Skeletal Radiol (2013) 42:1361–1375
DOI 10.1007/s00256-013-1667-7

REVIEW ARTICLE

The deltoid, a forgotten muscle of the shoulder

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Received: 17 February 2013 / Revised: 29 May 2013 / Accepted: 30 May 2013 / Published online: 20 June 2013

Abstract The deltoid is a fascinating muscle with a significant role in shoulder function. It is comprised of three distinct portions (anterior or clavicular, middle or acromial, and posterior or spinal) and acts mainly as an abductor of the shoulder and stabilizer of the humeral head. Deltoid tears are not infrequently associated with large or massive rotator cuff tears and may further jeopardize shoulder function. A variety of other pathologies may affect the deltoid muscle including enthesitis, calcific tendinitis, myositis, infection, tumors, and chronic avulsion injury. Contracture of the deltoid following repeated intramuscular injections could present with progressive abduction deformity and winging of the scapula. The deltoid muscle and its innervating axillary nerve may be injured during shoulder surgery, which may have disastrous functional consequences. Axillary neuropathies leading to deltoid muscle dysfunction include traumatic injuries, quadrilateral space and Parsonage–Turner syndromes, and cause denervation of the deltoid muscle. Finally, abnormalities of the deltoid may originate from nearby pathologies of subdeltoid bursa, acromion, and distal clavicle.

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Keywords Deltoid muscle · Shoulder · Anatomy · Tears · Nerve injuries

Introduction

The deltoid is an essential, although lesser considered, muscle of the shoulder and thus it is rarely mentioned in MRI reports, which tend to focus on rotator cuff tendon and muscles.

In this paper, we aimed to review the normal anatomy and function of the deltoid muscle and to describe imaging features of various pathologies.

Anatomy and function

Overview and functional anatomy

The deltoid encompasses three portions: anterior or clavicular, middle or acromial, and posterior or spinal (from the scapular spine). From these proximal insertions, all the muscular fibers converge to attach on the deltoid tuberosity on the lateral aspect of the proximal humerus (Fig. 1).

The anterior portion is contiguous to the clavicular head of the pectoralis major, only separated by the deltopectoral sulcus hosting the cephalic vein. In rare occasions, this sulcus is absent and the two muscles merge together. The trapezius muscle shares its insertions on the scapula and lateral clavicle with the deltoid and the superficial deltotrapezial fascia covers both muscles [1].

The deltoid closely envelops the glenohumeral joint and determines the silhouette of the shoulder. Its action is complex, depending on the muscle portion involved. The posterior portion provides extension, adduction and lateral rotation of the arm in synergy with the latissimus dorsi. The anterior portion is responsible for flexion, adduction, and medial rotation of the arm in synergy with the pectoralis major. The largest middle portion allows abduction of the arm, which is also the foremost action of the deltoid. Abduction is more

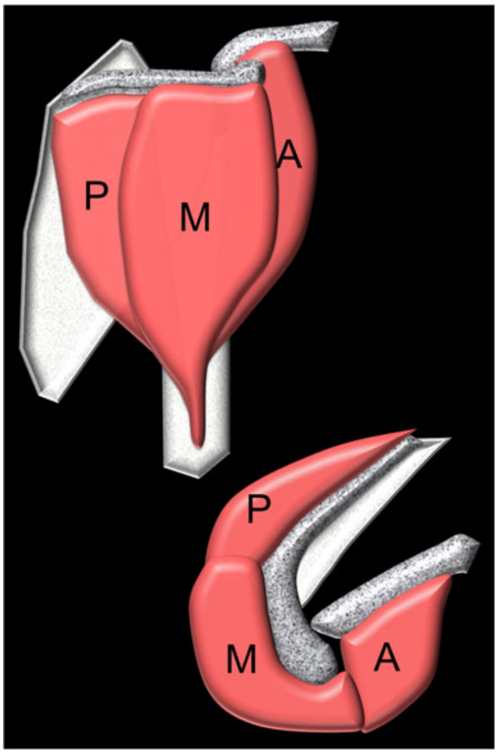


Fig. 1 Anatomic representation of the deltoid muscle on cranial and lateral views. *A* anterior or clavicular portion, *M* middle or acromial portion, *P* posterior or spinal portion

effective when the arm is medially rotated and additionally relies on the synergistic action of the supraspinatus muscle during the first 30°. The deltoid is classically an elevator of the humerus, but recent biomechanical studies demonstrated that it also provides stabilization of the humeral head during abduction (Fig. 2) [2].

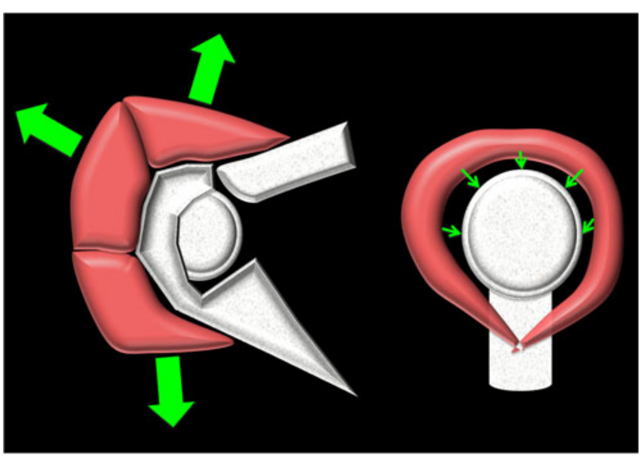


Fig. 2 Actions of the deltoid muscle: (1) flexion, medial rotation and adduction of the arm for the anterior portion; (2) extension and lateral rotation for the posterior portion; (3) abduction of the arm for the middle portion and as a whole; (4) stabilization of the humeral head

Overall, the deltoid is critical for shoulder motion and any pathology involving this muscle is highly detrimental to the normal function.

Proximal and distal insertions

The deltoid displays a multipennate structure organized around a fibrous frame (Fig. 3). Authors usually describe nine internal tendon bands, counting six proximal (one each for the anterior and posterior portions, four for the middle portion) and three distal (one for each portion) [3, 4].

The proximal insertions of the anterior and middle portions have been specifically studied in the perspective of their surgical detachment during open acromioplasty. The anterior portion attaches directly to the periosteum on the anterior surface of the distal clavicle. The middle portion is reinforced by three to four strong tendons, which are implanted on the superior surface of the acromion. These strong tendons may cause bone indentations that are occasionally seen on radiographs (Fig. 4) [5]. In addition, the deep deltoid fascia of the middle portion is continuous with the coracoacromial ligament (Fig. 5) [6].

The distal insertion of the muscle on the deltoid tuberosity of the humerus is noticeably long, measuring 65–97 mm in height, and relatively narrow, about 30 mm wide, equivalent to the lateral third of the proximal humeral circumference [7, 8].

Innervation and vascularization

The deltoid muscle is entirely innervated by the axillary nerve, which arises from the fifth and sixth cervical nerve roots and is a terminal branch of the posterior cord of the brachial plexus. The axillary nerve crosses the anterior surface of the subscapularis muscle from medial to lateral, then travels posteriorly under the glenohumeral joint where it receives sensory branches from the inferior capsule. It travels across the quadrilateral space (delineated by the long head of the triceps, teres minor, humeral shaft and teres major) accompanied by the posterior circumflex artery and exits to divide into two major trunks. The posterior trunk gives off branches for the teres minor and posterior deltoid and terminates as the superior lateral cutaneous nerve of the arm. The anterior trunk passes anteriorly around the humerus on the deep surface of the deltoid, approximately five centimeters distal to the lateral border of the acromion, and supplies the lateral and anterior deltoid portions (Fig. 6) [9, 10].

The axillary nerve is at risk during shoulder surgery and should always be identified and protected. With an anterior deltopectoral approach, the arm is positioned in adduction and external rotation to increase the distance between the nerve and the operative field. With a deltoid-splitting approach, the vertical incision should not extend more than 5 cm below the acromion to avoid the anterior trunk [10].

