Title
Lesser Tuberosity Avulsions in Adolescents

Journal
HSS Journal ®, 10(3)

ISSN
1556-3316

Authors
Nardo, Lorenzo
C., Benjamin
Steinbach, Lynne S

Publication Date
2014-10-01

DOI
10.1007/s11420-014-9400-1

Peer reviewed

HSSJ (2014) 10:201–207
DOI 10.1007/s11420-014-9400-1

HSS Journal®
The Musculoskeletal Journal of Hospital for Special Surgery

Lesser Tuberosity Avulsions in Adolescents

Lorenzo Nardo, MD · Benjamin C. Ma, MD · Lynne S. Steinbach, MD

Received: 26 February 2014/Accepted: 28 April 2014/Published online: 18 July 2014

Abstract *Background:* Subscapularis tendon avulsions of the lesser tuberosity are relatively rare and often missed acutely and their characteristic appearance is frequently not recognized or is misinterpreted for an osteochondroma or a neoplastic process. *Questions/Purposes:* This report reviews our experience with six adolescents who had subscapularis tendon avulsions of the lesser tuberosity. *Methods:* Six male adolescents (12–15 years) presented with shoulder pain following history of trauma during amateur sport. Clinical notes including range of motion, strength tests, and pain assessment were reviewed along with imaging studies pre- and post treatment. Treatment consisted of either surgical or conservative measures. *Results:* Two of the six patients had a large avulsion that simulated an exostosis of the proximal humerus that was misdiagnosed as an osteochondroma at two different outside institutions. All six cases were diagnosed with subscapularis tendon avulsion of the lesser tuberosity following clinical and imaging evaluation at our institution. Five of the patients underwent surgical repair and fixation of the tendon and the lesser tuberosity with suture anchors. One patient was treated conservatively. All patients had a good outcome with recovery of full shoulder strength and motion upon follow-up. *Conclusion:* Clinicians should have a high index of suspicion of lesser tuberosity avulsions in adolescents who present with loss of internal rotation and anterior shoulder pain following traumatic injuries. In addition, an osseous fragment or exostosis along the inferomedial humeral head should suggest a subscapularis tendon avulsion and also should not be confused with an osteochondroma or a neoplastic process.

Keywords MRI · shoulder · rotator cuff · subscapularis · trauma

This work was performed at University of California San Francisco.

Level of Evidence: Level IV Case Series.

Electronic supplementary material The online version of this article (doi:10.1007/s11420-014-9400-1) contains supplementary material, which is available to authorized users.

L. Nardo, MD
Department of Radiology and Biomedical Imaging,
University of California, San Francisco,
505 Parnassus,
San Francisco, CA 94143-0628, USA

B. C. Ma, MD
Department of Orthopaedic Surgery,
University of California, San Francisco,
500 Parnassus Avenue, MU 320W,
San Francisco, CA 94143, USA

L. S. Steinbach, MD (✉)
Radiology and Orthopaedic Surgery,
University of California, San Francisco,
505 Parnassus, Suite M392,
San Francisco, CA 94143-0628, USA
e-mail: Lynne.Steinbach@ucsf.edu

Introduction

Although the recognition of subscapularis tendon injuries has become easier with the use of magnetic resonance imaging, subscapularis tendon avulsion injuries of the lesser tuberosity in the adolescents are missed or incorrectly diagnosed [10, 14]. Isolated subscapularis injuries in children and adolescents are seldom reported in the literature [13, 14, 33]. These injuries are known to be associated with avulsion fracture of the lesser tuberosity, for which treatment has traditionally included either physical therapy or open reduction and internal fixation [14]. Isolated avulsion injuries of the lesser tuberosity tend to occur in two populations—adolescents and middle-aged men [8, 15, 19, 27, 29]. In the current literature, there are reports on 80 cases of isolated fractures of the lesser tuberosity [1, 3, 4, 6, 8, 9, 15, 16, 18–20, 26, 28–30, 32]. Some of these injuries had been misdiagnosed initially and were subsequently treated as an adult [19].

Due to the rarity of rotator cuff injuries and the difficult examination specifically assessing the function of the subscapularis following acute injuries and subtle

radiographic findings [31], most shoulder trauma in young patients is quickly attributed to contusions or sprains by their primary pediatricians or emergency department physicians. It is often difficult to make a diagnosis of these injuries during the acute phase, and for this reason, more than half of these fractures present with chronic shoulder pain, sometimes years after initial injury [19, 27]. Most cases present after completion of a course of physical therapy [27]. For pediatric patients, the delay in diagnosis of the underlying pathology may potentially result in significant clinical disability related to irreversible degeneration of the subscapularis muscle and tendon as well as the biceps tendon [11, 12]. An early diagnosis is the most important prerequisite for a successful treatment [3, 6, 15, 18, 19, 27].

