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REVIEW ARTICLE

Scapulothoracic pathology: review of anatomy, pathophysiology, imaging findings, and an approach to management

Walter Osias[1] · George R. Matcuk Jr.[1] · Matthew R. Skalski[1] · Dakshesh B. Patel[1] · Aaron J. Schein[1] · George F. Rick Hatch[2] · Eric A. White[1]

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Abstract Symptomatic scapulothoracic disorders, including scapulothoracic crepitus and scapulothoracic bursitis are uncommon disorders involving the scapulothoracic articulation that have the potential to cause significant patient morbidity. Scapulothoracic crepitus is the presence of a grinding or popping sound with movement of the scapula that may or may not be symptomatic, while scapulothoracic bursitis refers to inflammation of bursa within the scapulothoracic articulation. Both entities may occur either concomitantly or independently. Nonetheless, the constellation of symptoms manifested by both entities has been referred to as the snapping scapula syndrome. Various causes of scapulothoracic crepitus include bursitis, variable scapular morphology, post-surgical or post-traumatic changes, osseous and soft tissue masses, scapular dyskinesis, and postural defects. Imaging is an important adjunct to the physical examination for accurate diagnosis and appropriate treatment management. Non-operative management such as physical therapy and local injection can be effective for symptoms secondary to scapular dyskinesis or benign, non-osseous lesions. Surgical treatment is utilized for osseous lesions, or if non-operative management for bursitis has failed. Open, arthroscopic, or combined methods have been performed with good clinical outcomes.

Keywords Snapping scapula · Scapulothoracic articulation · Scapulothoracic crepitus · Scapulothoracic bursitis

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✉ Eric A. White
Eric.white@med.usc.edu

1 Department of Radiology, Keck School of Medicine, University of Southern California, 1500 San Pablo Street, Second Floor Imaging, Los Angeles, CA 90033, USA

2 Department of Orthopedic Surgery, Keck School of Medicine, University of Southern California, Los Angeles, CA, USA

Introduction

The scapulothoracic articulation differs from other joints of the shoulder in that there is no capsule, cartilage, or a synovial lined joint. It is comprised of muscles and bursae that lie in between the scapula and thoracic wall that normally allow a smooth, gliding motion [1, 2]. Any disruption of this gliding motion can result in painful crepitus and/or bursitis [3]. While symptoms arising from disorders of the scapulothoracic articulation are relatively uncommon, when present, associated pain can range from mild to severe [3].

Patients who present with symptomatic scapulothoracic crepitus and bursitis, also known as snapping scapula syndrome, typically report a history of pain during overhead activities, overuse of the shoulder, or a single traumatic event [4]. Furthermore, patients describe the sensation of crepitus, or even audible or palpable crepitus, with active shoulder movement [4]. While scapulothoracic crepitus and bursitis may occur concomitantly, it is important to note that they can also occur independently, and that crepitus can also be otherwise asymptomatic [2]. Because a multitude of etiologies can present themselves as crepitus, it is important to identify the underlying cause so that the most optimal treatment is pursued.

The purpose of this article is to review the anatomy of the scapulothoracic articulation, discuss the different etiologies of scapulothoracic crepitus and bursitis, describe their appearances on imaging, and discuss the appropriate non-operative and operative management.

Anatomy

The scapula is a triangular shaped bone located approximately 5 cm lateral to the thoracic spinous processes and spanning from the second to the seventh ribs [3]. It is comprised of three borders—superior, axillary (lateral) and vertebral (medial)—and three angles (superomedial, inferomedial, and lateral) [2]. While the ventral surface of the scapula is typically concave, the osseous topography of the scapula is highly variable. Aggarwal et al. [5] found that the angle formed between the costal surfaces of the superior and inferior segments of the scapula, with the apex at the level of the root of the scapular spine and with imaginary lines projecting to the superomedial and inferomedial angles, ranged from 124 to 162°. The depth of the costal surface of the scapula ranged from 10.5 to 26.5 mm. Superomedial angle thickness ranged from 2 to 4 mm, while inferomedial angle thickness ranged from 5 to 8 mm. The variation of the scapula corpus (costal surface of the scapula below the scapular spine) has been categorized as either having a flat, S-shaped, or concave configuration [6]. The suprascapular notch is found at the proximal aspect of the lateral third of the superior scapular border. The transverse scapular ligament extends across the notch, with the suprascapular artery lying above and the suprascapular nerve coursing below the ligament [1]. The spinoglenoid notch lies below the lateral border of the scapular spine with the suprascapular nerve and artery passing through it [1].

Movement at the scapulothoracic articulation is dictated by the coordinated effort between several muscles since there is no direct bony attachment to the chest wall beyond the clavicle through the acromioclavicular and sternoclavicular joints. Therefore, dysfunction of any of these muscles can result in abnormal motion [7]. While a total of 17 muscles are known to attach to the scapula, several are directly involved at the scapulothoracic articulation [1]. Williams et al. [8] described three muscle layers that comprise the articulation: superficial, intermediate, and deep (Fig. 1). The superficial layer includes the trapezius, which inserts on the scapular spine; and the latissimus dorsi, which can sometimes attach to the inferior angle of the scapula. The intermediate layer consists of, from superior to inferior, the levator scapulae and the two rhomboids (rhomboid minor and rhomboid major), that insert on the medial border of the scapula. The deep layer is comprised of the serratus anterior, which originates from the ribs and inserts on the medial border of the scapula; and the subscapularis, which originates from the anterior surface of the scapula and inserts on the greater and lesser tuberosities of the humerus [9, 10]. The latter two muscles provide a cushion between the scapula and the thoracic wall during motion [1, 11].

A bursa is a synovial lined sac that reduces friction at either bone-tendon or tendon-tendon interfaces [12]. Two anatomic (major) and four adventitial (minor) bursae at the scapulothoracic articulation have been described [4, 11] (Fig. 2). The anatomic bursae are thought to be physiologic bursae that allow normal gliding of the structures within the scapulothoracic articulation and are routinely found on arthroscopy [3, 11]. These bursae include the infraserratus (scapulothoracic) bursa, which lies between the serratus anterior and chest wall; and the supraserratus (subscapularis) bursa, which is located between the subscapularis and the serratus anterior [1, 13].