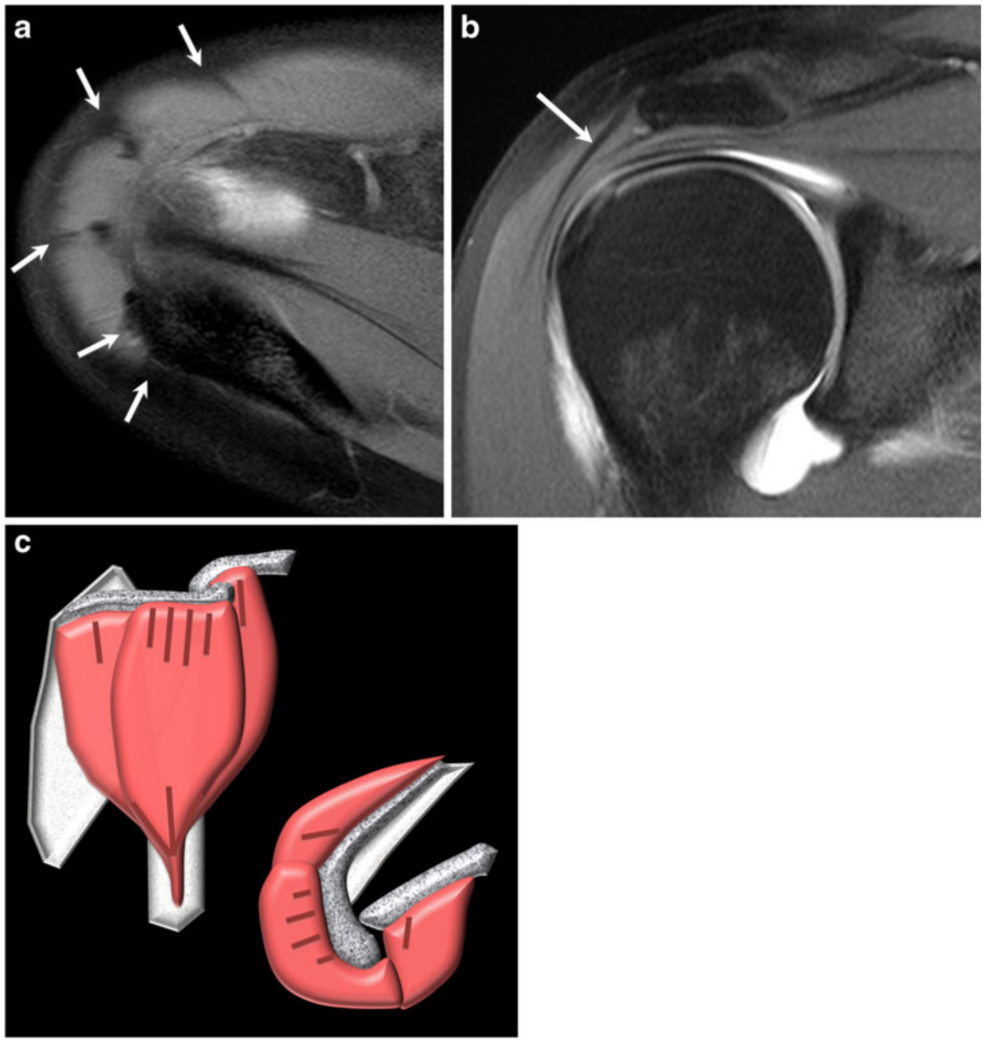


Fig. 3 Demonstration of the fibrous frame of the deltoid on axial (**a**) and coronal (**b**) T1W MR arthrography, and corresponding diagram (**c**)

Fig. 4 Neer view of the shoulder in a 60-year-old woman reveals the tendinous insertions of the deltoid on the superior aspect of the acromion: "serrated acromion"

The deltoid derives most of its vascularization from the posterior circumflex artery that reaches the posterior portion at its exit from the quadrilateral space. The acromial branch of the thoracoacromial artery provides additional supply to the middle and anterior portions [11]. These acromial vessels are regularly seen with MRI just lateral to the acromion and should not be confused with partial detachment.

Deltoid tears

Deltoid tears may be recognized in different settings at acute or chronic stages (Fig. 7).

Postoperative deltoid detachment

Postoperative detachment of the deltoid is a well-recognized complication of shoulder surgery and principally acromioplasty. The acromial edge measures 6–13 mm in height (9 mm on average), while the acromioplasty usually removes 6–9 mm of

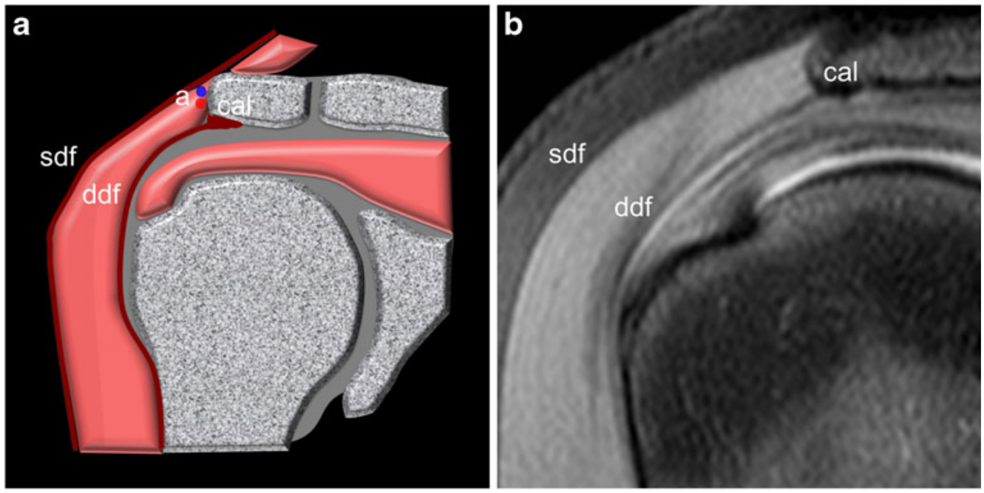


Fig. 5 Diagrammatic representation (**a**) and corresponding MRI (**b**) of the deltoid fasciae: the superficial deltoid fascia (*sdf*) is continuous with the trapezius fascia; the deep deltoid fascia (*ddf*) is continuous with the coracoacromial ligament (*cal*). The acromial vessels (*a*) run along the deltoid enthesis

bone, detaching about 70 % of the muscle fibers but normally preserving the superiorly inserted tendons (Fig. 8) [5, 12]. Bone resection is fairly extensive with the conventional acromioplasty procedure described by Neer [13] and even more with the modified technique of Rockwood and Lyons [14] that includes the acromial extension beyond the clavicle. Both authors recommend careful reattachment of the deltoid fibers with heavy non-absorbable suture at the conclusion of the procedure. On the other hand, arthroscopic subacromial decompression allows selective resection of bony spurs through minimal detachment of muscle fibers, but with no possibility of subsequent deltoid reconstruction [15, 16].

In a series of 112 patients operated on for massive rotator cuff tear, postoperative deltoid detachment (Fig. 9) occurred in 8 % during the first 3 months of active rehabilitation. It manifested by abnormal deltoid silhouette (crease sign) and abduction weakness rather than pain and was associated with

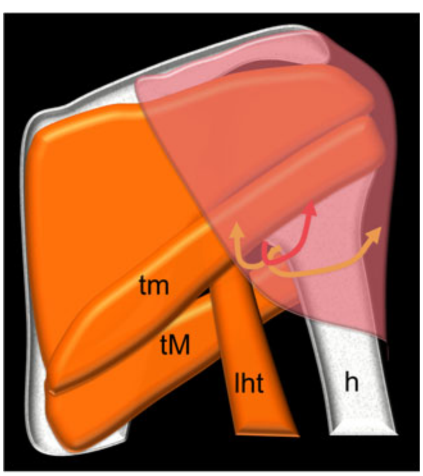


Fig. 6 Representation of the innervation and vascularization of the deltoid muscle on a posterior view of the shoulder. The two branches of the axillary nerve (*yellow*) and the posterior circumflex artery (*red*) emerge from the quadrilateral space delineated by the teres minor (*tm*), teres major (*tM*), long head of the triceps (*lht*) and humerus (*h*)

less functional improvement as assessed with the Constant score. The authors also mention that revision surgery in two of these patients brought unsatisfactory results, which underlines the importance of avoiding this complication [17].

Deltoid tears associated with rotator cuff tears

In the past, deltoid tears concomitant to massive rotator cuff tears have rarely been reported [18, 19]. They are now increasingly documented with MRI and ultrasound [20–22].

Ilaslan et al. prospectively observed 24 deltoid tears (15 full-thickness tears and nine partial-thickness tears) among 8,562 shoulder MRI studies (0.3 %) [23]. All of these were associated with full-thickness rotator cuff tears, which were massive (>5 cm wide) in 14, large (3–5 cm wide) in eight and moderate (1–3 cm wide) in two patients. All of these tears involved the middle portion of the deltoid, either at it acromial attachment (five patients), or in the muscle belly near its myotendinous junction (19 patients). Partial-thickness tears were associated with intramuscular delamination and cyst formation in 14 patients. Concurrent intramuscular edema and subcutaneous fluid were frequent as well.

Lecours et al. retrospectively reviewed 380 consecutive shoulder MRI studies and identified 35 patients with deltoid abnormalities (9.2 %), including minimal undersurface irregularities (type 1) in seven patients, partial-thickness tear less than 50 % (type 2) in 17 patients, partial-thickness tear more than 50 % (type 3) in ten patients and full-thickness tear (type 4) in one patient [24]. These tears were located at the acromial attachment in ten patients and at the myotendinous junction in 25 patients. A large or massive tear of the rotator cuff coexisted in 21 patients (60 %).

