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Approach to the diagnosis of shoulder pain using physical exam and ultrasound: an evidence-based approach

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Abstract
Purpose of review The differentiation and diagnosis of shoulder pain is a complex process. Developing an evidence-based approach to shoulder pain can provide the clinician focused, validated physical exam maneuvers and imaging modalities to promote timely and accurate diagnosis. In this paper, we will attempt to provide an evidence-based approach to three common causes of shoulder pain (Subacromial impingement, rotator cuff pathology, and adhesive capsulitis) and the diagnostic strength of physical exam and ultrasound for these pathologies.
Recent findings The current body of literature shows a mixed landscape of evidence with regard to physical exam maneuvers. Musculoskeletal ultrasound is a well-validated tool in the evaluation of extra articular shoulder pathology and when combined with plain film radiographs may be sufficient to characterize a majority of shoulder pathology.
Summary Developing an evidence-based approach to the evaluation of shoulder pain helps to focus the physical exam, imaging, and eventual management. The current literature shows no single exam maneuver as being perfectly sensitive or specific for differentiating pathology. Utilizing selected combinations of physical exam tests that individually provide either high sensitivity or specificity may yield a more targeted diagnosis. Additionally, incorporating MSK-US as a routine extension of the physical exam can expedite diagnosis and allow for the timely initiation of appropriate treatments.

Keywords Shoulder · Ultrasound · Physical exam · Evidence-based · Impingement · Rotator cuff

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Introduction

Shoulder pain is common, but the complexity of the shoulder joint frequently creates a diagnostic challenge for clinicians trying to identify the source of pain. As the most mobile joint in the body, the shoulder has a wide variety of physical exam maneuvers and tests designed to help the clinician isolate shoulder pathology. Therefore, the current challenge from the clinician's perspective is to understand which physical exam test(s) can provide sensitive and specific data to diagnose shoulder pathology. Much of the literature formally evaluating these exam maneuvers is of moderate to low quality, but still provides valuable information on how to interpret these exam results [1]. In addition to the physical exam, point-of care diagnostic musculoskeletal ultrasound has evolved as a useful and powerful tool for both diagnosis and treatment of shoulder pain. In this paper, we will provide an evidence-based approach to three common causes of shoulder pain and the strength of evidence for use of physical exam and ultrasound to diagnose these pathologies. We chose to examine the diagnoses of subacromial impingement, rotator cuff tear, and adhesive capsulitis given the high incidence and prevalence of these conditions. Together, these three causes of shoulder pain account for the majority of incident shoulder pain in a community-based setting [2].

Subacromial Impingement Syndrome

Subacromial impingement syndrome is a process whereby soft tissue structures within the shoulder are degraded due to repetitive abnormal compressive or shearing forces resulting in pain and overall shoulder dysfunction. Subacromial impingement is described as periarticular shoulder pain due to repetitive entrapment of soft tissue structures within the subacromial space leading to tendinopathy, rotator cuff tears, and bursitis. The kinematics of impingement are complex, and pathology may arise due to variations in scapular morphology, narrowing of the subacromial space, trauma, joint laxity, humeral elevation, and scapular dyskinesis [3]. This creates a complex diagnostic scenario for clinicians attempting to interpret physical exam findings that often represent the strain, compression, and contortion of numerous structures [3].

Physical exam evidence

When there is a suspicion for impingement, the examiner should begin with evaluation of scapular positioning and mechanics, since scapular dyskinesis may be a contributing factor to impingement syndrome [4]. A typical dyskinetic pattern observed in impingement is early upper trapezius activity (shoulder shrug), late or poor lower trapezius activation, and decreased serratus anterior activity (scapular winging), which grossly results in poor acromial elevation [3].

If dyskinesis is present, the examiner should attempt dynamic corrective maneuvers such as the scapular assistance test (SAT) to determine the impact of scapular dyskinesis on pain symptoms. The SAT is performed by manually stabilizing the scapula and rotating the inferior border of the scapula superolaterally as the patient forward flexes their arm. This assistance simulates the force couple of the serratus anterior and lower trapezius in normal scapular motion. Reduction of pain indicates a positive test and is a positive indicator that scapular rehabilitation may improve symptoms [5].