The goal of our study is to report our experience in diagnosis and management of subscapularis tendon avulsions of the lesser tuberosity. Presentation, workup, and outcomes following treatment of this rare, but disabling injury will be reviewed.

Patients and Methods

The design of this multicenter retrospective case series was compliant with standards set forth by the Health Insurance Portability and Accountability Act (HIPAA) and approved by the local committee for human research (CHR).

The picture archiving and communication system (PACS) (Agfa, Ridgefield Park, NJ) database was queried to identify the cases over a period of 20 years (1991–2011). Radiology reports were searched for the terms "subscapularis avulsion" and "lesser tuberosity fracture".

All patients enrolled in this study were age 16 years or younger at the time of the injury, had a clear history of shoulder trauma and accurate orthopedic physical examination notes in their medical records. Preoperative radiographs and MRIs demonstrating lesser tuberosity avulsion, with follow-up imaging after treatment represented inclusion criteria. Age older than 16, low-quality images, lack of clinical notes regarding pain and rotator cuff muscle strength or range of motion resulted in exclusion of those patients for this study. Considering these criteria, the study population consisted of six males ranging in age from 12 to 15 years (Table 1).

All injuries occurred during sporting activities. Four patients had injuries during throwing (three baseball players and one lacrosse player), one fell off a bike and one was injured during a cross-body punch towards an opponent. All patients were referred to our institution for second opinion; two patients were given the diagnosis of an osteochondroma and four were clinically diagnosed with rotator cuff strain. The time of presentation to our institution ranged from 2 weeks to 13 years (Table 2).

All patients had physical examinations that included subscapularis muscle testing with measurement of passive and active external rotation with the arm at the side. Specific evaluation of subscapularis muscle strength included the lift-off test and the belly-press test as described by Gerber at al. [11, 12]. The range of motion was graded as normal if within 10° of the contralateral uninjured side. Impingement signs, supraspinatus strength, and specific biceps tendon (O'Brien test) as well as instability tests were also performed. At the last visit (within 6–12 months from the procedure), the patients were asked to grade the current function of the affected shoulder as a percentage of the pre-injury level. Shoulder function was divided into three groups: grade 1 represented complete recovery without any limitation in function; grade 2 included mild to moderate limitations (>80% pre-injury level) and grade 3 had severe limitation (<80% pre-injury level).

Pain variability was also graded before and after treatment using a scale previously published by Cofield and Neer [7, 23]. According to this scale, pain is classified as (0) when absent, (1) when slight, (2) minimal, (3) moderate, and (4) severe.

All patients had preoperative radiographs and MRIs within 3 weeks of the trauma and a standard radiographic follow-up within a month following diagnosis and treatment. In addition, one patient had a preoperative CT and a radiograph and MRI 2 years after the treatment (for minor trauma), one patient had ultrasound imaging pretreatment and one patient had several follow-up shoulder radiographs.

Standard radiographs for preoperative planning and for follow-up included anteroposterior and axillary views of the glenohumeral joint.

Five of the six patients had routine MRI of the shoulder. One case was performed outside of our institution on a General Electric 1.5-T MR unit. The other four patients were imaged at our institution. One study was performed on a General Electric 1.5-T MR unit. The other three were performed on General Electric 3-T MR units. Sequences for all five were similar and were as follows: axial T2 fat saturation (TR/TE=4,000/60; FoV=12 cm Sl=4 mm; Matrix=256×256; Nex=2), axial PD (TR/TE=2,500/25; FoV=12 cm; Sl=4 mm; Matrix=256×256; Nex=1.5), oblique T2 coronal fat saturation (TR/TE=3,000/50; FoV=12 cm; Sl=4 mm; Matrix=256×256 Nex=3), oblique coronal T1 (TR/TE=500/10; FoV=12 cm; Sl=4 mm; Matrix=256×256 Nex=1), sagittal T2 fat saturation (TR/TE=4,500/60; FoV=12 cm Sl=4 mm; Matrix=256×256; Nex=3), oblique sagittal PD (TR/TE=2,500/25; FoV=12 cm Sl=4 mm; Matrix=256×256; Nex=1.5).

The last study was an MR arthrogram obtained on a General Electric 3-T MR unit; 10 cm^3 of a 1:200 solution of gadolinium in a combination of 50% saline and 50% Ropivicaine was injected directly into the glenohumeral joint. Sequences for this study were as follows: oblique coronal T1 fat saturation (TR/TE=500/20; FoV=12 cm Sl=4 mm; Matrix=256×192; Nex=2) and oblique coronal T2 fat saturation (TR/TE=3,500/60; FoV=12 cm; Sl=4 mm; Matrix=256×256; Nex=1.5), axial T1 (TR/TE=500/20; FoV=12 cm; Sl=4 mm; Matrix=256×256 Nex=1.5) and axial T2 fat saturation (TR/TE=4,500/40; FoV=12 cm; Sl=4 mm; Matrix=256×256 Nex=1), sagittal T2 fat saturation (TR/TE=3,500/45; FoV=12 cm Sl=4 mm; Matrix=256×256; Nex=1.5) and oblique coronal T1 (TR/TE=500/20; FoV=12 cm Sl=4 mm; Matrix=256×192; Nex=1.5).