The retrospective nature of the second study with the inclusion of minor abnormalities may account for the apparent discordance of prevalence between these two studies. Both studies reveal that deltoid tears involve predominantly the deep surface of the deltoid, which is consistent with the

Fig. 7 Clinical presentation of deltoid tears in two different patients. **a** 77-year-old woman with acute deltoid tear associated with rotator cuff tear as demonstrated on T2W coronal MRI. **b** 50-year-old woman sport teacher with chronic deltoid tear associated with calcific tendinitis, as demonstrated on radiograph, and medical history of systemic sclerosis. The rotator cuff was continuous at ultrasound examination (not shown) and we hypothesized that the deltoid was progressively eroded by the calcification during repetitive abduction of the shoulder

alleged pathophysiology where following large or massive cuff tear, the humeral head migrates superiorly and impinges on the acromion, leading to progressive detachment of the deltoid enthesis (Fig. 10) [20, 22]. The same mechanism is also responsible for acromioclavicular joint cyst formation and fatigue fracture of the acromion [25, 26]. Superior humeral subluxation also causes the greater tuberosity, which is often irregular from chronic bone remodeling, to impinge on

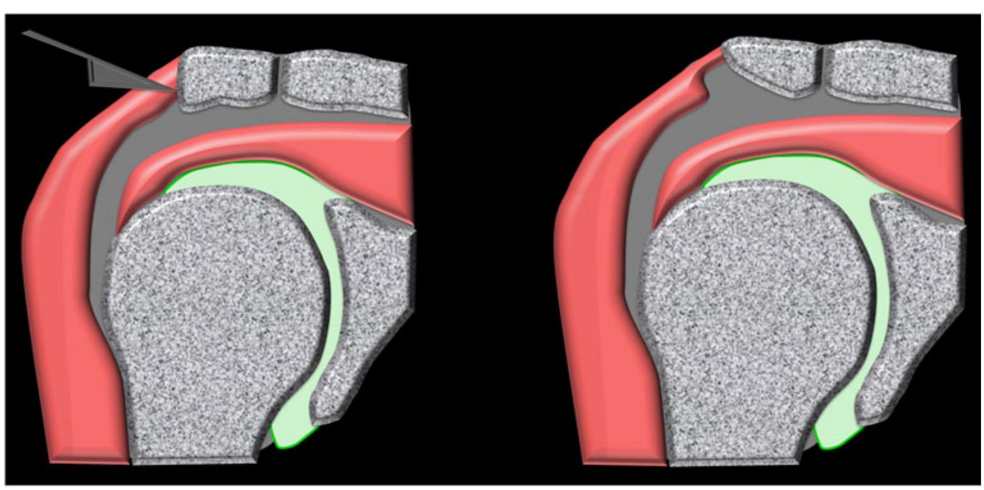


Fig. 8 During conventional acromioplasty, about 70 % of the deltoid insertion on the acromion is removed. Careful surgical reattachment is required to avoid postoperative detachment

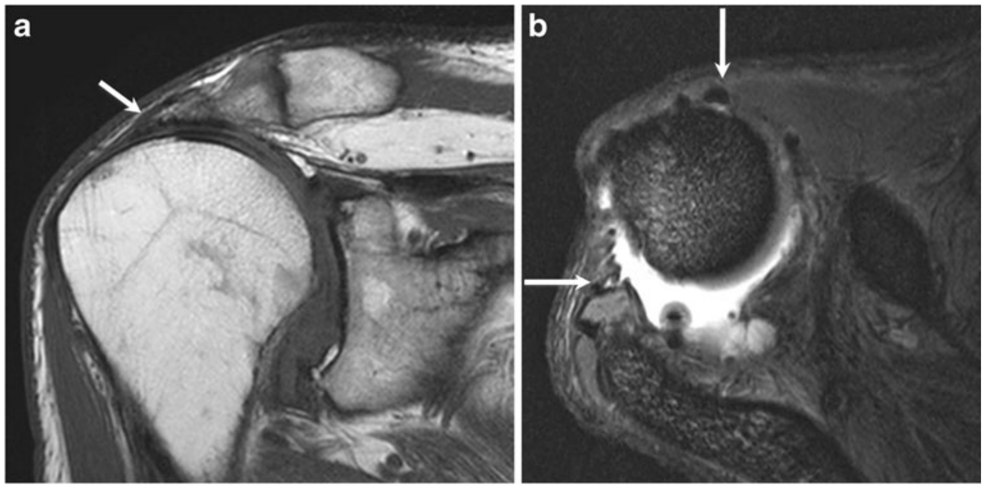


Fig. 9 A 66-year-old man presents with deltoid detachment following acromioplasty. Coronal T1W (**a**) and transverse T2*W (**b**) MR sections demonstrate previous acromioplasty with susceptibility artifacts and proximal detachment of the middle deltoid portion. This patient has chronic massive rotator cuff tear as well

the undersurface of the muscle belly near the myotendinous junction, which represents the second mechanism of deltoid tears (Fig. 11). Muscle edema and tear are frequently observed in this location. In addition, disruption of the deep deltoid fascia may promote penetration of fluid from the subdeltoid bursa and glenohumeral joint, resulting in intramuscular delamination and cyst formation (Fig. 12), as described for rotator cuff cysts [27].

These two conceivable mechanisms (Fig. 13) provide a rational explanation for the two distinct patterns of deltoid tears observed with imaging studies: proximal acromial detachment and undersurface tear at the myotendinous junction. This latter is more frequent, and observed in 71–80 % of patients with deltoid tears [23, 24].

Furthermore, deltoid tears are more frequent in older individuals, predominantly women, who typically have a lower muscle mass. Repeated corticosteroid injections are also believed to foster deltoid tears, possibly through inadvertent non-guided intramuscular injection [20, 22].

Deltoid tears are well demonstrated with MRI, and even more with direct MR arthrography as opacification of the subdeltoid bursa through a full-thickness rotator cuff tear exquisitely reveals undersurface tears of the deltoid muscle. Sonographic examination may also reveal such tears and is enhanced by performing a dynamic abduction maneuver [22].

The clinical significance of deltoid tears complicating rotator cuff tears remains unclear, as well as indications for surgical repair. However, it is suggested that these patients perform less well than those with isolated cuff tear and may require a specific or different management [28]. Importantly, patients with massive cuff tear are more often considered for reverse total shoulder arthroplasty because of glenohumeral joint osteoarthrosis. The particular conception of this prosthesis requires an undamaged deltoid muscle and therefore, detection of deltoid tears at preoperative imaging becomes essential in examining these patients [29, 30].

Isolated deltoid tears

Isolated tears of the deltoid have been infrequently reported in the setting of sports injuries [31, 32] and motor vehicle accidents [33]. These tears are more often located at the acromial insertion (Figs. 14 and 15).

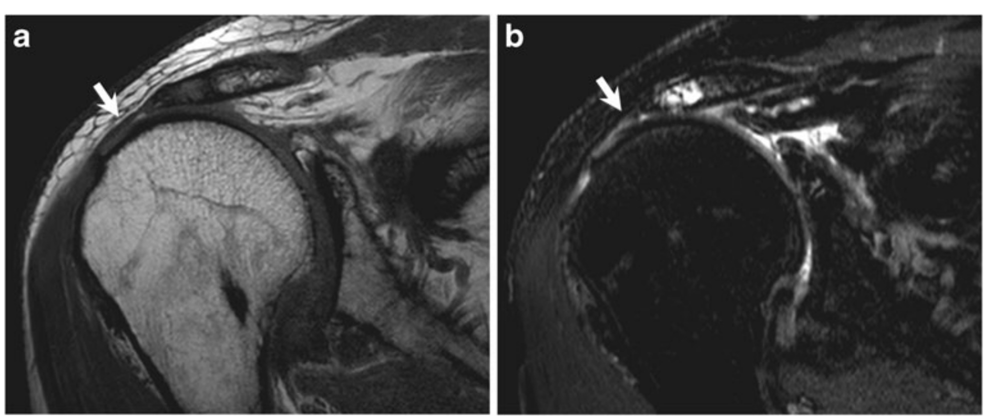


Fig. 10 Images of a 74-year-old man with deltoid tear associated with rotator cuff tear. Coronal T1W (**a**) fat-saturated T2W (**b**) images demonstrate proximal detachment of the deltoid associated with massive rotator cuff tear. The humeral head impinges on the acromion whose signal intensity is abnormal

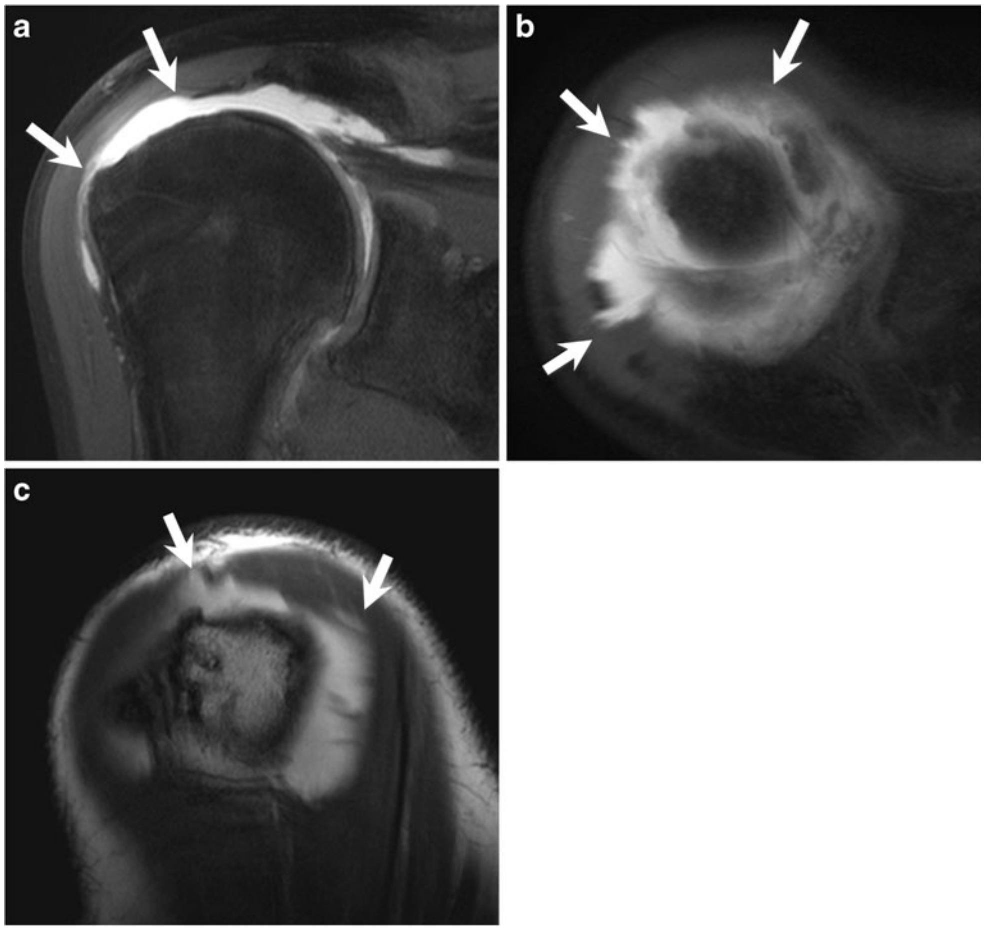


Fig. 11 Images of a 65-year-old man with deltoid tear associated with rotator cuff tear. Coronal (**a**) and axial (**b**) fat-saturated T1W, sagittal T1W (**c**) MR arthrography sections demonstrate large undersurface ulcerations of the middle deltoid portion. The humeral head is not elevated and the acromial attachment is preserved

Contracture of the deltoid

Deltoid contracture is observed in children and adults of all ages, as a consequence of repeated intramuscular injections of vaccines, antibiotics, or other pharmaceutics [34, 35]. Additional genetic factors may have a role, as suggested by the ethnic predominance and propensity to keloid formation in these patients. Analogous contracture may affect the quadriceps, gluteus, and triceps muscles as well. The pathophysiology implies intramuscular hemorrhage and necrosis followed by excessive fibrosis, atrophy, and retraction. Contracture of the deltoid predominates in its middle portion as it is the frequent target for intramuscular injections and its rich tendinous frame is prone to retraction with scarring.