Four adventitial bursae have been described and are not always found, as they are believed to be present in the background of abnormal gliding mechanics at the scapulothoracic articulation [11, 13]. Two of these bursae lie at the superomedial angle either superior or inferior to the serratus anterior. Another bursa is found at the inferior angle between the chest wall and the serratus anterior [11]. Finally, the fourth bursa (scapulotrapezial or trapezoid) has been reported to lie between the medial spine of the scapula and trapezius [11, 13].

Understanding of the neurovascular structures around the scapulothoracic articulation is important to minimize iatrogenic injury during imaging-guided intervention [3]. The spinal accessory nerve travels with the superficial branch of the transverse cervical artery along the central aspect of the

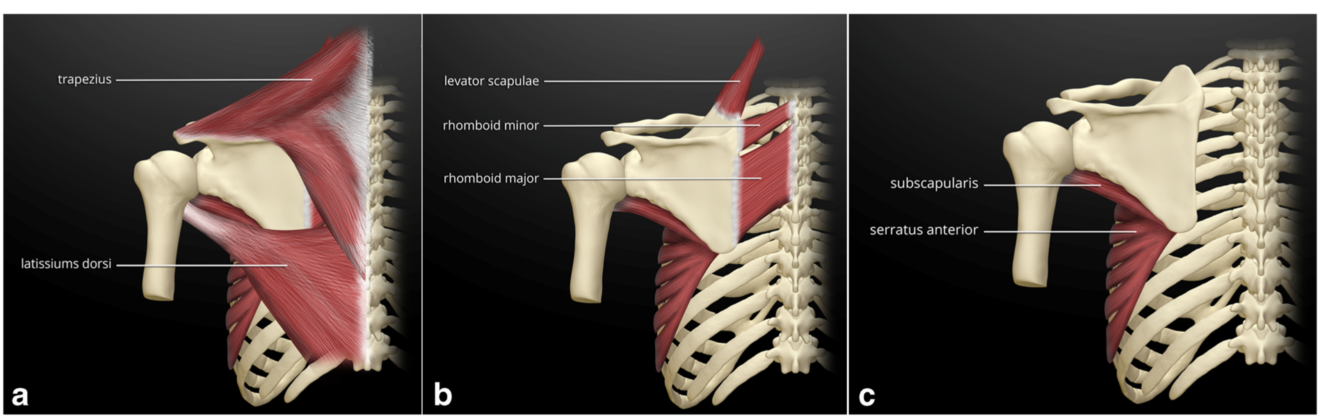

Fig. 1 Muscle layers of the scapulothoracic articulation. Posterior illustrations show the **a** superficial, **b** intermediate, and **c** deep musculature of the scapulothoracic articulation

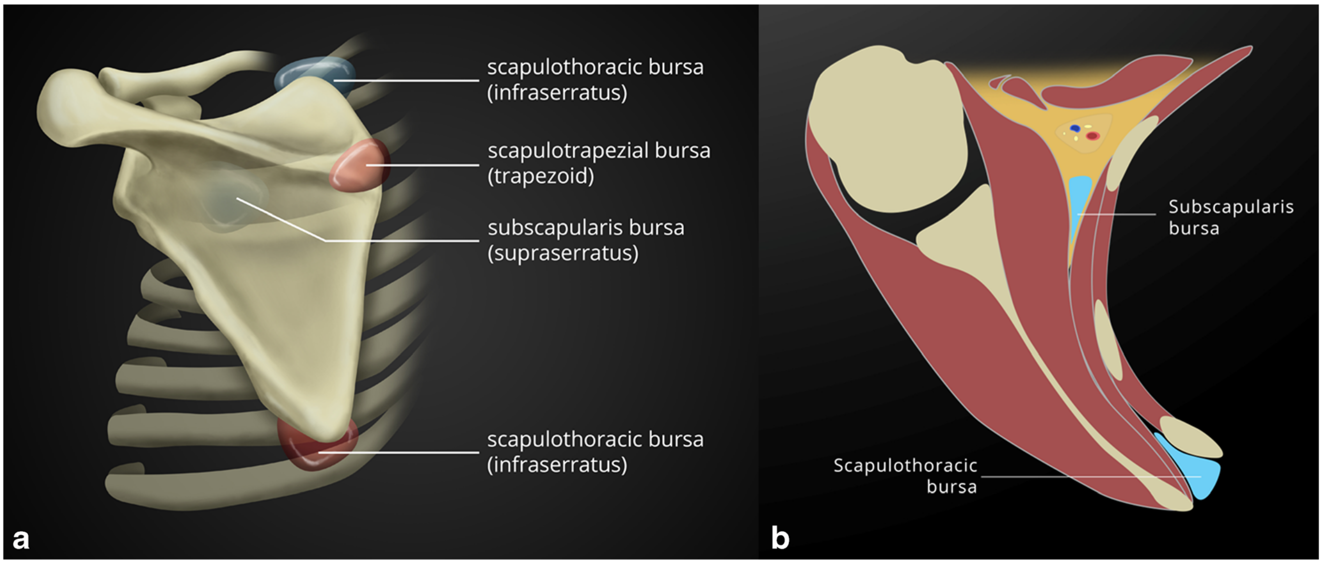

Fig. 2 Scapular Bursae. **a** Posterior and **b** axial illustrations of the scapula show the locations of the adjacent bursae

levator scapulae [14] and deep to the trapezius. The dorsal scapular nerve and artery lie deep to the rhomboid minor and major and courses approximately 1–2 cm medial to the vertebral border of the scapula. The long thoracic nerve courses along the anterior margin of the serratus anterior. Injury to this nerve is infrequent unless a more lateral approach is taken [14]. The suprascapular nerve originates from the upper trunk of the brachial plexus and courses toward the suprascapular notch with the suprascapular artery [3, 15].

Pathophysiology

Scapulothoracic crepitus occurs with there is disruption of the normal gliding of the concave surface of the scapula over the convex thorax [13]. A smooth, gliding motion at the scapulothoracic articulation is dependent on the normal function of the underlying muscles and intervening bursae rather than cartilage or a synovial lined joint. Therefore, causes of crepitus have been divided into abnormalities involving bursae, bones, muscles, and other space occupying soft tissues.

It is important to note that inflammation of the underlying scapulothoracic bursae can occur with or without the presence of a scapulothoracic crepitus. Any activity that causes repetitive movement of the scapula over the thoracic wall can irritate the underlying scapulothoracic bursae, leading to chronic inflammation, bursal fibrosis, and recalcitrant bursitis [3]. This could cause abnormal gliding of scapula that can result in symptomatic crepitus. Repetitive overhead motions in sports such as baseball or swimming have been reported to cause scapulothoracic bursitis [16]. Scapular dyskinesis, otherwise known as impaired scapular motion, can arise from nerve injury, muscle atrophy, glenohumeral instability, and rotator cuff pathology [7] that can ultimately result in scapulothoracic bursitis [17, 18]. Fujikawa et al. reported a case of scapulothoracic bursitis in response to chronic irritation between the scapula and a deformed thoracic wall after thoracoplasty [19].