All radiological studies were reviewed by two radiologists with 5 and 30 years of experience in musculoskeletal imaging.

Table 1 Symptoms and signs before and after treatment of the six patients

Physical examination	Before treatment	After treatment
Pain	Severe (3); moderate (3)	Absent (6)
Range of forward flexion	Normal (6)	Normal (6)
Range of passive external rotation	Normal (5); reduced (1)	Normal (6)
Range of passive internal rotation	Reduced (6)	Normal (6)
Strength of supraspinatus	Normal (6)	Normal (6)
Lift-off test	Positive (5) impossible (1)	Negative (6)
Belly-press test	Positive (6)	Negative (6)
Impingements signs	Mild (1); absent (5)	Absent (6)
Biceps test (O'Brien and palm-up)	Negative (6)	Negative (6)

Results

At the time of presentation, with the clinical evaluation all patients had shoulder pain especially with internal rotation of the arm and with palpation over the anterior-medial proximal humerus. Two of the six patients reported popping and clicking of the shoulder. All patients had normal range of forward flexion and normal strength of the supraspinatus muscle. The range of passive external rotation was normal in all patients except for one who had reduction of 15° when compared with the contralateral uninjured shoulder (Table 1).

All patients had internal rotation deficit (two vertebral levels), significant weakness (≤3/6) with internal rotation of the shoulder and a positive lift-off and belly-press test (in one patient, it was not possible to test lift-off sign due to pain). Only one patient had mild impingement symptoms. All patients had a negative O'Brien's test.

Pretreatment conventional radiographs demonstrated various patterns. If there was a large ossific fragment, it presented as a density overlying the medial humeral neck that simulated an exostosis on frontal radiographs and was mistaken for an osteochondroma by referring clinicians in two cases (Figs. 1 and 2). Other patients had smaller avulsions best seen on the axillary radiographs (Fig. 3). CT obtained in a patient who had a delayed diagnosis at one outside institution showed the osseous fragment adjacent to the humeral neck and shaft (Fig. 1c) which was not continuous with the medullary space, confirming that this was not an osteochondroma. In that patient, MRI was useful to show the tendon avulsion (Fig. 1d). In cases of smaller avulsion fragments, MRI as able to show the tendon avulsion, but not the smaller osseous fragments seen on corresponding radiograph and ultrasound (Fig. 3b).

Surgery with general anesthesia was performed on five of the patients with a displaced lesser tuberosity. The other patient was treated with immobilization. Routine preoperative antibiotics were utilized. The injury pattern and size of the lesser tuberosity were confirmed intraoperatively. Treatment consisted of open rotator cuff repair with subscapularis tendon fixation using bioabsorbable anchors and excision of any large osseous fragments. Postoperatively, patients were immobilized in a sling for a period of 3–6 weeks, followed by rehabilitation therapy. There were no neurovascular complications. Follow-up examinations demonstrated restoration of full range of motion, especially with internal rotation. All treated patients were asymptomatic with full shoulder function on follow-up.

Discussion

Avulsion fractures are more common in the adolescent in other parts of the body and not as frequent in the shoulder [33]. Subscapularis tendon osseous avulsions are rare [19] and are often overlooked [14]. Most of the lesser tuberosity fractures described in the literature present as chronic injuries, diagnosed several months after the traumatic event [4, 15, 19, 20, 29, 33]. This is usually a result of the lack of recognition of this clinical problem as well as misinterpretation of conventional radiography. During the diagnostic process, it is important to evaluate (i) clinical history, (ii) physical examination, and (iii) radiological findings, which can be suggestive of lesser tuberosity avulsion.