Patients present with a fixed abduction of the shoulder and winging of the scapula that is sagittalization with dorsal protrusion of its medial border. Skin dimpling and injection scars are common and the fibrotic cord is often palpable [34, 35].

Shoulder radiographs may demonstrate the characteristic deformity (abduction and restricted rotation of the humerus, lateral shift and winging of the scapula, lateral down-sloping of the acromion and traction enthesophyte) and soft-tissue calcification [36].

At ultrasound, the deltoid appears heterogeneous with hypoechoic and hyperechoic fibrotic cords [37].

MR imaging demonstrates hypointense fibrotic cords (Fig. 16) and allows calculation of the winging angle (abnormal over 45°) [36].

The surgical treatment includes resection of the fibrotic cord and release of the distal tendon [34, 35].

Neurogenic abnormalities

Lesions of the axillary nerve may occur as a consequence of closed-blunt trauma, traction injury, penetrating trauma and iatrogenic injury, or within the circumstance of quadrilateral space and Parsonage–Turner syndromes [38].

Severe nerve injury is followed by muscle denervation with typical changes that are readily appreciated with MRI: denervation edema initially, followed by muscle atrophy with fatty degeneration in absence of nerve recovery [39].

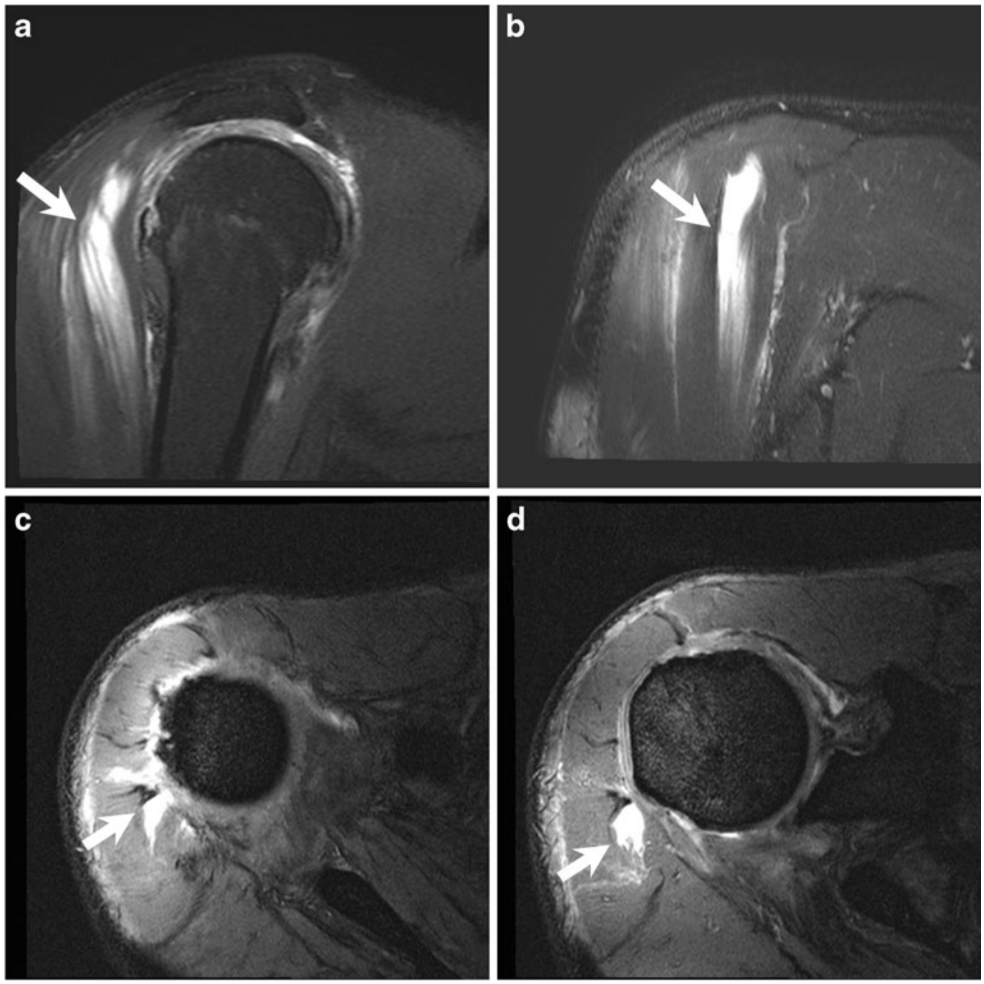


Fig. 12 Images of a 66-year-old woman with deltoid tear associated with rotator cuff tear. Coronal (**a**) and sagittal (**b**) fat-saturated T2W and transverse T2*W (**c**, **d**) images demonstrate extensive disruption of the deep deltoid fascia with intramuscular cyst formation

Traumatic injuries

Posttraumatic axillary nerve injury occurs in up to 45 % of anterior shoulder dislocations during which it is stretched over the dislocated humeral head. It should always be looked at before attempting reduction [40, 41]. However, manifestations of deltoid denervation may be observed at MRI performed afterward. Therefore, evidence of axillary neuropathy should lead to questions about prior shoulder dislocation.

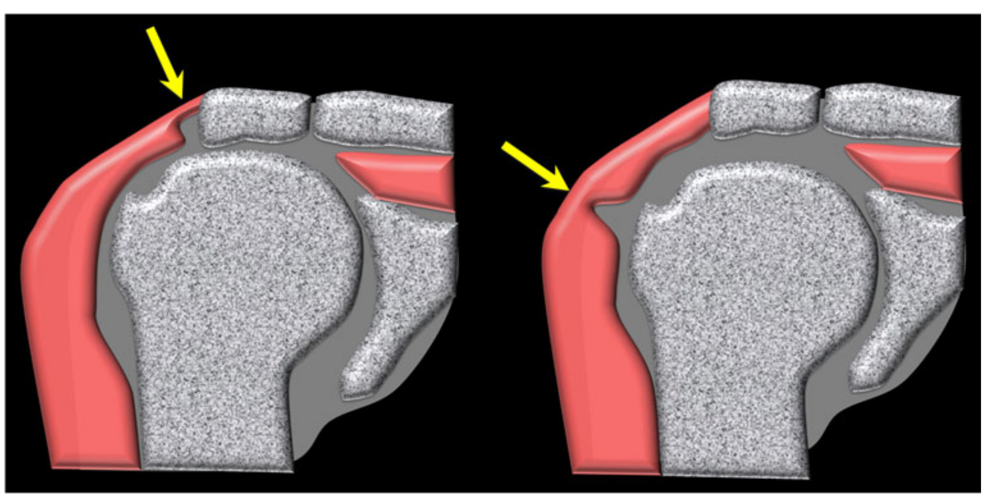


Fig. 13 Two different patterns of deltoid tears associated with rotator cuff tears. **a** Proximal detachment, attributed to friction of the elevated humeral head at the site of acromial insertion. **b** Myotendinous junction tear, which may result from impingement of the greater tuberosity

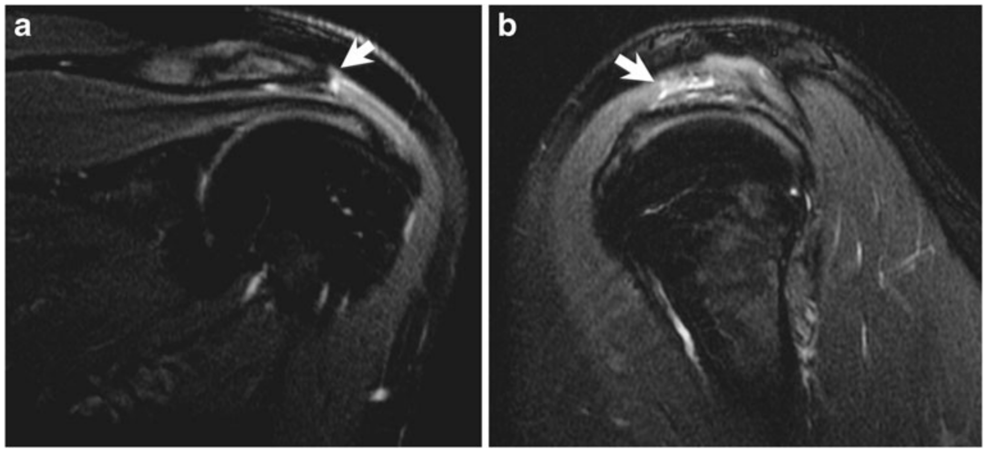


Fig. 14 Images of a 37-year-old woman with isolated deltoid tear. Coronal (**a**) and sagittal (**b**) fat-suppressed T2W MR sections demonstrate proximal detachment of the middle portion from the acromion

Isolated injury of the anterior trunk may result from a direct blow to the lateral aspect of the shoulder and lead to selective denervation of the anterior and middle deltoid portions (Fig. 17).

