 15 patients with similar clinical presentations who also had not undergone reconstructive surgery. The MR imaging examinations in these patients showed either a focal nodular mass or displacement of a tongue-like anterior portion of the torn ACL impinged in the intercondylar notch between the lateral femoral condyle and the tibial plateau with the knee in extension (Fig. 2). This finding has been termed *stump entrapment* [3]. Mechanical obstruction is compounded by anterior translation of the tibia secondary to the ACL tear. The resultant impingement leads to inflammation and deposition of fibrous tissue [2, 3]. In a large arthroscopic series, 3% of patients with ACL tears were diagnosed with stump entrapment as the cause of persistently decreased knee extension [4].

The entrapped ACL stump shows hypointense to intermediate signal on intermediate-weighted MR imaging examinations and heterogeneously hypointense to slightly hyperintense signal on T2-weighted sequences (Fig. 2), similar to the described MR imaging appearance of the cyclops lesion. Furthermore, many of the lesions in the adult studies of stump entrapment showed histology similar to that of the post-operative cyclops lesions [2, 3].

Types of stump entrapment

Stump entrapment has been subdivided into types 1 and 2 [3]. In the type 1 form, the anterior free end of the ACL segment and resultant fibroproliferative tissue form a nodular mass in the anterior aspect of the intercondylar notch. The type 1 form of stump entrapment most resembles a classic post-operative cyclops lesion (Figs. 2 and 3). In contrast, a type 2 stump entrapment lacks the mass-like appearance of the type 1 lesion; instead, the anterior portion of the torn ACL is folded upon itself with a thin, tongue-like free end extending anteriorly out of the intercondylar notch (Figs. 4 and 5). It is speculated that a type 2 lesion eventually progresses to become a type 1 lesion, as the ACL fragment is chronically impinged between bone, and fibrotic changes ensue [3] (Fig. 6). Supporting a probable transition of type 2 lesions to type 1 lesions is patients who present with MR imaging characteristics of both types of lesions; a bulbous mass-like free end of the torn ACL, and a portion of ACL stump folded anteriorly upon itself (Fig. 7).

Stump entrapment also has been reported in patients with partial ACL tears. These tears selectively involve either the anteromedial or posterolateral bundles of the ACL [5, 6]. In one patient, chronic limitation of extension caused by stump entrapment diagnosed at surgery was