Table 2 Patient demographics, imaging, and initial diagnosis

Patient	Age at injury	Pretreatment imaging and findings	Time to presentation	Initial diagnosis
1	14	CR and MRI: irregularity of the anterior aspect of the humeral head consistent with subscapular tendon avulsion.	2 weeks	Sport injury: rotator cuff strain
2	15	CR and MRI: avulsion injury of the subscapularis tendon.	2 weeks	Sport injury: rotator cuff injury.
3	14	CR, CT and MRI: smooth exostotic mass anteromedial to the proximal humerus metaphyseal region	7 months	Osteochondroma
4	13	CR and MRI: abnormal ossification at the anterior humerus	13 years	Osteochondroma
5	12	CR and MRI: osseous avulsion of the lesser tuberosity	2 months	Sport injury: rotator cuff strain
6	12	CR, US, MRI	2 weeks	Sport injury: lesser tuberosity avulsion

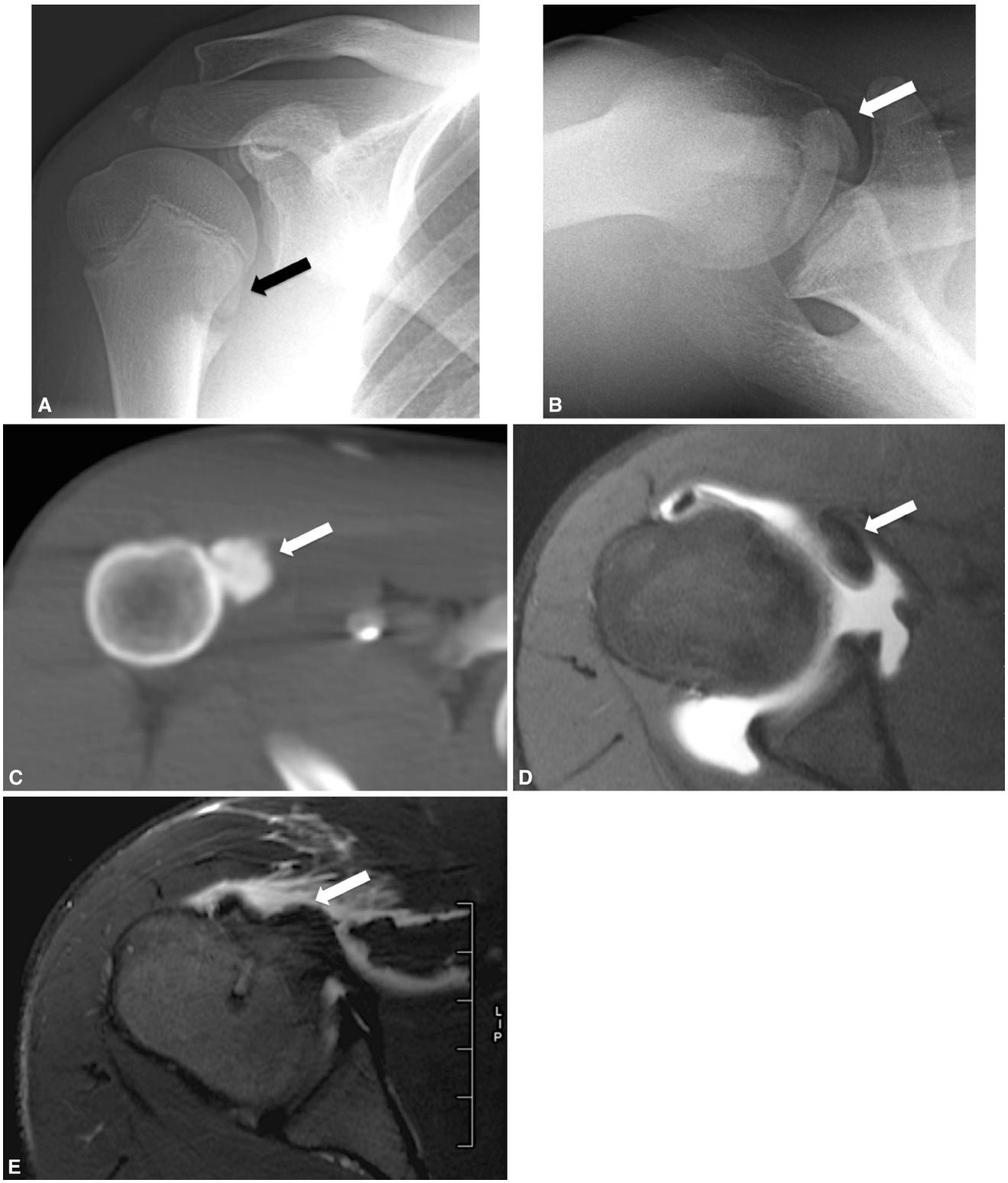

Fig. 1. A 14-year old male (patient 3), 7 months after injury. **a** AP view of the shoulder demonstrates ossific density overlying the humeral neck and extending off the bone, thought to represent an osteochondroma and referred to us by an outside institution. **b** Axillary view of the right shoulder shows a triangular osseous structure lies anterior to the humeral neck which represents the lesser tuberosity avulsion (*arrow*). **c** CT image at the level just below the lesser tuberosity demonstrates the fragment anteromedial along the humeral neck (*arrow*). **d** T1-weighted fat suppressed axial MR arthrogram at the inferior aspect of the glenohumeral joint demonstrates the lesser tuberosity avulsion fragment attached to the subscapularis tendon (*arrow*). **e** Axial T2-weighted image from an MR arthrogram obtained after surgery shows the repaired tendon attaching to the area of the lesser tuberosity with a biosabsorbable anchor (*arrow*).