Parsonage-Turner syndrome

This syndrome is now recognized as a brachial neuritis triggered by viral infection or other immunological causes

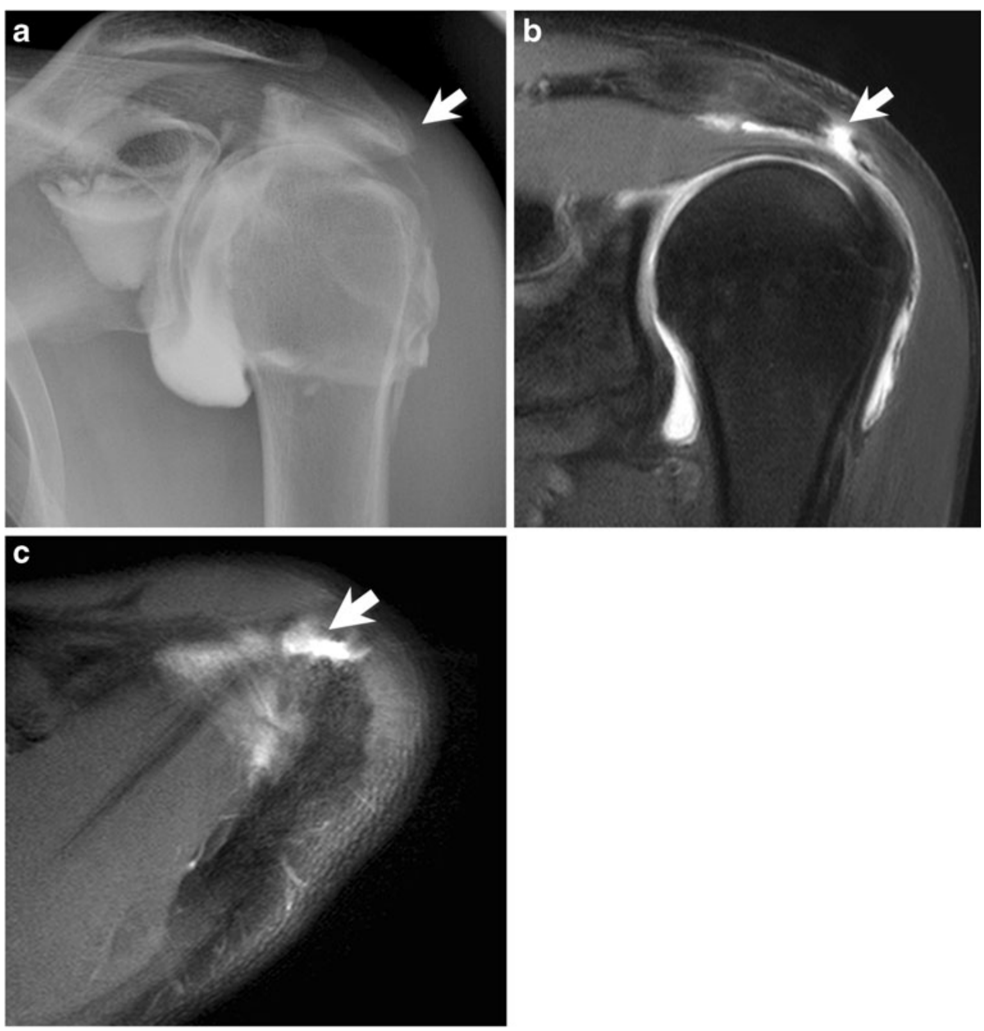


Fig. 15 Images of a 34-year-old man with proximal deltoid detachment and subscapularis tear (not shown). Arthrography (**a**) and fat-suppressed T1W MR arthrography coronal (**b**) and transverse (**c**) sections demonstrate contrast leakage at the site of acromial attachment. In absence of supraspinatus tear, the pathophysiology of this lesion may be similar to those of isolated tears

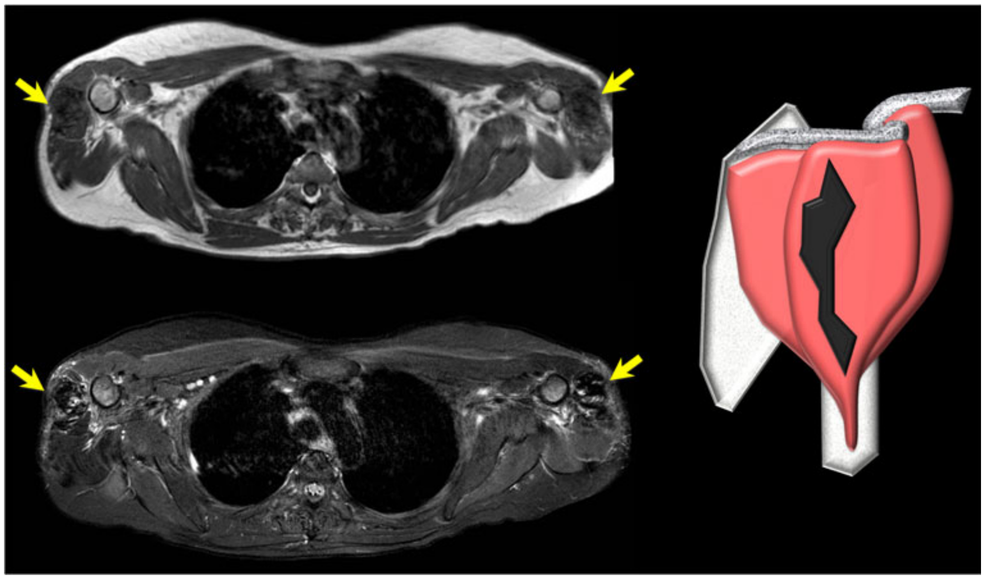


Fig. 16 Images of a 58-year-old woman with deltoid contracture following multiple intramuscular injections. Transverse T1W (**a**) and STIR (**b**) images demonstrate bilateral thick hypointense fibrous cords in the middle and posterior deltoid portions. **c** Diagrammatic representation

and typically affects the dominant extremity of middle-aged men. It predominantly involves the suprascapular, axillary and long thoracic nerves and manifests by an acute onset of severe shoulder pain without trauma. The pain gradually decreases in approximately 4 weeks as muscle weakness progresses. MR imaging contributes to the diagnosis by demonstrating muscle edema and atrophy representing denervation in the territories of involved nerves. Involvement of multiple nerve territories is characteristic of Parsonage–Turner syndrome (Fig. 18). Based on two large series of patients investigated with MRI, muscles innervated by the suprascapular nerve (supraspinatus and infrapinatus) are abnormal in 89–97 % and muscles innervated by the axillary nerve (deltoid and teres minor) in 30–50 % [42, 43].

Quadrilateral space syndrome

This uncommon and somewhat controversial condition is described as an entrapment of the axillary nerve and posterior circumflex artery within the quadrilateral space. Potential causes of compression include paralabral cyst, lipoma, venous dilatations, or fibrous bands. Patients typically present with posterior shoulder pain exacerbated by abduction and lateral rotation, paresthesias in a nondermatomal distribution, and posterior point tenderness [44–47].

The diagnosis was classically confirmed with subclavian arteriography demonstrating stenosis of the posterior humeral circumflex during abduction and lateral rotation of the arm [48]. MDCT arteriography may nowadays advantageously

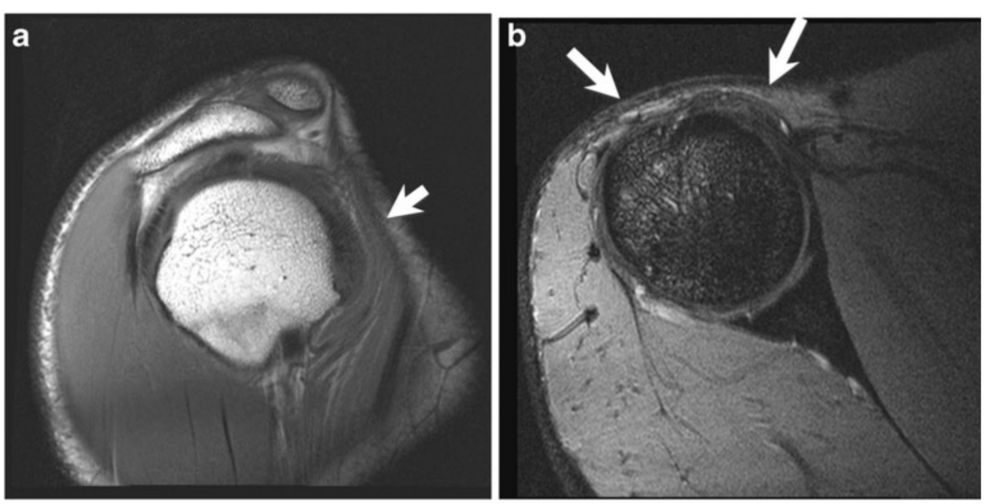


Fig. 17 Images of a 20-year-old man with atrophy of the middle and anterior portions of the deltoid on sagittal T1W (**a**) and transverse T2*W (**b**) images. The anterior branch of the axillary nerve was injured in a previous trauma