Scapular protraction can be a static or dynamic finding whereby there is poor upward acromial elevation and rotation due to excessive scapular internal rotation and anterior tilt [5]. If protraction is observed, the practitioner should also evaluate for pectoralis minor restriction, which may prevent posterior tilt and external rotation of the scapula [5]. It has been well documented that forward head posture and increased thoracic kyphosis may lead to scapular protraction with shortening of the pectoralis minor and the short head of the biceps [3]. Additionally, the rotator cuff is more prone to entrapment beneath the acromion between 0 and 70° of arm elevation [3]. At 90° of humerothoracic elevation, the acromiohumeral space is significantly reduced, although at this elevation, the supraspinatus tendon is thought to have cleared the undersurface of the acromion [3]. Consequently, pain is produced with arm elevation beyond 90° may be due to bursal irritation and not the rotator cuff [3].

Many special tests have been evaluated to diagnose impingement syndrome. However, many of these tests have relatively low sensitivity and specificity (Table 1). Several studies have shown that in isolation these tests are weak diagnostic tools, but when interpreted in combination yield stronger diagnostic accuracy [1]. A 2012 systematic review and meta-analysis concluded that there was no single test that was both sensitive and specific for subacromial impingement syndrome. In contrast, a combined sensitivity of 75% and specificity of 74% was achieved in the setting of positive results from three or more of the following maneuvers: Hawkins-Kennedy, Neer, Painful Arc, Empty can, or resisted-external rotation [1, 11]. The review concluded that the Hawkins-Kennedy had the strongest summary sensitivity, but it was merely on the sensitivity threshold (80%) for assisting in ruling out subacromial impingement. Due to its poor specificity, this test has little effect on post-test probability to rule out subacromial impingement when negative [11].

Ultrasound evidence

Musculoskeletal ultrasound (MSK-US) may provide valuable information in the diagnosis of impingement syndrome. Ultrasound provides static and dynamic visualization of important structures and their biomechanical relationships. Important structures include the lateral third of the acromion, the subacromial/subdeltoid bursa (SASD), supraspinatus tendon, and the head of the humerus. Ultrasound findings thought to be associated with impingement include bunching of the supraspinatus tendon and/or SASD bursa beneath the acromion during abduction, bursal thickening, and bursal distention. To date, there have been few studies evaluating the diagnostic accuracy of dynamic ultrasound for impingement syndrome. One study by Read et al. reported an overall sensitivity and specificity of 81 and 91%, respectively, with a positive predictive value of 0.91 when compared to clinical diagnosis [12]. The same study also noted that bunching of the bursa was the most commonly observed finding thought to be indicative of impingement, though it was commonly seen on the asymptomatic side [12].

Though potentially indicative of pathology, abnormal ultrasound findings involving bursal thickness and bunching may also be seen in asymptomatic individuals. Daghir et al. observed bunching and thickening of the SASD bursa in both patients with a clinical diagnosis of impingement syndrome and normal controls [13]. This study reported no statistical difference (p = 0.72) in the mean increase in SASD bursal thickness following arm abduction in symptomatic (0.39 ± 0.41 mm) and asymptomatic controls (0.35 ± 0.32 mm) [13]. A more recent study by Bouju et al. supported these results by finding no correlation between

Table 1 Reported values of sensitivity and specificity of physical exam maneuvers for subacromial impingement syndrome

Test	Author	Sensitivity	Specificity
Empty can	Kelly [6]	52%	33%
	Kelly [6]	52%	67%
	Silva [7]	74%	30%
Full can	Kelly [6]	35%	25%
	Kelly [6]	45%	75%
Hawkins-Kennedy	Kelly [6]	74%	50%
	Michener [8]	63%	62%
	Silva [7]	74%	40%
	Fodor [9]	72%	89%
	Salaffi [10]	64%	71%
Neer's	Kelly [6]	62%	10%
	Michener [8]	81%	54%
	Silva [7]	68%	30%
	Fodor [9]	54%	95%
Painful arc	Kelly [6]	49%	33%
	Michener [8]	75%	67%
	Fodor [9]	67%	80%
Patte's	Silva [7]	58%	60%
Resisted abduction	Kelly [6]	55%	75%
	Kelly [6]	38%	50%
	Silva [7]	58%	20%
Resisted external rotation	Kelly [6]	33%	90%
	Michener [8]	56%	87%
Yocum	Silva [7]	79%	40%
	Fodor [9]	70%	92%