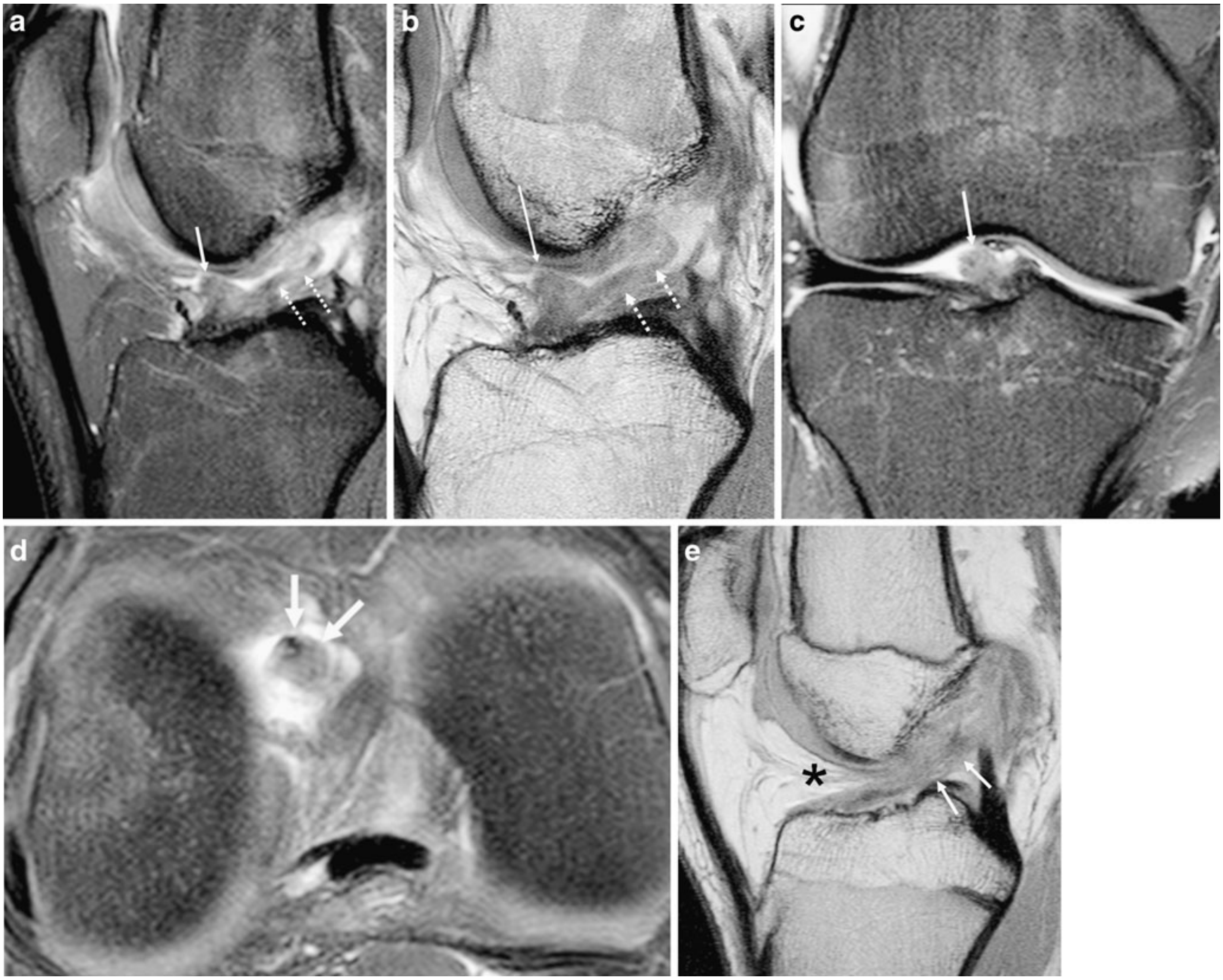

Fig. 2 Stump entrapment in a 17-year-old boy who sustained a complete ACL tear during a football game 11 days prior to MR imaging. **a** Midline sagittal spectral presaturation with inversion recovery (SPAIR) T2-weighted (3,076/50) MRI shows a somewhat bulbous configuration of the torn ACL with heterogeneous signal intensity (*white arrow*) within the intercondylar notch. Torn fibers of the ACL that are not entrapped within the intercondylar notch (*dashed white arrows*) are seen more posteriorly. In younger patients, this appearance might occur earlier than is typically described in adults. **b** Midline sagittal proton density-weighted (2,573/20) MRI shows the intermediate signal intensity of the anterior portion of the torn ACL within the intercondylar notch. It has a bulbous configuration (*white arrow*). The remaining torn fibers of the ACL that are not entrapped within the intercondylar notch (*dashed white arrows*) are seen more posteriorly. **c** Coronal SPAIR T2-W (2,774/50) MRI shows the bulbous anterior portion of the torn ACL with heterogeneous signal intensity (*arrow*) within the lateral aspect of the intercondylar notch. **d** Axial SPAIR T2-W (3,324/50) MRI shows the bulbous anterior portion of the torn ACL with heterogeneous signal intensity (*arrows*) within the intercondylar notch. **e** For comparison, no stump entrapment is seen in images of this 15-year-old boy, who sustained a complete ACL tear during a football game 9 months prior to imaging. Midline sagittal fat-suppressed turbo spin-echo (TSE) proton density-weighted (2,000/13) MRI shows disruption of the normal hypointense signal of the ACL consistent with a complete tear (*arrows*). There is normal homogeneous hyperintense signal within the infrapatellar fat pad that extends to the intercondylar notch (*asterisk*)

thought to result from an undiagnosed partial ACL tear that had been incurred 20 years prior [7].