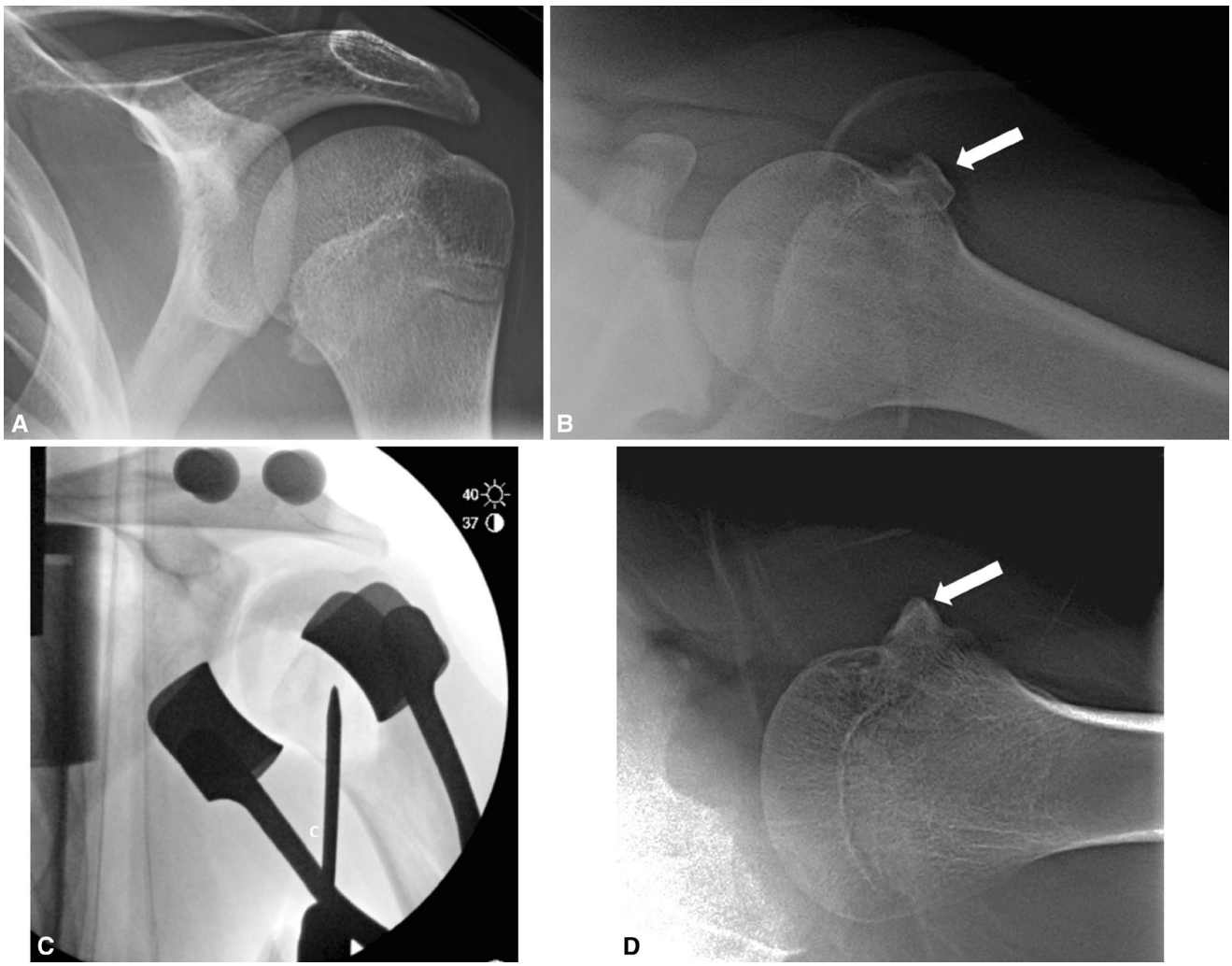

Fig. 2. A 15-year-old baseball player (patient 2), 2 weeks after injury. **a** The frontal radiograph shows an osseous density extending beyond the humeral neck, simulating an exostosis. **b** Axillary radiograph shows an osseous fragment anterior the humeral head. **c** Imaging obtained during surgical reattachment of the lesser tuberosity. **d** Axillary radiograph obtained 1 year following successful surgical reattachment of the lesser tuberosity (*arrow*).