Empty can test Shoulder abducted with slight adduction and internal rotation with isometric resistance causing pain or weakness

Full can test Shoulder abducted with slight adduction and external rotation with isometric resistance causing pain or weakness

Hawkings-Kennedy test Pain caused by maximal internal rotation with the arm forward flexed to 90° and elbow flexed to 90°

Neer's test With scapula stabilized and the arm internally rotated. Pain with passive forward flexion of arm above head

Patte's test Patient standing with arm in 90° of abduction in the scapular plane and 90° external rotation with elbow flexed 90°. Pain or weakness with isometric resistance of external rotation

Yocum test The patient's hand is placed on the opposite shoulder with the elbow flexed and anterior to the body. Pain is produced with forward flexion of the arm toward the patients face

Painful arc test Active abduction with pain reproduced between 70 and 120°

ultrasound findings and the efficacy of a local anesthetic injection into the SASD bursa [14]

In contrast to bursal thickening and dynamic bunching, SASD bursal distention may be a better indicator of symptomatic shoulder impingement. In a review by Henderson et al. shoulder ultrasound had high diagnostic value for subacromial bursitis [15]. A study by Ottenheijm et al. reported that MSK-US had a sensitivity and specificity of 79–81 and 94–99%, respectively, when compared to arthroscopy or MRI when detecting bursitis [16]. Similarly, Le Corroller et al. showed a sensitivity and specificity of 96% and 90%, respectively, when compared to MRA [17]. All of these studies reported similar criteria of bursal thickening, fluid accumulation, and distention as consistent findings with SASD bursitis [16, 17]. Finally, a recent study by Lee et al. reported better outcomes of pain and function following ultrasound guided subacromial corticosteroid injection in patients with bursal thickening (>2 mm when measured from the peribursal fibrofatty tissue to the upper margin of the supraspinatus) or bursal effusion (>2 mm measured effusion) when compared to normal controls [18]

Rotator cuff tears

The rotator cuff is a common location of shoulder pathology that may or may not cause shoulder pain. Diagnosing a symptomatic rotator cuff tear may pose a challenge given the increased prevalence of cuff pathology with older age [19]. A study by Yamamoto et al. reported 25% of patients older than age 60, and 50% of patients older than age 80 were found to have a rotator cuff tear [20]. Degenerative rotator cuff tears commonly occur in the supraspinatus and infraspinatus in an anterior to posterior distribution. [21]. A recent study by Kim et al. showed that the majority of both full- and partial-thickness tears were located more posteriorly (approximately 15 mm posterior to the biceps tendon) near the junction of the supraspinatus and infraspinatus [22].

The presence of a degenerative rotator cuff tear does not always correlate with shoulder pain. For instance, in one study, 50% of patients age 66 or older diagnosed with a symptomatic rotator cuff tear were found to have a tear on the contralateral asymptomatic side [23]. Both symptomatic and asymptomatic cuff tears also have a high likelihood of progression. In one recent cohort of 224 patients, roughly 50% of rotator cuff tears progressed by at least 5 mm in any direction at a mean of 2.8 years since initial evaluation. Full-thickness tears were more likely to progress (61%) than partial-thickness tears (44%). Pain was a significant predictor of tear progression ($p < 0.05$), and 46% of patients developed new pain during the study. In patients with tear progression and pain, the most significant functional change was the loss of shoulder abduction and external rotation strength [24].

Physical exam evidence

The diagnosis of rotator cuff pathology by physical exam alone can be challenging. The current literature shows a spectrum of sensitivity and specificity values for commonly used "special tests." This heterogeneity of results is partly due to the challenge of isolating movement within the rotator cuff.