The effect of stump entrapment on treatment of ACL injury

The treatment of ACL injury in children remains a subject of great debate. The youngest, skeletally immature children who may suffer physeal injury and subsequent growth disturbance from surgical reconstruction often are closely monitored during a conservative non-surgical treatment plan [14]. Older adolescents who are skeletally mature usually undergo surgical repair with less concern for resultant deformity [14]. However, the appropriate treatment plan for the skeletally immature patients late in

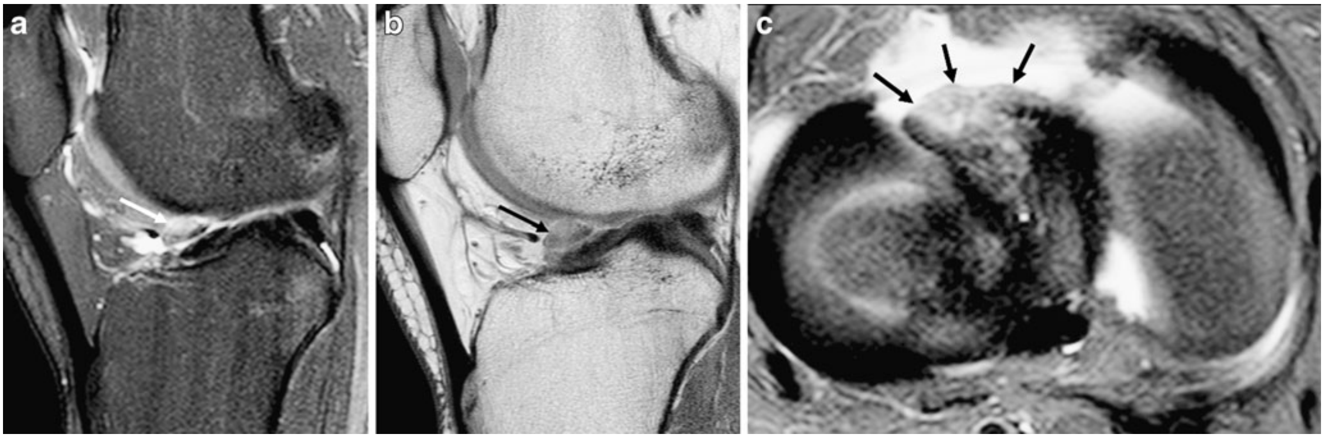

Fig. 3 Type 1 stump entrapment in a 19-year-old woman who was injured in a basketball game 6 weeks prior to imaging. **a** Midline sagittal SPAIR T2-W (3,442/62) MRI shows a bulbous configuration of the torn ACL with heterogeneous intermediate and hyperintense signal (*arrow*) within the intercondylar notch. **b** Midline sagittal TSE proton density-weighted (2,509/20) MRI shows a bulbous configuration of the torn ACL with heterogeneous signal intensity (*arrow*) within the intercondylar notch. **c** Axial SPAIR T2-W (3,556/65) MRI shows the bulbous anterior portion of the torn ACL with heterogeneous signal intensity (*arrows*) within the intercondylar notch

childhood remains controversial, and plans for surgery must take the risks of unrepaired knee instability and iatrogenic injury into account [14]. Thus, it is in the immature and late childhood groups of patients in whom the identification of stump entrapment is a critical variable that might influence the decision to pursue surgical reconstruction. Similarly, because stump entrapment can occur with partial ACL tears, (injuries that are not always surgically repaired in children [15]), it is important that these lesions be recognized and that surgical resection, rather than conservative non-operative treatment, be undertaken to restore a full range of motion.

In the adolescents with complete ACL tears in whom surgery is the usual management decision [14, 16], identifying stump entrapment might influence the timing of repair. There is debate in the orthopedic literature