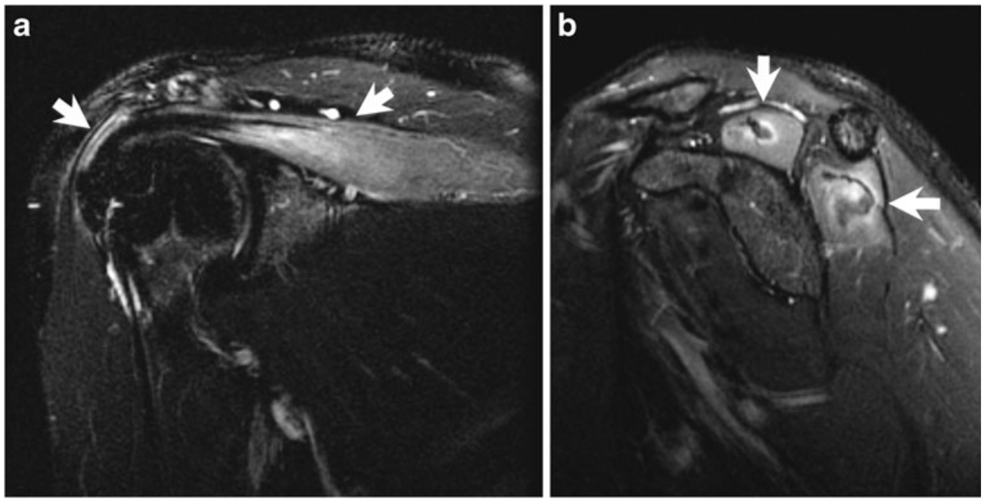


Fig. 18 Images of a 37-year-old woman with Parsonage–Turner syndrome. Coronal (**a**) and sagittal (**b**) fat-saturated T2W images demonstrate denervation edema in supraspinatus, infraspinatus, and deltoid muscle corresponding to two different nerve territories

replace arteriography [45] but MRI is probably better suited to demonstrate abnormal structures in the quadrilateral space, although fibrous bands are not visible (Fig. 19). In addition, atrophy or abnormal signal from edema or fatty degeneration of the teres minor and deltoid muscles may reflect denervation [49]. However, isolated atrophy of the teres minor is quite common and not synonymous of this rare entity [50].

Miscellaneous conditions

Other pathological conditions may either originate within the deltoid muscle or spread from the acromion, acromioclavicular joint, and subdeltoid bursa.

Myositis and related conditions

A muscle edema pattern may be observed in early infection, polymyositis, dermatomyositis, traumatic injuries, delayed-onset muscle soreness (DOMS), rhabdomyolysis, and following radiation therapy [39].

This imaging pattern is not dissimilar to what has been described for acute denervation although the distribution is typically different, with involvement of other muscle territories, skin and subcutaneous tissues, and the subdeltoid bursa or adjacent structures.

Polymyalgia rheumatica is an inflammatory arthropathy with a particular tropism for the shoulder and pelvic girdles that may manifest at MRI with subdeltoid effusion and edema of adjacent structures including the deltoid muscle (Fig. 20).

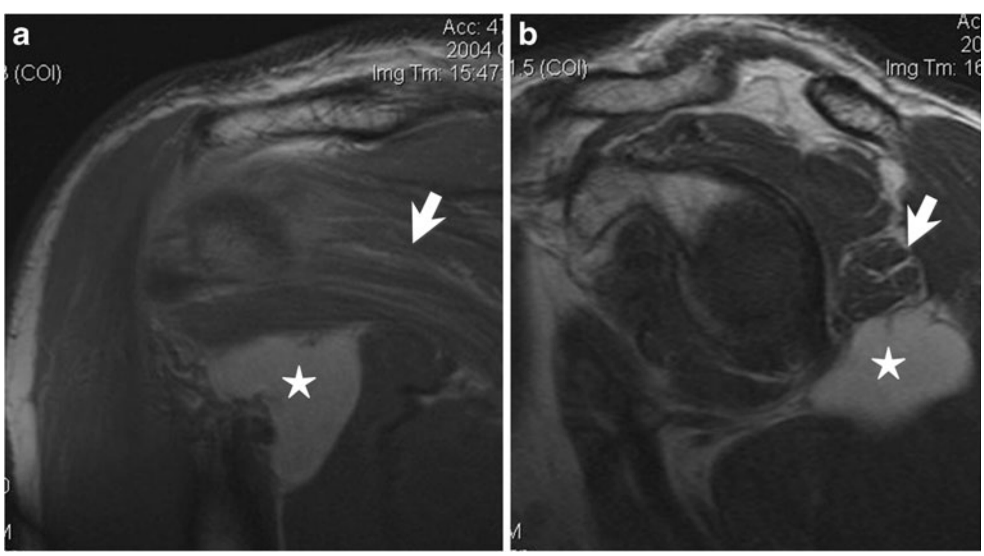


Fig. 19 Images of a 53-year-old man with quadrilateral space syndrome caused by a lipoma. Coronal (**a**) and sagittal (**b**) T1W images demonstrate atrophy and fatty infiltration of the teres minor secondary to compression of the axillary nerve by a lipoma (*asterisk*). The deltoid was unremarkable in this case

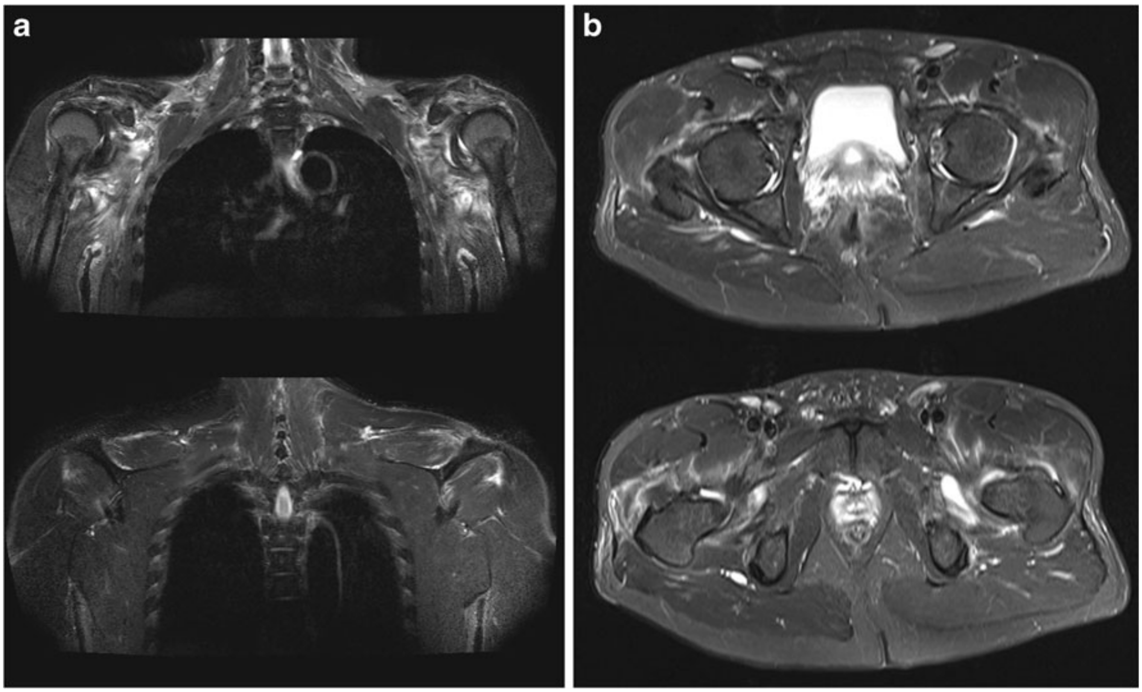


Fig. 20 Images of a 52-year-old man with polymyalgia rheumatica. MRI with STIR images of the shoulder (**a**) and pelvic (**b**) girdles demonstrate myofascial edema

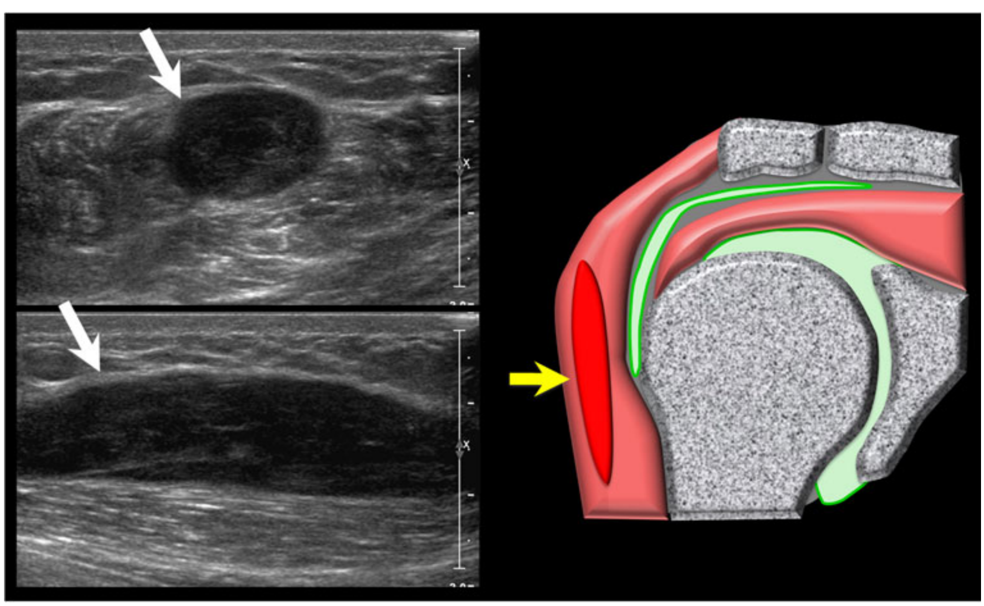
Tumors and other mass lesions

Soft tissue tumors involving the deltoid muscle (Fig. 21) share their imaging characteristics with other locations. Bone tumors may extend from the acromion and metastases represent by far the most frequent etiology. Other possible mass lesions include bacterial abscess (Fig. 22) and parasitic infection, hematoma, myositis ossificans, muscular sarcoidosis, and focal myositis [39].