The supraspinatus muscle is very difficult to isolate given the co-activation of the deltoid. Several studies have looked at deltoid and supraspinatus activity with varying degrees of shoulder abduction and found the supraspinatus to be more active between 0 and 30° of abduction. An older study by Colachis et al. demonstrated that following axillary and suprascapular nerve blocks, the supraspinatus was responsible for virtually all arm abduction strength when measured at 30°, and the deltoid was the primary shoulder abductor when measured at 90° [25]. An MRI study by Ruckstuhl demonstrated that the supraspinatus is at a mechanical disadvantage when compared to the deltoid with increasing shoulder abduction, and that internal rotation decreased the biomechanical advantage of the supraspinatus [26]. Finally, a recent study by Chalmers et al. demonstrated through electromyographic (EMG) evaluation of healthy subjects that the "champagne toast" position (30° of abduction, mild external rotation, 30° of shoulder flexion, and 90° of elbow flexion) provides five-fold better supraspinatus isolation from the deltoid than Jobe's position (90° abduction and maximal internal rotation) [27]. There have been no formal studies to date validating the clinical utility of the champagne toast position although it presents a unique consideration for further research.

As for the other components of the rotator cuff, an EMG study by Jenp et al. showed that subscapularis activation was the greatest with the arm in the scapular plane at 90 degrees of elevation and neutral humeral rotation. The infraspinatus and teres minor muscles were isolated with the arm in the sagittal plane and the humerus elevated to 90° in mid-range of external rotation. This is also referred to as the "hornblower's position" [28]. Additionally, the infraspinatus had the highest level of activity with the elbow adducted to the body and resisted external rotation. During resisted external rotation, the supraspinatus was active as well, confirming the role of the supraspinatus as a "centering" force for the humeral head [28].

The current evidence of shoulder exam special testing with regard to rotator cuff pathology presents a landscape of mixed results. Similar to impingement syndrome, there is no single exam maneuver that has been shown to be completely diagnostic for rotator cuff pathology. In reviewing the current literature (Table 2), we can conclude that the combination of several tests may improve diagnostic accuracy. For supraspinatus tears, the empty can and full can tests have a combined sensitivity range of 76–87% and specificity of 39–53% [28, 29]. The painful arc has a reported sensitivity of 96%, and the external rotation lag sign has a specificity of 94% [28, 31, 32]. With regard to supraspinatus tendinopathy, when the empty can test produced pain or weakness, it held a sensitivity range of 72–90% and a specificity range of 37–50% across all reviewed studies. The drop arm test held the highest sensitivity for supraspinatus tendinopathy at 93%.

Three tests have demonstrated utility when identifying pathology of the infraspinatus. For the diagnosis of infraspinatus tears, pain with resisted external rotation showed high sensitivity, but low specificity (84 and 53%), and the external rotation lag sign was highly sensitive and specific for infraspinatus tears (97 and 93%), respectively. Additionally, a positive Patte's test (pain or weakness with isometric resistance of external rotation) held a specificity of 95% for tears [30]. Patte's test also showed utility when diagnosing infraspinatus tendinopathy with a sensitivity range of 62–71% and a specificity range of 73–90% among reviewed studies [10, 30, 34]. Finally, two special tests should be considered when evaluating the subscapularis for tendinopathy. The belly-off tests have the highest combined sensitivity and specificity (86 and 91%), and the lift off test have a specificity range of 48–84% (median of 79%) [10, 30, 34, 36]. With regard to subscapularis tears, the internal rotation lag sign has strong sensitivity and specificity (100 and 84%), and the lift off test is highly specific (95%), but poorly sensitive (50%) [30, 32].