Variations in scapular osseous anatomy causing abnormal gliding at the scapulothoracic articulation can contribute to symptomatic crepitus and bursitis. As mentioned previously, the angle formed between the costal surfaces of the superior and inferior segments of the scapula has been reported to range from 124 to 162°, with lower angles predisposing the patient to snapping [5]. Thus, forward bending of the upper segment of the scapula toward the thoracic wall may reduce the space at the scapulothoracic articulation and increase the likelihood of friction (Fig. 3). A so-called bare area of the

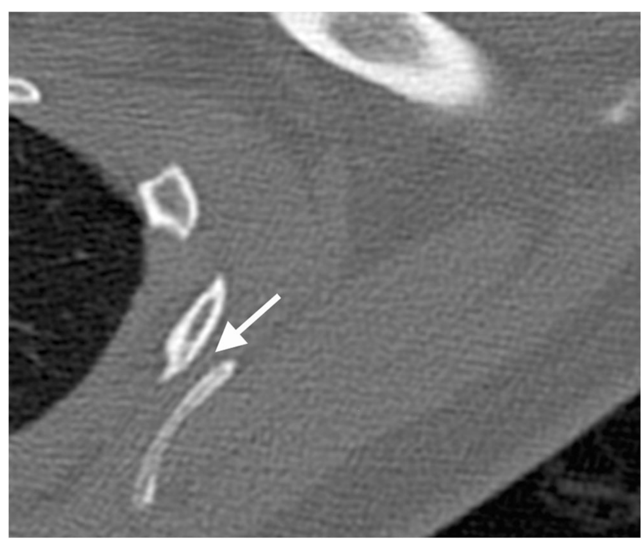

Fig. 3 Abnormal scapular superior angle curvature. 25-year-old female with left scapular pain and crepitus. Axial CT of the left shoulder demonstrates narrowing of the distance between the superomedial scapula and third rib with mass effect on the serratus anterior muscle (arrow)

scapula near the superomedial angle, where there is no underlying subscapularis muscle has also been a proposed cause [20]. An osseous prominence arising from the superomedial angle of the scapula called a Luschka's tubercle has been frequently described [21]. A 12-fold increased risk of symptomatic crepitus has been reported with two specific axial variations of the scapula corpus [6]. These include angulation of the scapula corpus toward the thorax, and a concave configuration that results in a decreased distance between the vertebral border and the thoracic wall. Other reported variants include hooking of the superomedial and inferomedial angle [22] and an anteriorly angulated teres major tubercle [23] .

Other osseous abnormalities, including those resulting from prior trauma (Fig. 9) or postsurgical changes have been described. Potential etiologies include malunion or callus from fractures of the ribs or scapula [24], and reactive bone spurs from partial avulsions secondary to prior injury or repetitive microtrauma [17]. Patients with prior first rib resection for thoracic outlet syndrome [25], as well as migration of rib fracture fixation devices [26] have been reported as causes of scapulothoracic crepitus. In addition, spinal deformities such as kyphosis and scoliosis can lead to crepitus as a result of abnormal angulation of the thoracic wall and the scapula [27].

Space occupying masses at the scapulothoracic articulation can lead to symptomatic crepitus and bursitis. Osteochondromas arising from either the anterior scapula or ribs have been frequently reported [2, 28, 29]. When a large osteochondroma causes widening of the scapulothoracic articulation, the term "pseudo-winging has been used [16]. Elastofibroma dorsi, a benign soft tissue growth thought to result from repetitive trauma, are usually found near the inferomedial angle of the scapula and can elevate the inferior scapula [16, 30]. These are more commonly found in women than men, and almost exclusively occur in patients over 40 years of age [31]. While there is a right-sided predilection, they have been reported to occur bilaterally in up to 60% of cases [32]. Elastofibroma

Fig. 4 22-year-old female with snapping scapula syndrome caused by an osteochondroma. **a** Scapular Y view shows an osseous excresence with cortical and meduallry continuity extending anteriorly from the body of the scaupla (arrows). **b** Post operative scapular Y view shows interval surgical resection with only a minimal excresence remaining (arrow). Pathology revealed an osteochondroma