Calcific tendinosis

Calcific tendinosis, particularly frequent around the shoulder and its manifestations, may involve the deltoid muscle. Calcification at the acromial attachment of the deltoid is not infrequent but rarely symptomatic (Fig. 23). Intrabursal migration of a rotator cuff calcification is much more frequent and may generate intense shoulder pain. Inflammatory changes of the subdeltoid bursa are well demonstrated with

Fig. 21 Images of B-cell lymphoma of the deltoid associated with VIH infection in a 65-year-old man. Transverse (**a**) and coronal (**b**) ultrasound images demonstrate a hypoechoic fusiform tumor oriented along the deltoid fibers, with diagrammatic representation. Ultrasound-guided biopsy confirmed the diagnosis



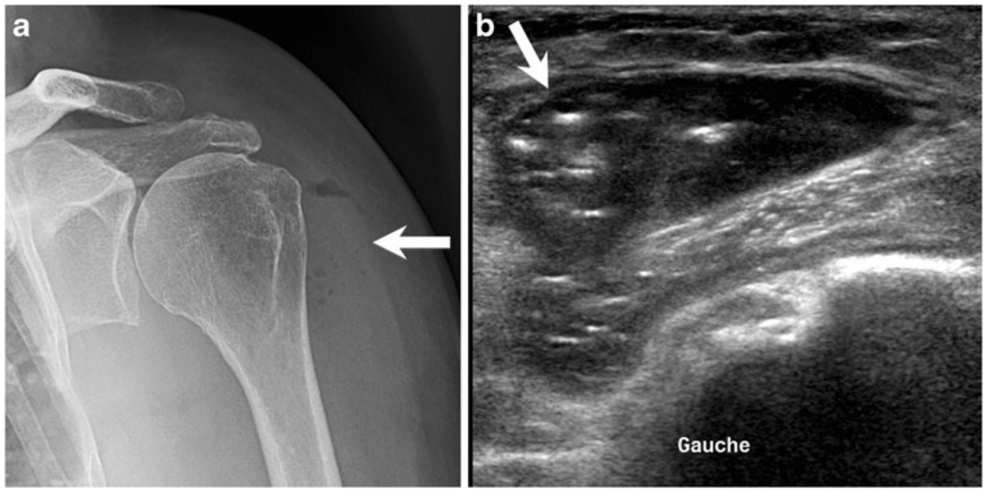


Fig. 22 Images of an 85-year-old woman with deltoid abscess. **a** AP radiograph demonstrates gas lucencies in projection of the deltoid. The narrowing of the subacromial space indicates chronic cuff tear. **b** Transverse ultrasound at the level of the bicipital groove confirms the abscess communicating with the subdeltoid bursa and the articular space and guided-aspiration yielded *E. coli*

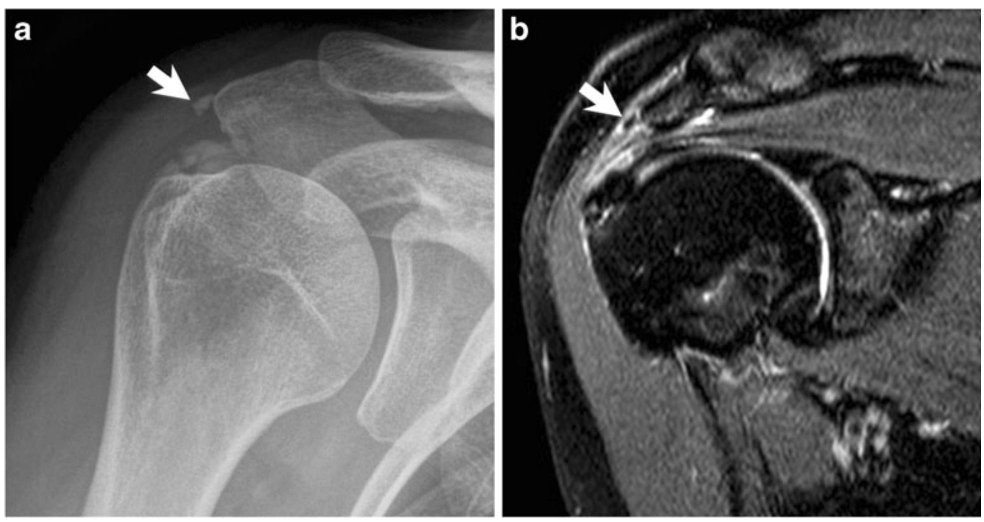


Fig. 23 Images of a 52-year-old man with calcific tendinosis of the deltoid. Radiograph (**a**) and coronal fat-saturated T2W image (**b**) demonstrate a small calcification of the deltoid surrounded by muscle edema. Effusion of the sub-acromiodeltoid bursa and calcific tendinosis of the supraspinatus are present as well

Fig. 24 Images of a 44-year-old woman with ankylosing spondylitis and shoulder pain. Sagittal T2W images (**a**, **b**) demonstrate abnormal signal at the insertion of the posterior deltoid tendon, consistent with enthesitis, which is the hallmark of this disease

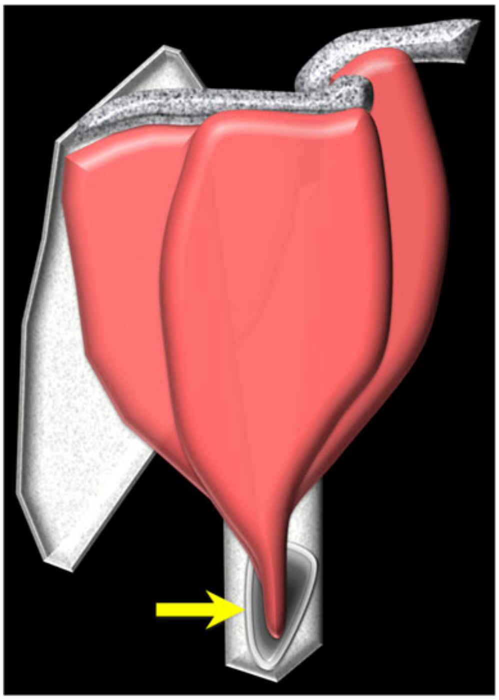


Fig. 25 Diagrammatic representation of pseudotumor deltoideus considered to be a normal variant or secondary to chronic avulsion injuries

MRI and may extend to the deep surface of the deltoid muscle.

Enthesitis

Deltoid enthesitis is a characteristic feature of spondyloarthropathies, which may be demonstrated with radiographs, MRI, and sonography (Fig. 24).

Lambert et al. [51] reviewed the MR examinations of 15 patients with ankylosing spondylitis and observed bone marrow edema at the acromial enthesis, clavicular enthesis, or humeral tuberosity in 70.6 %. When matched with MR studies from patients with another diagnosis, deltoid enthesitis was found specific for ankylosing spondylitis.

In another study, Falsetti et al. [52] performed sonographic examinations in 100 patients with spondyloarthropathies and observed that deltoid enthesitis was present in 9 % and could clinically mimic impingement syndrome because of pain.

Chronic avulsive injury and normal variants

Morgan et al. [53] described as pseudotumor deltoideus a spectrum of bone modifications at the humeral insertion of the deltoid. Variable bone lucencies, cortical irregularities, abnormal signal of bone marrow, and increased radionuclide uptake of the deltoid tuberosity represent anatomic variants that may simulate pathologic processes (Fig. 25).

Donnelly et al. [54] published three observations of chronic avulsive injury of the deltoid insertion in adolescents. Similar radiographic and MR bone abnormalities with occasional adjacent soft-tissue were documented and confirmed to be benign.

Conclusions

The deltoid muscle is the largest shoulder muscle and should be specifically assessed during shoulder imaging, especially in a setting of large rotator cuff tear. The basic anatomy and pathophysiology of a variety of abnormal conditions of the deltoid muscle were reviewed and illustrated.

Financial disclosures The authors declare that they have no conflicts of interest.