Ultrasound evidence

Ultrasound has consistently demonstrated high sensitivity and specificity in the diagnosis of rotator cuff tears. Although the current imaging gold standard for the diagnosis of both partial and full thickness rotator cuff tears is an MR arthrogram, the literature shows that MSK-US is comparable to MRI in both sensitivity and specificity [38]. A recent 2015 meta-analysis by Henderson et al. concluded that MSK-US is indicated for any rotator cuff tear although it is less sensitive for ruling out partial thickness tears than full thickness tears [15]. MSK-US has an average sensitivity and specificity of 69 and 94% in the diagnosis of partial thickness rotator cuff tears when compared to MRI, MRA, arthroscopy, and open surgery (Table 3) [16, 38–41] [17]. A similar series of studies examining the use of MSK-US to diagnose complete rotator cuff tears compared to MRI, MRA, arthroscopy, and open surgery showed an average sensitivity and specificity of 92 and 94%, respectively (Table 3) [15]. With respect to location, a majority of degenerative rotator cuff tears began within the supraspinatus tendon approximately 15 mm posterior to the biceps tendon. Less than 33% involve the anterior edge of the supraspinatus tendon [24].

MSK-US also has good evidence for the diagnosis of rotator cuff tendinopathy. A review by Ottenheijm et al. reported a range of sensitivity from 67 to 93% and specificity ranging from 88 to100% for MSK-US when compared to MRA, MRI, and arthroscopy. The discrepancy in the sensitivity numbers was felt to be due to out-dated ultrasound technology used in earlier studies [16]. The use of ultrasound for the evaluation of rotator cuff pathology may also be a more cost effective approach to shoulder pain than MRI. A retrospective study by Sheehan et al. used advanced imaging guidelines to assess

Table 2 Sensitivity and specificity of physical exam maneuvers by rotator cuff pathology

Pathology	Exam maneuver	Study	Sensitivity (%)	Specificity (%)
Supraspinatus tear	Drop arm test	Bak [29]	41	83
	Drop sign		45	70
	Empty can	Itoi [30]	78	40
		Itoi [30]	87	43
		Itoi [30]	80	50
		Bak [29]	76	39
	Full can test	Itoi [30]	80	50
		Itoi [30]	83	53
	External rotation lag sign	Bak [29]	45	91
		Castoldi [31]	56	98
		Miller [32]	46	94
	Hawkins-Kennedy	Bak [29]	77	26
	Neer	Bak [29]	60	35
	Painful arc	Bak [29]	96	4
Supraspinatus tendinopathy	Drop arm	Chew [33]	24	93
	Empty can	Chew [33]	83	49
		Kim [34]	72	45
		Naredo [35]	79	50
		Goyal [36]	90	37
	Hawkins-Kennedy	Chew [33]	87	32
	Painful Arc		71	81
	Full can	Chew [33]	75	68
	Neer	Chew [33]	64	61
Infraspinatus tear	External rotation lag sign	Castoldi [31]	97	93
	Patte's test	Naredo [35]	36	95
	Resisted ER	Itoi [30]	84	53
Infraspinatus tendinopathy	Resisted ER	Goyal [36]	50	100
	Patte's test	Kim [34]	63	73
		Salaffi [10]	62	74
		Naredo [35]	71	90
Subscapularis tendinopathy	Belly-off	Bartsch [37]	86	91
	Belly press	Bartsch [37]	80	88
	Internal rotation lag sign	Bartsch [37]	71	60
	Lift off test	Bartsch [37]	40	79
		Naredo [35]	50	84
		Kim [34]	69	48
		Salaffi [10]	35	75
Subscapularis tears	Lift off test	Naredo [35]	50	95
	Internal rotation lag sign	Miller [32]	100	84

Drop arm test Shoulder passively abducted to 90°. Patient then actively lowers the arm to their side. Positive is inability to lower in a controlled fashion

External rotation lag sign The shoulder is abducted and elbow flexed to 90° with maximal external rotation. The patient must maintain this position after the practitioner releases the arm. Positive test is inability to maintain this position

Internal rotation lag sign The arm is brought into maximal internal rotation behind the back. The elbow wrist/hand is passively brought into 20 degrees of extension. The patient must actively maintain this position as examiner releases the wrist but maintains support at the elbow. A lag is indicative of a subscapularis tendon tear

Empty can Shoulder abducted with slight adduction and internal rotation with isometric resistance causing pain or weakness

Full can test Shoulder abducted with slight adduction and external rotation with isometric resistance causing pain or weakness

Belly off test Inability of the patient to maintain the palm of the hand attached to the abdomen with the arm passively brought into flexion and internal rotation