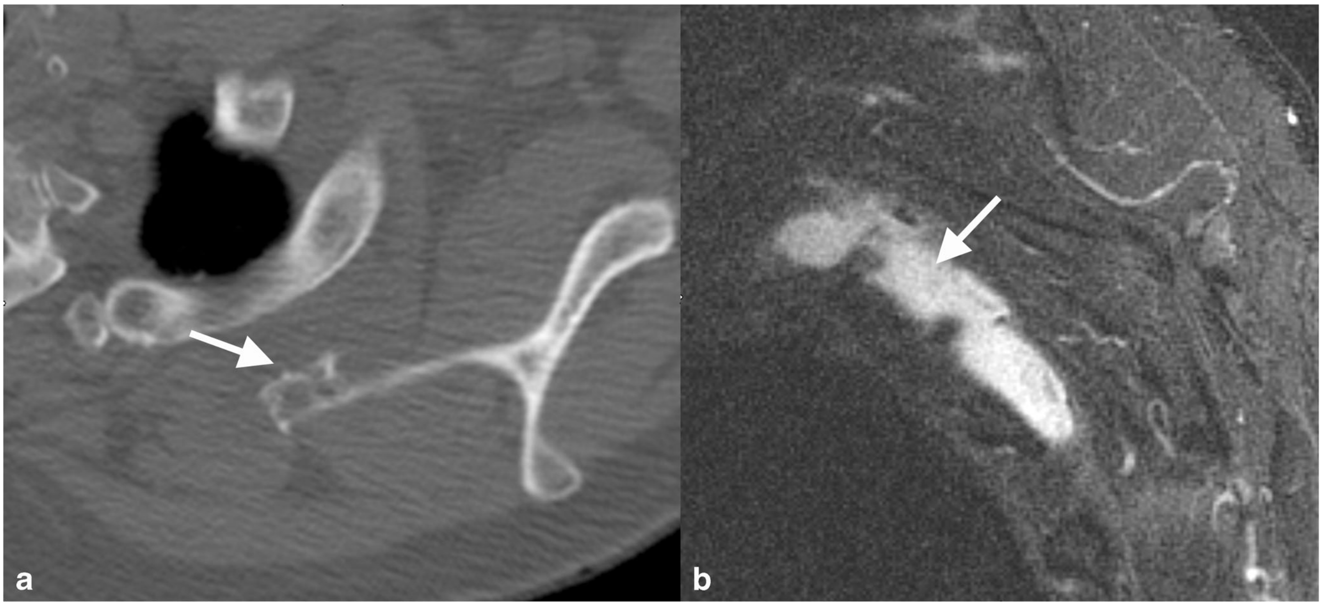

Fig. 5 Osteochondroma. 73-year-old male with shoulder pain. **a** Axial CT shows an osseous protuberance arising from the superior scapula (arrow) with resultant decreased scapulothoracic distance. **b** Sagittal oblique STIR sequence shows a lobulated fluid collection (arrow) between the chest wall and superior angle of the scapula consistent with scapulothoracic bursitis

dorsi may be a cause of snapping scapula or crepitus as clunking may be a symptom [33]. Scapular chondrosarcomas are a rare cause of symptomatic crepitus and bursitis occurring predominantly in older patients [34].

The stabilizer muscles of the scapula help to adequately position the glenohumeral fossa for overhead activities [13]. Therefore, any muscle abnormality can cause abnormal scapular motion leading to crepitus. Serratus anterior atrophy from long thoracic nerve palsy, subscapularis atrophy from glenohumeral fusion, and rhomboid and levator scapulae weakness have been reported as causes of crepitus [5, 13, 16, 25, 35]. Other reported causes include muscle fibrosis, and anomalous muscle insertions [16, 21, 35, 36]. A tight pectoralis minor can cause anterior tilting on the scapula via its insertion on the coracoid process, leading to abnormal friction between the thoracic wall and scapula [7, 13]. Posterior tilting as a result of arm elevation compresses the space between the inferior pole of the scapula and the rib cage [27].

Imaging

Plain radiographs are helpful as a screening modality to find osseous lesions that can potentially cause bursitis or snapping, such as osteochondromas (Fig. 4). A tangential view (Y-view), axillary, and anteroposterior view are obtained in the plane of the scapula [2, 13]. The threshold to obtain computed tomography (CT) or magnetic resonance imaging (MRI) is low, as pathologic etiologies or anatomic variations along the anterior

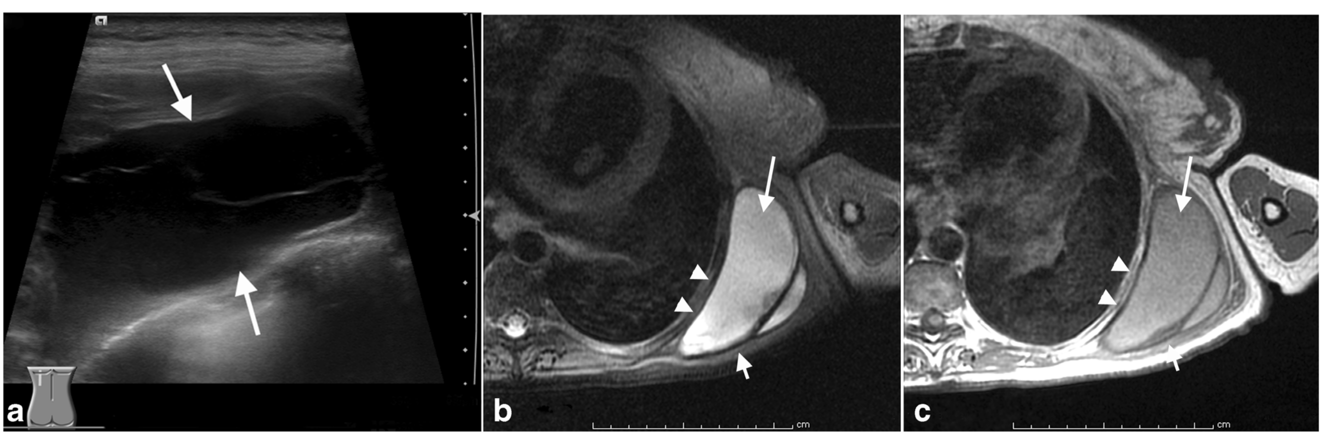

Fig. 6 Scapulothoracic bursitis. 51-year-old female with shoulder pain and a palpable abnormality. **a** Longitudinal ultrasound image shows anechoic fluid superficial to the chest wall and deep to the superficial musculature. **b** axial T2 FSE and **c** axial T1 images show shows hyperintense septated fluid signal (long arrows) deep to the serratus anterior muscle (short arrows) and superficial to the thoracic wall (arrowheads). The signal intensity represents hemorrhagic or proteinaceous material