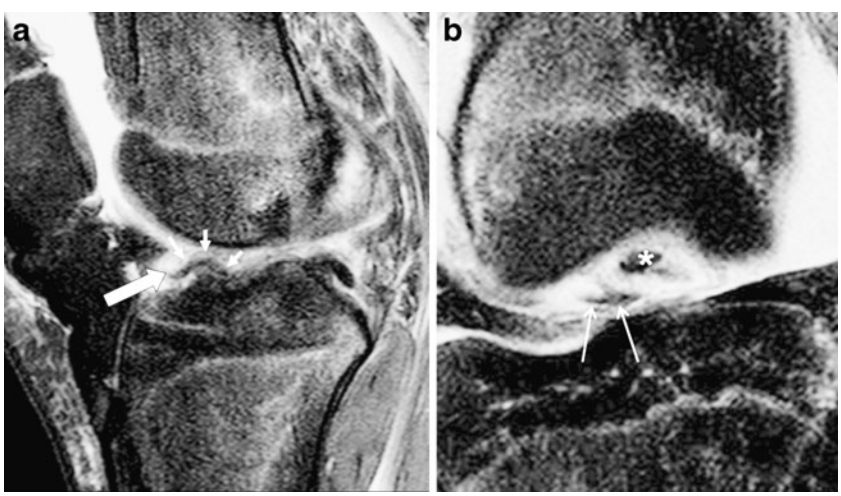

Fig. 4 Type 2 stump entrapment in a 15-year-old girl who sustained a complete right ACL tear during an assault 10 days prior to imaging. **a** Midline sagittal SPAIR T2-W (5,541/50) MRI shows the anterior portion of a torn ACL flipped forward on itself (*small arrows*). There is a thin tongue-like configuration of the free end of the torn ACL extending anteriorly out of the intercondylar notch (*large arrow*), consistent with type 2 stump entrapment. **b** Coronal SPAIR T2-W (5,543/50) MRI shows a thin linear projection of hypointense signal from torn ACL fibers extending to the lateral aspect of the intercondylar notch (*arrows*). A portion of the normal posterior cruciate ligament is also seen (*asterisk*)