Belly press test The examiner places a hand on the abdomen so that the he or she can feel how much pressure the patient is applying to the abdomen. The patient places his or her hand on the examiner's hand and pushes into the stomach while attempting to bring the elbow forward in the scapular plane. A positive test is pain or weakness

Lift off test The arm is brought into maximal internal rotation behind the back. The patient then lifts his hand away from the back. Positive is weakness or pain

Hawkins-Kennedy test Pain caused by maximal internal rotation with the arm forward flexed to 90° and the elbow flexed to 90°

Neer's test With scapula stabilized and the arm internally rotated. Pain with passive forward flexion of the arm above the head

Patte's test Patient standing with arm in 90° of abduction in the scapular plane and 90° external rotation with elbow flexed 90°. The test is positive with pain or weakness with isometric resistance of external rotation

Yocum test The patient's hand is placed on the opposite shoulder with the elbow flexed and anterior to the body. Pain is produced with forward flexion of the arm toward the patient's face

Painful arc Active abduction with pain reproduced between 70 and 120°

order appropriateness of 237 shoulder MRI studies and found that ultrasound could have been the indicated imaging modality for 157 (66%) of cases. They also found that most cases (133/157; 85%) could have had all relevant pathologies identified with ultrasound combined with radiographs. Regardless of indicated modality, ultrasound could have characterized 80% of all cases ordered by nonorthopedic providers and 50% of cases ordered by orthopedic specialists ($P = .007$) [44].

Adhesive capsulitis

Adhesive capsulitis or "frozen shoulder," is a debilitating condition of the shoulder that affects women more than men typically over the age of 40 [45]. The pathogenesis of adhesive capsulitis is due to thickening and contraction of the glenohumeral joint capsule causing shoulder restriction and pain. The pathophysiology of adhesive capsulitis is largely unknown, although typical findings include synovial hypervascularization and proliferation with deposition of collagen resulting in the formation of capsular adhesions [46]. Common risk factors include immobilization, trauma, diabetes, and thyroid disease. Less common risk factors include cerebral palsy, hemiplegia, cervical dystonia, hypercholesterolemia, inflammatory lipoproteinemia, and hemorrhage [47]. Adhesive capsulitis can be classified as primary, where there is no identifiable cause, and secondary, where adhesive capsulitis can be linked to an event such as hemiplegia [48].

Table 3 Sensitivity and specificity of MSK-US in the diagnosis of partial and full thickness rotator cuff tears

Author	Year of study	Reference standard	Sensitivity	Specificity
Partial thickness rotator cuff tears				
Lenza [39]	2013	Arthroscopy or open surgery	52%	93%
Smith [40]	2011	Arthroscopy or open surgery	84%	89%
Ottenheijm [16]	2010	Arthroscopy or MRI	72%	93%
Kelly [41]	2009	MRI	67%	94%
De Jesus [38]	2009	Arthroscopy or Surgery	67%	94%
Le Corroller [17]	2008	MRA	71%	98%
Full thickness rotator cuff tears				
Lenza [39]	2013	Arthroscopy or open surgery	92%	93%
Alavekios [42]	2013	MRI	95%	90%
Murphy [43]	2013	Arthroscopy	90%	97%
Smith [40]	2011	Arthroscopy or open surgery	96%	93%
Ottenheijm [16]	2010	Arthroscopy or MRI	95%	96%
Kelly [41]	2009	MRI	87%	96%
De Jesus [38]	2009	Arthroscopy or surgery	92%	94%
Le Corroller [17]	2008	MRA	91%	91%

Physical exam evidence

The physical exam of frozen shoulder is far more apparent in the later phases than the initial onset as most patients will present with impaired glenohumeral abduction and external rotation [48]. However, in the early stage of the disease, pain is the primary complaint, and range of motion may be relatively normal. The "freezing" phase can last 10 to 36 weeks and is typified by pain, gradual loss of both active and passive shoulder range of motion, and difficulty sleeping on the affected side. The "frozen" stage lasts 4–12 months with less pain, but severe stiffness is causing loss of up to 80% of shoulder motion (external rotation and abduction). Flexion, extension, and horizontal adduction motions are relatively preserved. The final "thawing" phase may persist for years though it typically spans 12 to 42 months during which stiffness improves and functional range of motion increases [49]. In total, the full course of uncomplicated primary adhesive capsulitis usually lasts between 12 and 24 months.