A history of traumatic eccentric contraction of the subscapularis muscle during external rotation and abduction of the shoulder in an adolescent should raise suspicion of the possibility of lesser tuberosity avulsion. This mechanism has been described in the literature [22, 27] and is the same as that which occurred in our patients at the time of injury, regardless of their sport.

Physical examination demonstrating loss of strength in internal rotation and shoulder pain in the absence of obvious impingement signs and biceps injury may be suggestive of adolescent subscapularis avulsion. In the adolescent lesser tuberosity avulsions described in the literature [19, 27], all patients had significantly decreased strength in internal rotation, almost all patients had stable joints without apprehension, normal strength, and motion in forward elevation and external rotation [2, 14]. Our study has very similar results. In particular, all of our patients had signs of subscapularis injury including reduced range of internal rotation, positive lift-off test, positive belly-press test, stable joints, normal biceps function, normal strength, and motion in forward extension, and all but one had normal external rotation.

Imaging findings of subscapularis tendon injury are different, depending on the age of the patient and time to presentation. In skeletally immature individuals, the weakest link is the interface between the lesser tuberosity and the humerus, rather than the tendinous insertion [31]. With osseous avulsion, the subscapularis tendon retraction displaces the bony fragment, which can be shown on radiographs with the best view being the axillary view (Figs. 1b, 2b, and 3a). In the skeletally mature individual, the tendon is usually pulled off of the lesser tuberosity and can be associated with biceps dislocation [5, 21].

Depending on time to presentation, avulsion fracture can be classified as acute or chronic. In both situations, they are difficult to diagnose [22]. In the acute phase, the avulsion can be easily overlooked because of the subtle findings on radiographs, especially when the lesser tuberosity is small or minimally displaced and if the axillary view is not obtained.

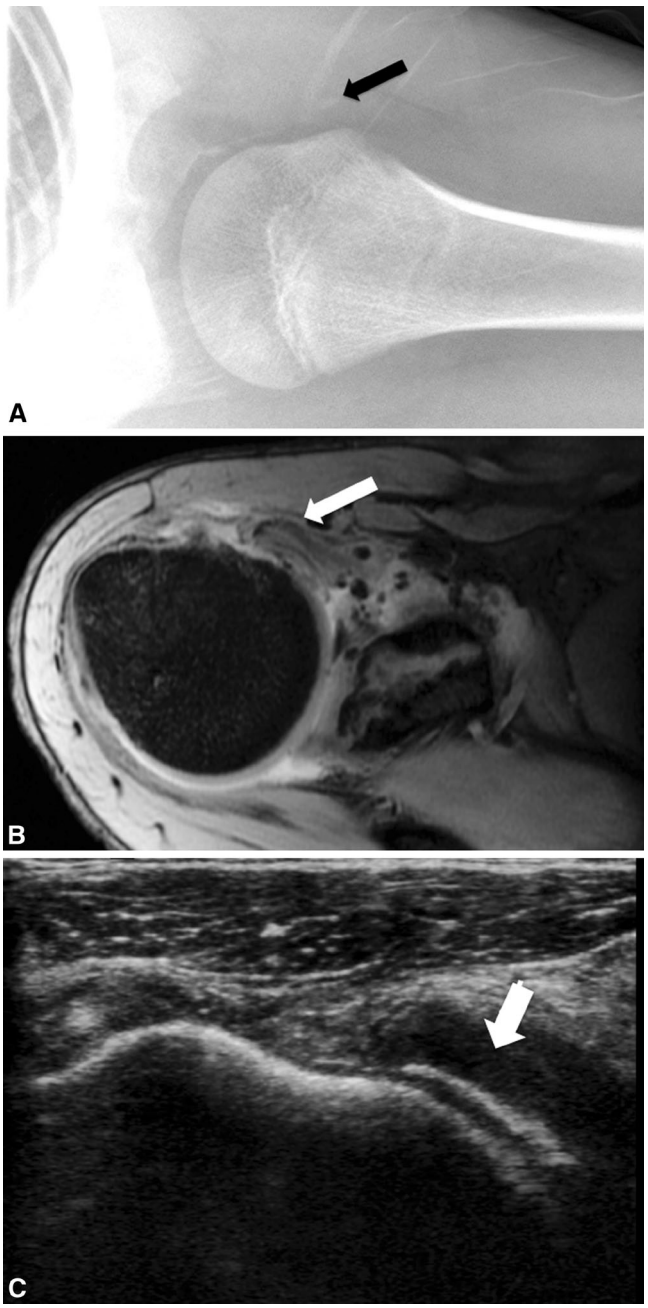

Fig. 3. A 12-year-old male (patient 6) with acute subscapularis avulsion 2 weeks before presentation at our clinic. **a** Axillary radiograph shows a small avulsion fragment anterior to the humeral head.(*arrow*). **b** Fat-suppressed T1-weighted image from an MR arthrogram demonstrates the avulsed tendon (*arrow*). **c** Transverse image from an ultrasound shows the subscapularis tendon avulsion (*arrow*).