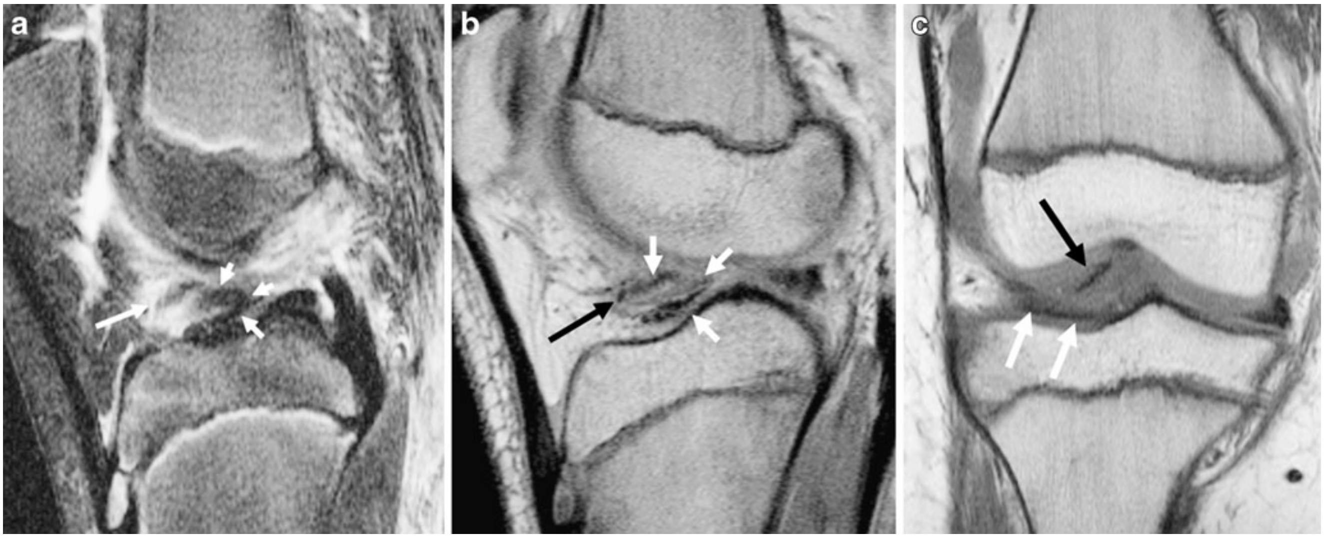

Fig. 5 Type 2 stump entrapment in a 9-year-old girl who sustained a right knee injury in a dirt bike accident 1 week prior to imaging. **a** Midline sagittal fat-suppressed TSE T2-W (3,150/75) MRI shows the anterior portion of a torn ACL flipped forward on itself (*small arrows*). There is a thin tongue-like configuration of the free end of the torn ACL extending anteriorly out of the intercondylar notch (*large arrow*), consistent with type 2 stump entrapment. **b** Midline sagittal proton density-weighted (2,000/16) MRI shows the anterior portion of a torn ACL flipped forward on itself (*white arrows*). There is a thin tongue-like configuration of the free end of the torn ACL extending anteriorly out of the intercondylar notch (*black arrow*), which could be confused with a meniscal fragment. **c** Coronal T1-W (585/16) MRI shows the thin linear projection of hypointense signal from the torn ACL (*black arrow*) and its relationship to the intact lateral meniscus (*white arrows*)

regarding the optimal timing of ACL repair [17–19]. Historically, it has been taught that surgery should be delayed until full range of motion of the knee has been regained. Acute hemarthrosis and soft-tissue swelling are the most common causes of decreased range of motion during the time immediately following injury [17]. Some studies also have shown that delaying surgery until the knee swelling subsides and the patient regains full hyperextension preoperatively gives patients the greatest chance to obtain full range of motion post-operatively, without the need for frequent formal physiotherapy [17]. Thus, many patients enter aggressive physical therapy with the goal of restoring full range of motion preoperatively. However, this management approach is not appropriate for the subset of patients with stump entrapment in whom a mechanical block will not resolve with physical therapy and full range of motion might not be achievable. Therefore, earlier surgical reconstruction is warranted in these patients.

The surgical procedure for ACL reconstruction in patients with stump entrapment consists of resection of the fibrotic tissue followed by manual manipulation of the knee during anesthesia to ensure restoration of the full range of motion, similar to uncomplicated ACL tear management [2]. Studies have shown that patients with ACL tears with mechanical block, including block from stump entrapment, do not need a pre-reconstruction

Fig. 6 Type 2 lesion progressing to a type 1 lesion. The girl in Fig. 5 returned 9 months later for MR imaging prior to surgical repair. Midline sagittal TSE proton density-weighted (3,000/9) MRI shows interval development of a bulbous configuration to the torn distal ACL fibers with heterogeneous signal intensity (*white arrow*) within the intercondylar notch. This is consistent with progression of the previous type 2 (Fig. 5) to a type 1 stump entrapment