Ultrasound evidence

The current literature supports the use of MSK-US for diagnosing adhesive capsulitis. The ultrasound examination should focus on the rotator interval looking for coracohumeral ligament thickening with hypoechoic echotexture and increased signal on power Dopper [48]. A study by Homsi et al. showed the coracohumeral ligament was nearly three times larger (3 vs. 1.34 mm) in patients with adhesive capsulitis when compared to asymptomatic controls [50]. A 2005 study by Lee et al. examined subjects with less than 1 year of symptoms due to adhesive capsulitis using ultrasound and then compared their findings to arthroscopy. Eighty-seven percent of their subjects had hypoechoic areas with increased vascularity within the soft tissue structures of the rotator interval [51]. The study found that visualizing increased signal on power Doppler, and hypoechoic areas within the soft tissues of the rotator interval has excellent sensitivity (97 and 87%) and specificity (100 and 100%) [51]. The increase in power Doppler signal has typically been observed during the "freezing" phase of the disease course indicating neovascularity, fibrosis, and scar formation [48]. Additional ultrasound findings in adhesive capsulitis include axillary pouch thickening (4 vs. 1.3 mm), mild fluid distention within the biceps sheath, and the subscapular recess [46, 52]. Dynamic evaluation of the glenohumeral joint is of limited utility though one can observe reduced humeral head rotation and decreased visibility of the supraspinatus under the acromion [46]. An additional clinically important use of MSK-US in suspected adhesive capsulitis is to rule out rotator cuff disease, since considerable overlap exists between the clinical presentation of adhesive capsulitis and rotator cuff tendinosis or tear. An MSK-US exam demonstrating no rotator cuff pathology strongly assists in the accurate diagnosis of adhesive capsulitis.