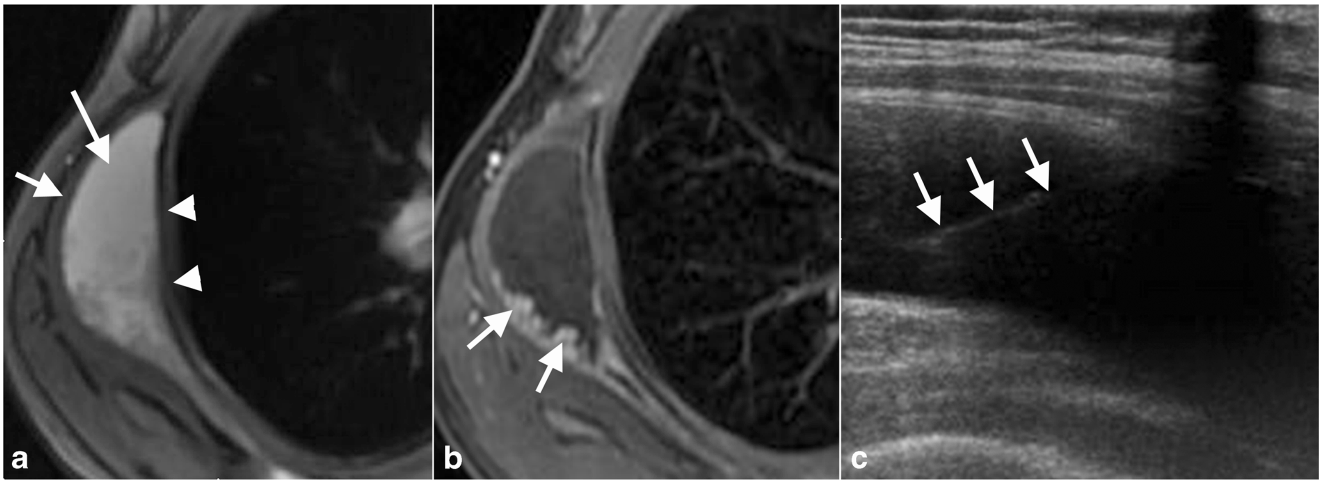

Fig. 7 Scapulothoracic bursitis. 23-year-old female with lupus presents with pain and palpable abnormality. **a** Axial T2 SSFSE sequence shows hyperintense fluid (long arrow) deep to the serratus anterior muscle (short arrow) and superficial to the chest wall (arrowheads). **b** Axial T1 fat saturation (FS) post contrast image shows irregular peripheral enhancement (arrows) consistent with synovitis. **c** Transverse ultrasound image obtained during needle (arrows) aspiration. The patient's pain decreased after the procedure, and cytology revealed synovial fluid

scapula can be difficult to identify on conventional radiography. CT scans, including three-dimensional reconstructions, provide better identification and characterization of osseous lesions [37] (Figs. 5 and 8). MRI provides better visualization of underlying soft tissues, including inflamed bursae or masses [2, 13, 16]; therefore, if osseous or soft tissue pathology or variants are suspected despite a normal appearing radiograph, CT or MRI should be considered [13].

There have been few cases of scapulothoracic bursitis with corresponding imaging correlation reported in the literature. The reported cases with CT correlation all demonstrated lesions at the scapulothoracic articulation with lower density than the surrounding muscle [19, 38–41]. The MRI characteristics reported in the literature have been variable. Some have reported well circumscribed lesions with predominantly bright signal on T2-weighted imaging (T2WI) either with [42] or without septations [11, 39, 43]. In a study that included four cases by Ken et al. [44], all of the lesions showed slightly hyperintense signal relative to the muscle on T1-weighted images, while three of the lesions demonstrated fluid-fluid levels on T2WI. Similar findings were reported by Higuchi et al. [41]. A thin rim of enhancement after the administration of gadolinium has been described [41, 42, 44]. A few sonographic features have also been reported. Seol et al. [43] reported a heterogeneous, cystic appearance with internal debris. One case [42] demonstrated a thick walled, cystic mass with intracystic papillary projections. In both these cases, the lesions were located between the serratus anterior and the thoracic wall. Five cases of scapulothoracic bursitis at our institution are shown in Figs. 5, 6, 7, 8 and 9. Imaging examples of elastofibroma dorsi, desmoid tumor, and spindle cell lipoma are shown in Figs. 10, 11 and 12 respectively.

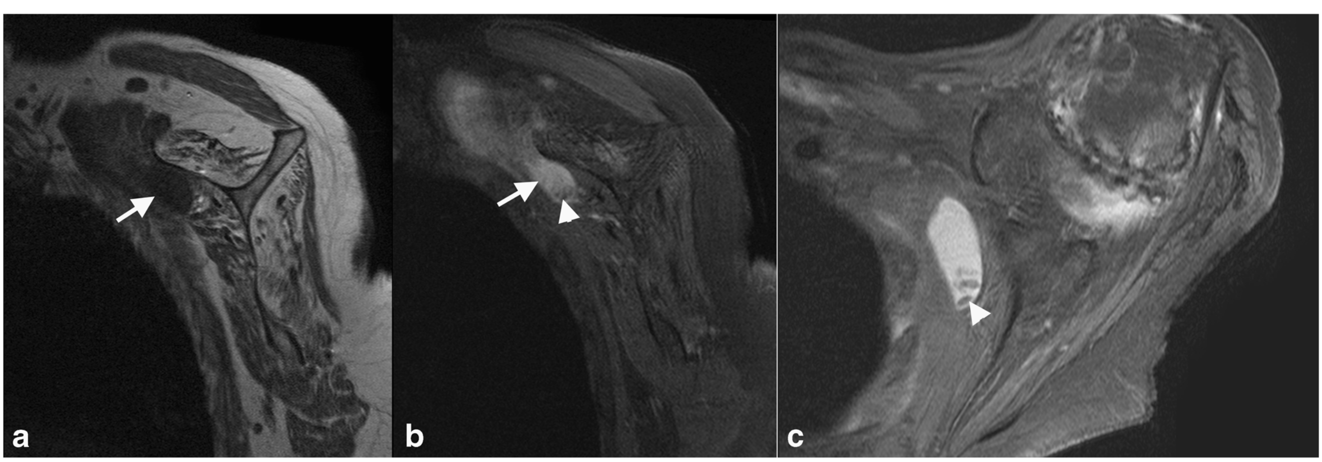

Fig. 8 71-year-old woman with advanced rheumatoid arthritis presenting with left shoulder pain with movement. Sagittal **a** T1, **b** sagittal STIR, and **c** axial PD FS images show subscapularis bursitis (arrows) with rice bodies (arrowheads)