Many practitioners try to rule out dislocation in adolescents with shoulder injury and fail to recognize signs of lesser tuberosity avulsion. With chronic injuries, there can be mineralization from the humeral neck to the displaced fragment because of the presence of an intact periosteum with healing potential in the skeletally immature patient [18]. The avulsion can be mistaken for an osteochondroma or a neoplastic process such as osteosarcoma if there is fluffy mineralization from the fragment. In our series, the radiographic appearance of this injury contributed to a delay in the referral of patients to the appropriate subspecialist for definitive management. In order to expedite the diagnosis, chronic subscapularis avulsion should be recognized radiographically and differentiated from osteochondroma based on the finding that the cortex separates the new bone formation from the medullary canal (Fig. 1c), in contrast to osteochondroma which is continuous with the medullary canal [17]. In addition to the two patients reported here, this type of presentation, mistaken for an osteochondroma, has been reported in three previous case reports and two of our patients [9, 22, 29].

In terms of treatment, the focus is to restore function and limit trauma to the growth plate to avoid epiphyseal injuries. In the literature, satisfactory results for non-operative management have been described for acute subscapularis avulsion with minimal/non-displaced fragments [19]. Some authors recommend a surgical approach for all acute subscapularis osseous avulsions, regardless of fragment size and displacement due to concerns about subsequent fracture displacement and the possibility of biceps dislocation [25]. Different surgical approaches have been also previously described in the literature; the main points of discussion are advantages and caveats of arthroscopic over open repair [24]. In all the fixation cases, intraoperative radiographs to locate the humeral epiphysis prior to anchor placement to avoid iatrogenic injuries were used. In our series, one patient was treated conservatively given the chronic presentation and the minimal displacement of the lesser tuberosity. Five of our patients were treated surgically with removal of the exostosis and fixation of the lesser tuberosity. All the patients were successfully treated with union of the fracture without evidence of bony exostosis on radiographs following treatment. The patients were able to participate in their sport without any difficulties upon follow-up. This highlights the importance of an accurate clinical and imaging diagnosis for osseous subscapularis tendon avulsion to avoid both overlooking lesser tuberosity avulsion during its acute phase and misdiagnosing it in the chronic phase.

In summary, this report highlights the importance of an accurate clinical and imaging diagnosis for subscapularis tendon avulsions in the adolescent followed by appropriate management. Clinicians should have a high suspicion of lesser tuberosity avulsions in adolescents who present with loss of internal rotation and shoulder pain following injuries, especially if the injury mechanism involved eccentric contraction of the subscapularis muscle during abduction of the shoulder. In addition, an osseous fragment or exostosis along the inferomedial humeral neck related to a recent or distant traumatic injury suggests a subscapularis tendon avulsion of the lesser tuberosity rather than an osteochondroma and can be further diagnosed with MR imaging or ultrasound.

Disclosures

Conflict of Interest: Nardo Lorenzo, MD, Benjamin C. Ma, MD and Lynne S. Steinbach, MD have declared that they have no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was waived from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