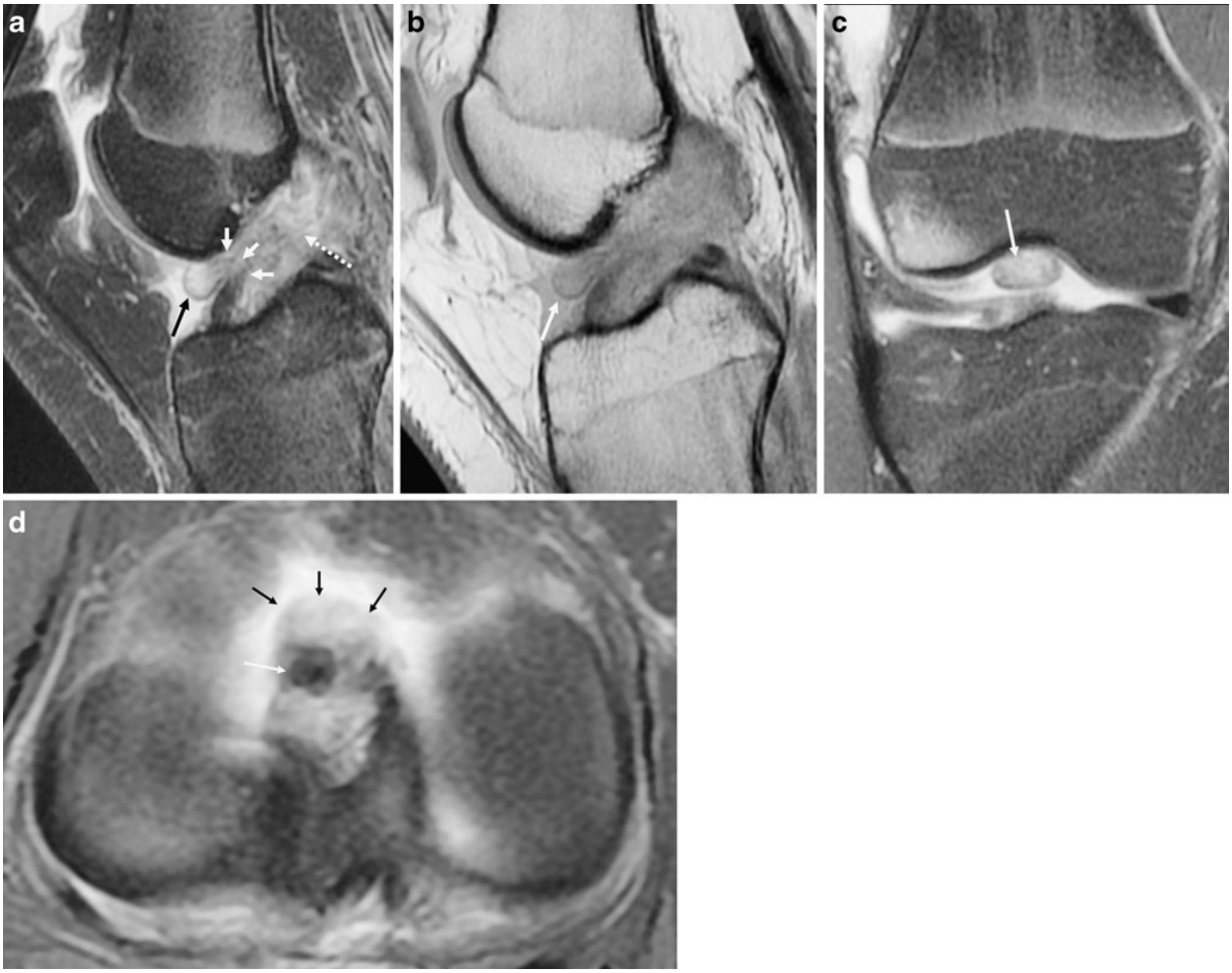

Fig. 7 Evidence of type 1 and type 2 stump entrapment in a 15-year-old girl with decreased range of motion after a cheerleading accident 11 days prior to imaging. **a** Midline sagittal fat-suppressed FSE T2-W (3,583/47) MRI shows a complete mid-substance ACL tear (*dashed white arrow*). The anterior portion of the ACL is flipped on itself (*small white arrows*), more consistent with type 2 stump entrapment. However, the free end of the torn ACL is within the intercondylar notch and has a bulbous configuration with increased signal (*black arrow*), consistent with type 1 stump entrapment. **b** Midline sagittal FSE proton density-weighted (1,700/11) MRI shows a bulbous configuration of the free end of the torn ACL with intermediate signal intensity (*arrow*). **c** Coronal fat-suppressed FSE T2-W (3,600/47) MRI shows a nodular focus of heterogeneous signal intensity within the intercondylar notch (*arrow*). **d** Axial fat-suppressed FSE T2-W (3,067/47) MRI shows focal hypointense signal within the intercondylar notch (*white arrow*) and mass-like heterogeneous intermediate and high signal intensity surrounding the ACL at this level (*black arrows*), consistent with fibroproliferative changes

debridement but that debridement can be performed at the time of reconstruction with good outcome [4].

Conclusion

While stump entrapment has been described in adults [3, 8, 9], its occurrence in children and adolescents has not been recognized in the pediatric literature. As more children and adolescents partake in sports and the incidence of resultant ACL injuries increases [20], it is increasingly important for pediatric radiologists to identify not only ACL tears, but also additional important findings that are crucial to successful treatment. For this purpose, we now illustrate examples of stump entrapment in an older child and adolescents that can be a cause of limited knee extension or locking after both complete and partial ACL tears. Articulating the need for resection of the stump mass or ACL segment to the orthopedic surgeon is vital to embark on a treatment plan that will restore full range of motion and achieve an optimal clinical outcome.

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