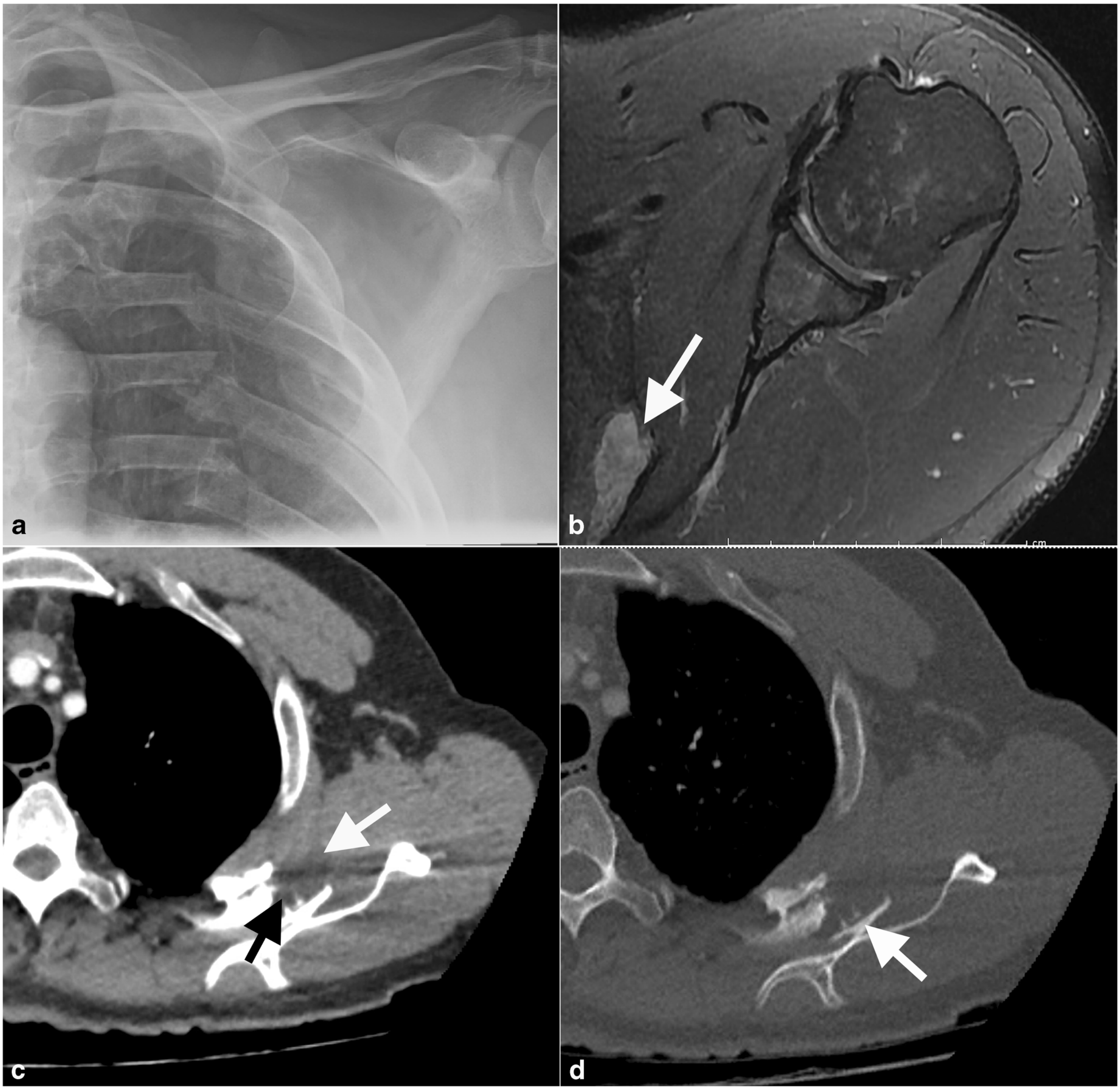

Fig. 9 48-year-old male with post traumatic scapulothoracic bursitis, presenting with a history of auto vs. pedestrian injury and left shoulder pain with movement. **a** PA radiograph of the chest shows multiple rib fracture deformities. **a** Axial PD FS image shows fluid signal (arrow) deep to the scapular body and superficial to the chest wall. **c**–**d** Axial CT images shows a water attenuation structure in this location (white and black arrows in **c**), with a fracture deformity of the scapular body (arrow in **d**)

Management

Conservative

Non-operative management is initially utilized in patients with scapular crepitus if the symptoms arise from altered posture, scapular winging, or scapulothoracic dyskinesis. While non-operative intervention can be attempted in patients with osteochondromas as the underlying cause, these patients are more likely to benefit from surgical resection [28]. Because the ultimate goal in treatment is for the patient to achieve a full functional recovery, physical rehabilitation involving strengthening of weak muscles and stretching of tight muscles about the scapula is used [27]. The primary function of the scapular muscles is to achieve static posturing of the shoulder girdle, therefore strength training exercises consisting of high repetition, low-intensity regimens should be emphasized [2, 27]. Attention is given to the subscapularis and serratus anterior in order to increase space between the chest wall and the scapula [11]. Furthermore, weakness in the serratus anterior

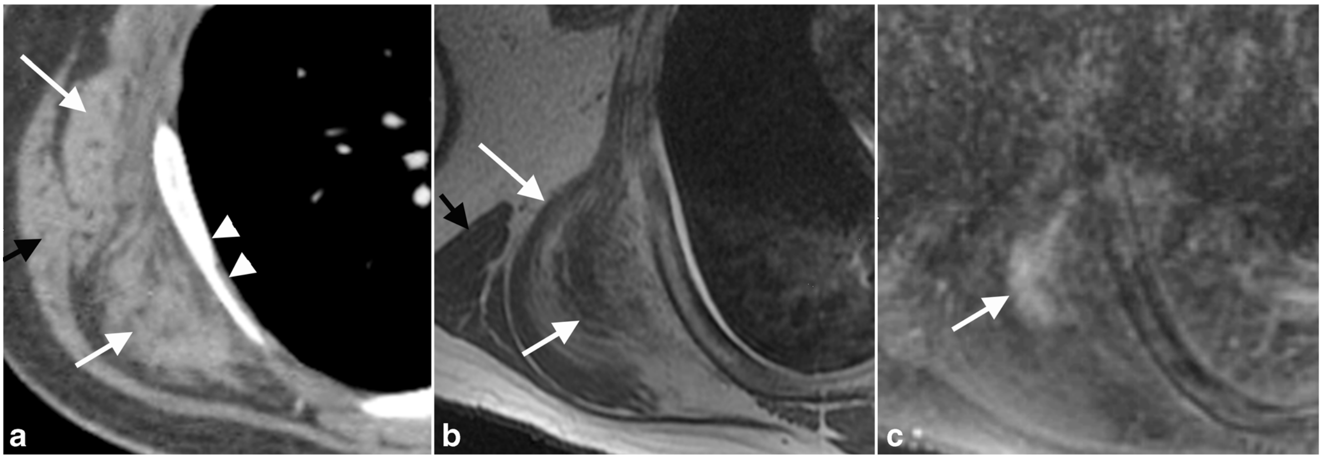

Fig. 10 49-year-old female with elastofibroma dorsi presents with left shoulder pain upon arm movement. **a** Axial CT and **b** Axial T1 MR images show a soft tissue lesion (arrow) with intervening linear areas of fat between the ribs (arrowheads) and serratus anterior (long arrow) and latissimus dorsi (black arrow) muscles. **c** axial T1 FS post contrast image shows mild enhancement of the lesion (arrow), consistent with elastofibroma dorsi

can cause forward tilting of the scapula [13]. Scapular adduction and postural shoulder shrug exercises strengthen scapular stabilizers including the serratus anterior, rhomboids, and levator scapulae [13]. Postural correction is also emphasized, with the goal of reducing kyphosis and achieving optimal movement at the scapulothoracic articulation [2, 11, 27]. Ice, heat, and ultrasound have been used, but with variable success [11].