References

1. Andreasen AT. Avulsion fracture of lesser tuberosity of humerus; report of a case. *Lancet*. 1948; 1(6507): 750.
2. Bartl C et al. Open repair of isolated traumatic subscapularis tendon tears. *Am J Sports Med*. 2011; 39(3): 490-6.
3. Berbig R, Keller H, Metzger U. Isolated fracture of the lesser tuberosity of the humerus: case reports and review of the literature. *Z Unfallchir Versicherungsmed*. 1994; 87(3): 159-68.
4. Caniggia M, Maniscalco P, Picinotti A. Isolated avulsion fracture of the lesser tuberosity of the humerus. Report of two cases. *Panminerva Med*. 1996; 38(1): 56-60.
5. Clark RJ et al. Isolated traumatic rupture of the subscapularis tendon. *J Am Board Fam Pract*. 2002; 15(4): 304-8.
6. Coates MH, Breidahl W. Humeral avulsion of the anterior band of the inferior glenohumeral ligament with associated subscapularis bony avulsion in skeletally immature patients. *Skeletal Radiol*. 2001; 30(12): 661-6.
7. Cofield RH. Total shoulder arthroplasty with the Neer prosthesis. *J Bone Joint Surg Am*. 1984; 66(6): 899-906.
8. Dhawan A et al. Isolated avulsion fracture of the lesser tuberosity of the humerus in an adult: case report and literature review. *Am J Orthop (Belle Mead NJ)*. 2008; 37(12): 627-30.
9. Earwaker J. Isolated avulsion fracture of the lesser tuberosity of the humerus. *Skeletal Radiol*. 1990; 19(2): 121-5.
10. Garrigues GE, Warnick DE, Busch MT. Subscapularis avulsion of the lesser tuberosity in adolescents. *J Pediatr Orthop*. 2013; 33(1): 8-13.
11. Gerber C, Hersche O, Farron A. Isolated rupture of the subscapularis tendon. *J Bone Joint Surg Am*. 1996; 78(7): 1015-23.
12. Gerber C, Krushell RJ. Isolated rupture of the tendon of the subscapularis muscle. Clinical features in 16 cases. *J Bone Joint Surg Br*. 1991; 73(3): 389-94.
13. Gibson ME, Gurley D, Trenhaile S. Traumatic subscapularis tendon tear in an adolescent american football player. *Sports Health*. 2013; 5(3): 267-9.
14. Heyworth BE, Dodson CC, Altchek DW. Arthroscopic repair of isolated subscapularis avulsion injuries in adolescent athletes. *Clin J Sport Med*. 2008; 18(5): 461-3.
15. Hepp P et al. Lesser tuberosity avulsion in combination with multifragment fracture of the greater tuberosity. A rare entity at the proximal humerus. *Unfallchirurg*. 2008; 111(8): 628-31.
16. Kanso I, Bricout JM. Isolated avulsion fracture of the lesser tuberosity of the humerus. Apropos of a case. *Rev Chir Orthop Reparatrice Appar Mot*. 1998; 84(6): 554-7.
17. Klasson SC, Vander Schilden JL, Park JP. Late effect of isolated avulsion fractures of the lesser tubercle of the humerus in children. Report of two cases. *J Bone Joint Surg Am*. 1993; 75(11): 1691-4.
18. LaBriola JH, Mohaghegh HA. Isolated avulsion fracture of the lesser tuberosity of the humerus. A case report and review of the literature. *J Bone Joint Surg Am*. 1975; 57(7): 1011.
19. Levine B, Pereira D, Rosen J. Avulsion fractures of the lesser tuberosity of the humerus in adolescents: review of the literature and case report. *J Orthop Trauma*. 2005; 19(5): 349-52.
20. Le Huec JC et al. Isolated avulsion fracture of the lesser tubercle of the humerus in children. *Acta Orthop Belg*. 1994; 60(4): 427-9.
21. Mansat P, Frankle MA, Cofield RH. Tears in the subscapularis tendon: descriptive analysis and results of surgical repair. *Joint Bone Spine*. 2003; 70(5): 342-7.
22. Morag Y et al. The subscapularis: anatomy, injury, and imaging. *Skeletal Radiol*. 2011; 40(3): 255-69.
23. Neer CS 2nd. Impingement lesions. *Clin Orthop Relat Res*. 1983; 173: 70-7.
24. Nove-Josserand L et al. Clinical and structural results of arthroscopic repair of isolated subscapularis tear. *J Bone Joint Surg Am*. 2012; 94(17): e125.
25. Ogawa K, Takahashi M. Long-term outcome of isolated lesser tuberosity fractures of the humerus. *J Trauma*. 1997; 42(5): 955-9.
26. Paschal SO, Hutton KS, Weatherall PT. Isolated avulsion fracture of the lesser tuberosity of the humerus in adolescents. A report of two cases. *J Bone Joint Surg Am*. 1995; 77(9): 1427-30.
27. Provance AJ, Polousky JD. Isolated avulsion fracture of the subscapularis tendon with medial dislocation and tear of biceps tendon in a skeletally immature athlete: a case report. *Curr Opin Pediatr*. 2010; 22(3): 366-8.
28. Ross GJ, Love MB. Isolated avulsion fracture of the lesser tuberosity of the humerus: report of two cases. *Radiology*. 1989; 172(3): 833-4.
29. Shah NN et al. Avulsion of the lesser tuberosity with a Salter-Harris type II injury of the proximal humerus: a case report. *J Shoulder Elbow Surg*. 2006; 15(5): e16-8.
30. Shibuya S, Ogawa K. Isolated avulsion fracture of the lesser tuberosity of the humerus. A case report. *Clin Orthop Relat Res*. 1986; 211: 215-8.
31. Sikka RS, Neault M, Guanche CA. An avulsion of the subscapularis in a skeletally immature patient. *Am J Sports Med*. 2004; 32(1): 246-9.
32. van Laarhoven HA, te Slaa RL, van Laarhoven EW. Isolated avulsion fracture of the lesser tuberosity of the humerus. *J Trauma*. 1995; 39(5): 997-9.
33. Vezeridis PS et al. Surgical treatment for avulsion injuries of the humeral lesser tuberosity apophysis in adolescents. *J Bone Joint Surg Am*. 2011; 93(20): 1882-8.