References

1. Le Double AF. Traité des variations musculaires de l'homme et de leur signification au point de vue de l'anthropologie zoologique. Paris: Schleicher frères; 1897.
2. Billuart F, Devun L, Skalli W, Mitton D, Gagey O. Role of deltoid and passives elements in stabilization during abduction motion (0 degrees–40 degrees): an ex vivo study. Surg Radiol Anat. 2008;30(7):563–8.
3. Lorne E, Gagey O, Quillard J, Hue E, Gagey N. The fibrous frame of the deltoid muscle. Its functional and surgical relevance. Clin Orthop Relat Res. 2001;386:222–5.
4. Leijnse JN, Han SH, Kwon YH. Morphology of deltoid origin and end tendons—a generic model. J Anat. 2008;213(6):733–42.
5. Kumar VP, Satku K, Liu J, Shen Y. The anatomy of the anterior origin of the deltoid. J Bone Joint Surg Br. 1997;79(4):680–3.
6. Edelson JG, Luchs J. Aspects of coracoacromial ligament anatomy of interest to the arthroscopic surgeon. Arthroscopy. 1995;11(6):715–9.
7. Morgan SJ, Furry K, Parekh AA, Agudelo JF, Smith WR. The deltoid muscle: an anatomic description of the deltoid insertion to the proximal humerus. J Orthop Trauma. 2006;20(1):19–21.
8. Klepps S, Auerbach J, Calhon O, Lin J, Cleeman E, Flatow E. A cadaveric study on the anatomy of the deltoid insertion and its relationship to the deltopectoral approach to the proximal humerus. J Shoulder Elbow Surg. 2004;13(3):322–7.
9. Kulkarni RR, Nandedkar AN, Mysorekar VR. Position of the axillary nerve in the deltoid muscle. Anat Rec. 1992;232(2):316–7.
10. Groh GI, Simoni M, Rolla P, Rockwood CA. Loss of the deltoid after shoulder operations: an operative disaster. J Should Elb Surg. 1994;3(4):243–53.
11. Hue E, Gagey O, Mestdagh H, Fontaine C, Drizenko A, Maynou C. The blood supply of the deltoid muscle. Application to the deltoid flap technique. Surg Radiol Anat. 1998;20(3):161–5.
12. Torpey BM, Ikeda K, Weng M, van der Heeden D, Chao EY, McFarland EG. The deltoid muscle origin. Histologic characteristics and effects of subacromial decompression. Am J Sports Med. 1998;26(3):379–83.
13. Neer 2nd CS. Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. J Bone Joint Surg Am. 1972;54(1):41–50.

14. Rockwood CA, Lyons FR. Shoulder impingement syndrome: diagnosis, radiographic evaluation, and treatment with a modified Neer acromioplasty. J Bone Joint Surg Am. 1993;75(3):409–24.
15. Ellman H. Arthroscopic subacromial decompression: analysis of one- to three-year results. Arthroscopy. 1987;3(3):173–81.
16. Gartsman GM. Arthroscopic acromioplasty for lesions of the rotator cuff. J Bone Joint Surg Am. 1990;72(2):169–80.
17. Gumina S, Di Giorgio G, Perugia D, Postacchini F. Deltoid detachment consequent to open surgical repair of massive rotator cuff tears. Int Orthop. 2008;32(1):81–4.
18. Samuel J, Levernieux J, de Seze S. A propos d'un cas de rupture du deltoïde. Rev Rhum Mal Osteoartic. 1975;42(12):769–71.
19. Pointud P, Clerc D, Manigand G, Deparis M. Rupture spontanée du deltoïde. Nouv Presse Med. 1976;5(35):2315–6.
20. Morisawa K, Yamashita K, Asami A, Nishikawa H, Watanabe H. Spontaneous rupture of the deltoid muscle associated with massive tearing of the rotator cuff. J Shoulder Elbow Surg. 1997;6(6):556–8.
21. Blazar PE, Williams GR, Iannotti JP. Spontaneous detachment of the deltoid muscle origin. J Shoulder Elbow Surg. 1998;7(4):389–92.
22. Bianchi S, Martinoli C, Abdelwahab IF. Imaging findings of spontaneous detachment of the deltoid muscle as a complication of massive rotator cuff tear. Skeletal Radiol. 2006;35(6):410–5.
23. Ilaslan H, Iannotti JP, Recht MP. Deltoid muscle and tendon tears in patients with chronic rotator cuff tears. Skeletal Radiol. 2007;36(6):503–7.
24. Lecours J, Moser T, Cardinal E. Incidence of proximal deltoid tears with MR imaging in shoulder pain patients. Chicago: Radiological Society of North America; 2010.
25. Craig EV. The acromioclavicular joint cyst. An unusual presentation of a rotator cuff tear. Clin Orthop Relat Res. 1986;202:189–92.
26. Dennis D, Ferlic D, Clayton M. Acromial stress fractures associated with cuff-tear arthropathy. A report of three cases. J Bone Joint Surg Am. 1986;68(6):937–40.
27. Sanders TG, Tirman PF, Feller JF, Genant HK. Association of intramuscular cysts of the rotator cuff with tears of the rotator cuff: magnetic resonance imaging findings and clinical significance. Arthroscopy. 2000;16(3):230–5.
28. Billuart F, Gagey O, Skalli W, Mitton D. Biomechanics of the deltoideus. Surg Radiol Anat. 2006;28(1):76–81.
29. Boileau P, Watkinson DJ, Hatzidakis AM, Balg F. Grammont reverse prosthesis: design, rationale, and biomechanics. J Shoulder Elbow Surg. 2005;14(1 Suppl S):147S–61.
30. Roberts CC, Ekelund AL, Renfree KJ, Liu PT, Chew FS. Radiologic assessment of reverse shoulder arthroplasty. RadioGraphics. 2007;27(1):223–35.
31. Lin JT, Nagler W. Partial tear of the posterior deltoid muscle in an elderly woman. Clin J Sport Med. 2003;13(2):120–1.
32. Allen AA, Drakos MC. Partial detachment of the deltoid muscle. A case report. Am J Sports Med. 2002;30(1):133–4.
33. Chiba D, Sano H, Nakajo S, Fujii F. Traumatic deltoid rupture caused by seatbelt during a traffic accident: a case report. J Orthop Surg (Hong Kong). 2008;16(1):127–9.
34. Banerji D, De C, Pal AK, Das SK, Ghosh S, Dharmadevan S. Deltoid contracture: a study of nineteen cases. Indian J Orthop. 2008;42(2):188–91.
35. Groves RJ, Goldner JL. Contracture of the deltoid muscle in the adult after intramuscular injections. J Bone Joint Surg Am. 1974;56(4):817–20.
36. Chen CK, Yeh L, Chen CT, Pan HB, Yang CF, Resnick D. Contracture of the deltoid muscle: imaging findings in 17 patients. AJR Am J Roentgenol. 1998;170(2):449–53.
37. Huang CC, Ko SF, Ko JY, Huang HY, Ng SH, Wan YL, et al. Contracture of the deltoid muscle: sonographic evaluation with MRI correlation. AJR Am J Roentgenol. 2005;185(2):364–70.
38. Steinmann SP, Moran EA. Axillary nerve injury: diagnosis and treatment. J Am Acad Orthop Surg. 2001;9(5):328–35.
39. May DA, Disler DG, Jones EA, Balkissoon AA, Manaster BJ. Abnormal signal intensity in skeletal muscle at MR imaging: patterns, pearls, and pitfalls. Radiographics. 2000;20 Spec No:S295–315.
40. Tuckman GA, Devlin TC. Axillary nerve injury after anterior glenohumeral dislocation: MR findings in three patients. AJR Am J Roentgenol. 1996;167(3):695–7.
41. Linda DD, Harish S, Stewart BG, Finlay K, Parasu N, Rebello RP. Multimodality imaging of peripheral neuropathies of the upper limb and brachial plexus. RadioGraphics. 2010;30(5):1373–400.
42. Gaskin CM, Helms CA. Parsonage-Turner syndrome: MR imaging findings and clinical information of 27 patients. Radiology. 2006;240(2):501–7.
43. Scalf RE, Wenger DE, Frick MA, Mandrekar JN, Adkins MC. MRI findings of 26 patients with Parsonage–Turner syndrome. AJR Am J Roentgenol. 2007;189(1):W39–44.
44. Cahill BR, Palmer RE. Quadrilateral space syndrome. J Hand Surg Am. 1983;8(1):65–9.
45. McAdams TR, Dillingham MF. Surgical decompression of the quadrilateral space in overhead athletes. Am J Sports Med. 2008;36(3):528–32.
46. Robinson P, White LM, Lax M, Salonen D, Bell RS. Quadrilateral space syndrome caused by glenoid labral cyst. AJR Am J Roentgenol. 2000;175(4):1103–5.
47. Sanders TG, Tirman PF. Paralabral cyst: an unusual cause of quadrilateral space syndrome. Arthroscopy. 1999;15(6):632–7.
48. Cormier PJ, Matalon TA, Wolin PM. Quadrilateral space syndrome: a rare cause of shoulder pain. Radiology. 1988;167(3):797–8.
49. Linker CS, Helms CA, Fritz RC. Quadrilateral space syndrome: findings at MR imaging. Radiology. 1993;188(3):675–6.
50. Cothran Jr RL, Helms C. Quadrilateral space syndrome: incidence of imaging findings in a population referred for MRI of the shoulder. AJR Am J Roentgenol. 2005;184(3):989–92.
51. Lambert RG, Dhillon SS, Jhangri GS, Sacks J, Sacks H, Wong B, et al. High prevalence of symptomatic enthesopathy of the shoulder in ankylosing spondylitis: deltoid origin involvement constitutes a hallmark of disease. Arthritis Rheum. 2004;51(5):681–90.
52. Falsetti P, Frediani B, Filippou G, Acciai C, Baldi F, Storri L, et al. Enthesitis of proximal insertion of the deltoid in the course of seronegative spondyloarthritis. An atypical enthesitis that can mime impingement syndrome. Scand J Rheumatol. 2002;31(3):158–62.
53. Morgan H, Damron T, Cohen H, Allen M. Pseudotumor deltoideus: a previously undescribed anatomic variant at the deltoid insertion site. Skeletal Radiol. 2001;30(9):512–8.
54. Donnelly LF, Helms CA, Bisset 3rd GS. Chronic avulsive injury of the deltoid insertion in adolescents: imaging findings in three cases. Radiology. 1999;211(1):233–6.