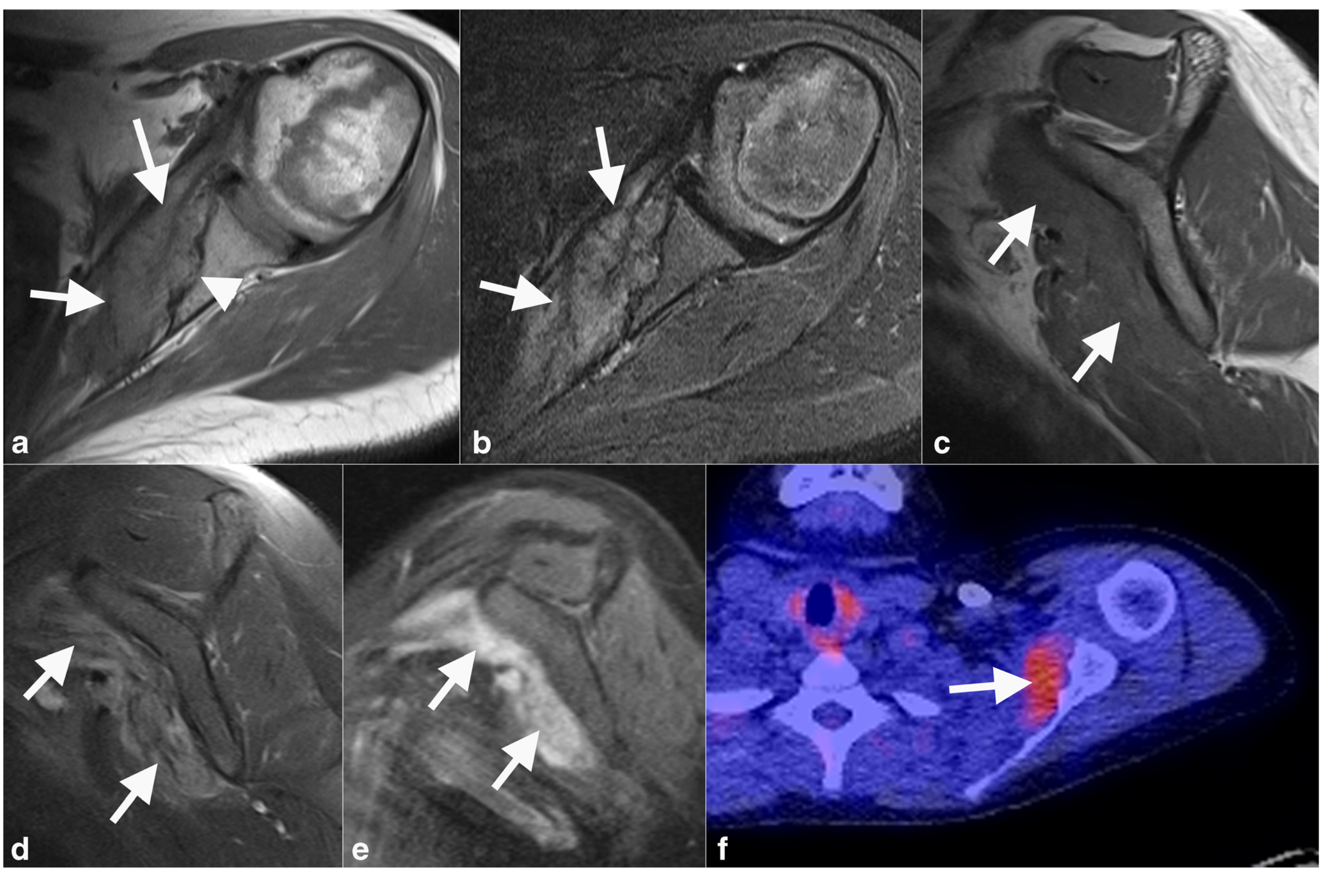

Fig. 11 13-year-old male with pathology confirmed desmoid tumor (fibromatosis) presenting with left shoulder pain with movement. Axial **a** TI and **b** STIR; **c** sagittal T1 and **d** STIR images show a lesion (arrows) deep to the subscapularis muscle which is mildly hyperintense on T1 and mildly hyperintense on STIR with respect to muscle. Note the scalloping of anterior scapular body (arrowhead in **a**). Sagittal T1 FS post contrast (**e**) image shows heterogeneous internal enhancement. Axial fused 18F-FDG PET/CT (**f**) image shows increased FDG activity (SUVmax = 2.5)

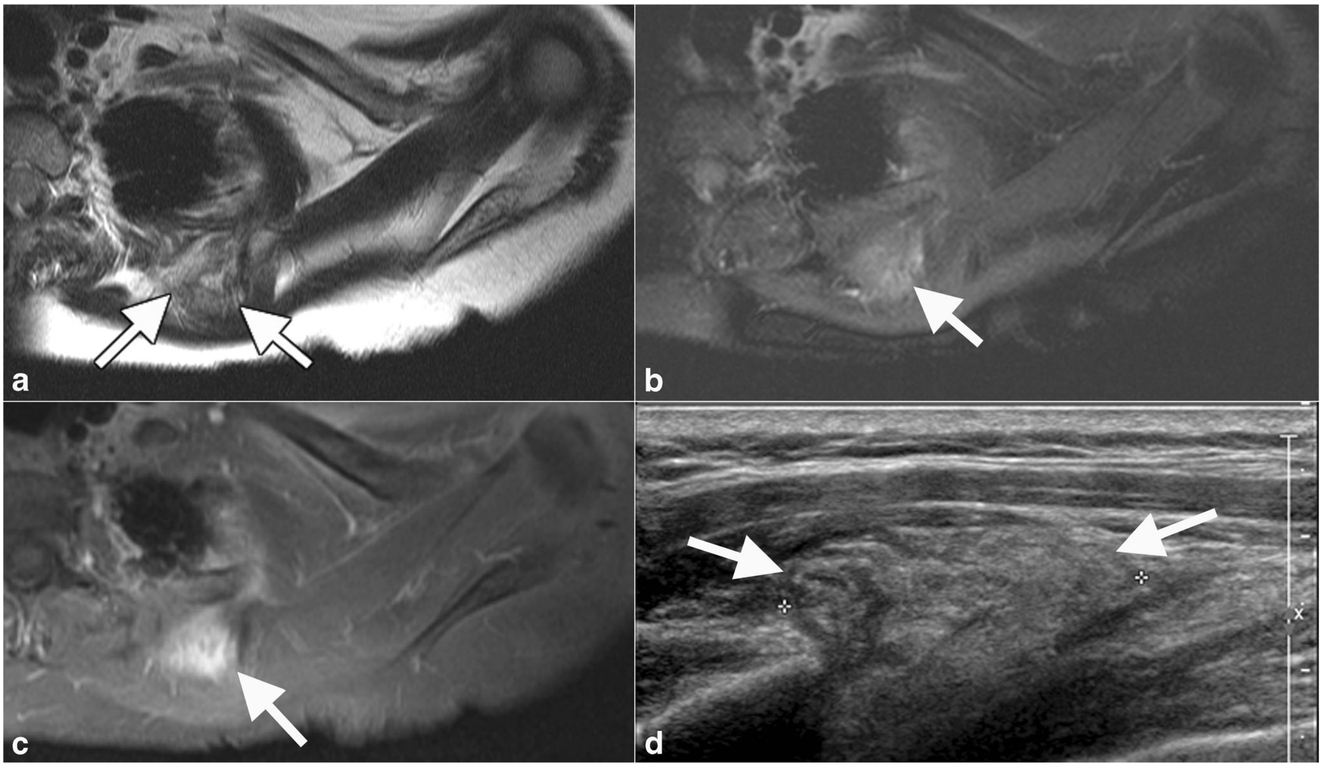

Fig. 12 54 year old female with pathology confirmed spindle cell lipoma presenting with left shoulder pain with movement. Axial **a** T1, **b** STIR, and **c** T1 FS post contrast images show a lesion which is deep to the trapezius muscle (arrows) which is hyperintense to muscle on T1 and STIR, with heterogeneous enhancement. **d** Transverse ultrasound image shows the lesion is mildly hyperechoic with respect to muscle

Image-guided interventions

For lesions that are partially or completely superficial to the scapula, ultrasound can be utilized to aspirate bursitis, or biopsy a solid lesion [45]. Advantages of ultrasound over fluoroscopy or CT include that it is nonionizing, low cost, portable, and its real-time imaging allows continuous observation of needle placement into the targeted area [46]. It is important to optimize image quality, and a linear array transducer (7.5–17 MHz) is typically utilized for scapulothoracic interventions as the anatomic region is superficial. With regards to needle choice, generally a small gauge needle (22 gauge) is used for injection, and a larger size (18 gauge) is used for aspiration [47]. For cases with debris or a fluid-fluid level on T2-weighted images, an 18-gauge needle can help prevent the debris from clogging the needle [44]. Core biopsies can be obtained with or without the use of an introducer. The introducer serves as a sheath and enables the user to obtain multiple core samples, minimize soft tissue damage, and contamination of tumor cells when multiple biopsies are performed [48].

Power or color doppler sonography is typically utilized prior to ultrasound-guided intervention to evaluate the vascular nature of the lesion [46]. When a soft tissue lesion has a portion with necrosis or hemmorhage, power doppler can help determine the viable portion of the lesion, which can provide a higher yield for diagnostic biopsies [49]. Before the procedure, a path to the lesion should be determined, which avoids vessels, nerves, or any structure that could be damaged [50]. Once a suitable point of entry is selected, a discussion with the orthopedic surgeon has been suggested, as the majority of surgeons would like to include the biopsy site in the surgical incision to avoid needle track recurrences [51]. Ultrasound-guided procedures can be performed in a prone or seated upright position with the humerus in internal rotation and the elbow flexed so that the dorsum of the hand lies superior to the thoracolumbar junction. This wings the scapula to increase the space at the scapulothoracic articulation. If the area of pain is at the inferior angle of the scapula, the needle is inserted along the inferomedial border of the scapula and directed laterally. If the area of pain is near the superomedial bursa, the needle is inserted near the superior angle of the scapula and directed 45° laterally in a craniocaudal dimension. The needle should be directed along the plane parallel to the scapular body and posterior chest wall to minimize risk of a pneumothorax [3]. An example of an ultrasound-guided aspiration of scapulothoracic bursitis is shown in Fig. 7.

Hodler et al. [52] proposed fluoroscopic guidance in order to ensure accurate needle placement within bursae; however, the authors also concluded that symptom relief was achieved in the area of pain even when the needle was not placed within a scapulothoracic bursa. Therapeutic corticosteroid injections have been used as an additional treatment option for scapulothoracic bursitis if symptoms persist despite nonsteroidal anti-inflammatory drugs and physical therapy [3, 4]. CT-guided aspiration, injection, or biopsy can be performed if the lesion is deep to the scapula, which would not allow visualization with ultrasound. To avoid bleeding that can result from any of the procedures, it is suggested to have the coagulation parameters within acceptable levels. An injection of corticosteroids is contraindicated when septic arthritis or bursitis is suspected [50].

Surgical management

Surgical management is typically reserved for patients with pain from impinging osseous structures, as well as failure of non-operative management for bursitis. The latter patients are considered for surgical bursectomy and/or superomedial angle resection [1]. This can be done with either an open, arthroscopic assisted, or all arthroscopic approach [1]. Despite the surgical approach used, most have resulted in good clinical outcomes [2, 3, 27]. In the open approach, after bursal excision is performed, the superomedial angle of the scapula can be resected to reduce crepitus and prevent recurrent bursitis [2].

The presence of a scapulothoracic mass requires the appropriate work up. If the underlying cause of scapulothoracic crepitus is from an osteochondroma or an elastofibroma, the surgical approach is usually determined by the size and location of the mass [2]. Pedunculated osteochondromas can be removed by arthroscopy, while sessile osteochondromas and elastofibromas can be resected by an open surgical approach [2].

Conclusion

Scapulothoracic crepitus and bursitis have the potential to cause significant shoulder dysfunction in many patients. It is important for the radiologist to understand the anatomy of the scapulothoracic articulation and the underlying osseous and soft tissue pathologies within this region. Imaging is an important adjunct to the physical examination for accurate diagnosis and appropriate management. Image-guided interventions, including aspiration, injection, and biopsy can help guide management. If non-operative interventions for scapulothoracic bursitis fail, surgical options including open, arthroscopic, or combined bursectomies with or without superomedial angle resections may provide symptomatic relief.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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