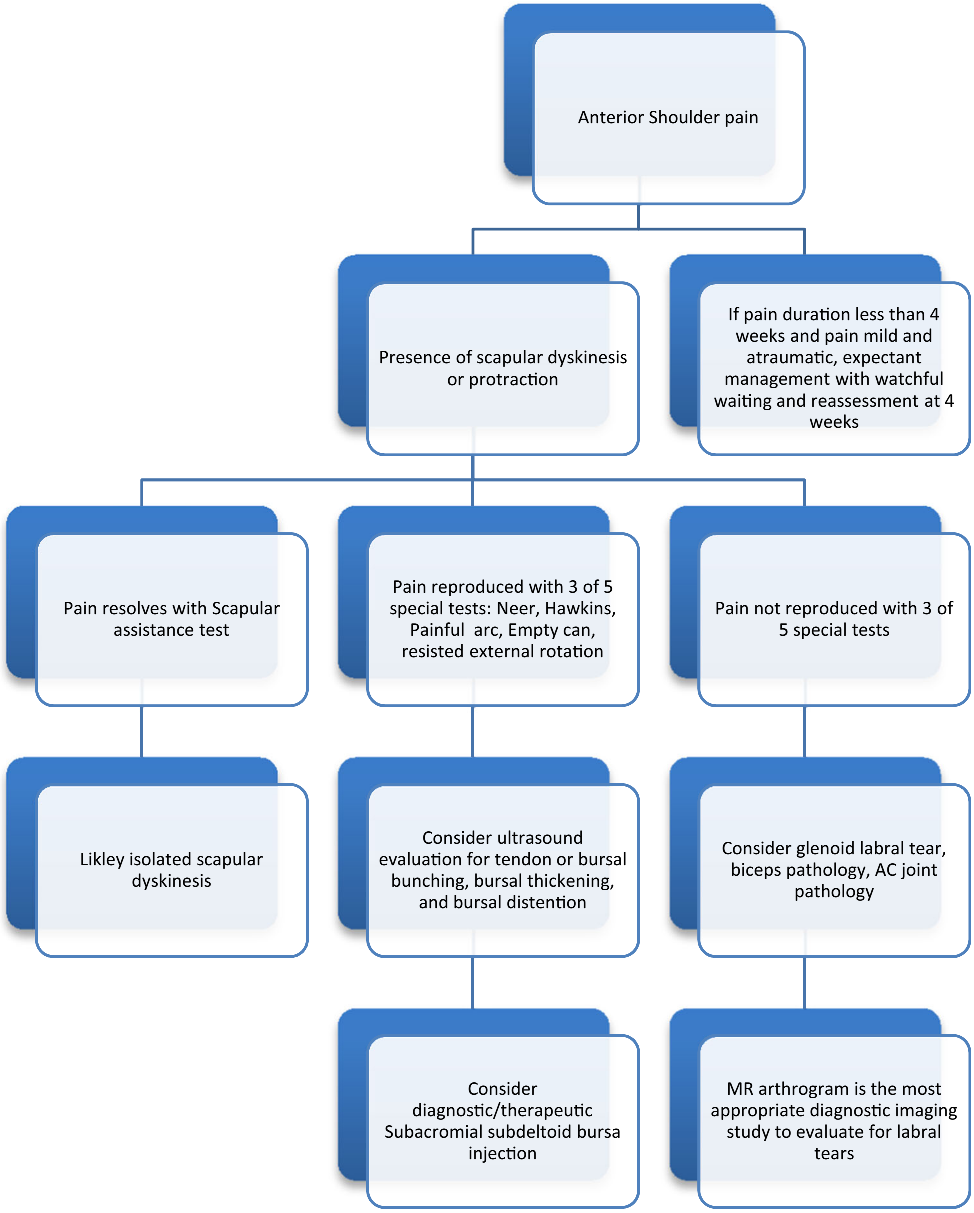
Discussion

When approaching the diagnosis of a painful shoulder, it may be useful to consider the location of patients' pain to inform the initial differential diagnosis. Duration of symptoms is also an important consideration because some atraumatic acute and subacute shoulder pain is due to soft tissue strain that will resolve completely without specific intervention other than rest and time; it is reasonable to treat mild to moderate shoulder pain of less than 4 weeks duration with an expectant approach, even in the absence of an accurate diagnosis. This will limit unnecessary imaging studies. However, if pain has been present for more than 4 weeks, an attempt to accurately establish the diagnosis is clearly warranted. An algorithmic approach is presented below.

Anterior shoulder pain is most commonly due to subacromial impingement, biceps tendinosis, glenoid labral tear, or acromioclavicular joint disease. Based on the evidence presented above, an approach to suspected subacromial impingement syndrome (Fig. 1) may begin by first examining for scapular protraction and dyskinesis [4]. If dyskinesis is present, perform the scapular assistance test and note reduction in pain or improvement in scapular motion. Further physical exam can then be limited to five exam maneuvers—Hawkins-Kennedy, Neer's, painful arc, empty can, and resisted external rotation. Reproduction of pain with three out of five of these tests has a sensitivity of 75% and specificity of 74% for impingement syndrome [1, 11]. This review also found that a negative Yocum test may also be useful in ruling out impingement [7, 9]. If three of the five exams are positive, a focused ultrasound exam can be considered to look for bunching of the supraspinatus tendon, SASD bursal thickening >2 mm, and bursal effusion >2 mm suggestive of subacromial bursitis. One final consideration if the diagnosis remains in question is to perform an ultrasound-guided diagnostic SASD bursal injection if either bursal thickening or effusion is present followed by a repeat history and physical examination to determine if the pain has resolved.

When evaluating a patient with lateral or posterior pain, a thorough evaluation of the rotator cuff should be completed. Physical exam tests should be carefully selected to isolate individual components of the rotator cuff. An evidence-based approach begins by testing the supraspinatus and infraspinatus muscles, as these are the most commonly affected structures (Fig. 2). The supraspinatus can be tested using the empty can, full can, and painful arc tests, all of which have high sensitivity, but poor specificity. Therefore, reproduction of pain with these examinations warrants a more detailed examination of the supraspinatus with ultrasound given its high

Fig. 1 Evidence-based approach to the diagnosis of subacromial impingement syndrome



specificity for identifying all tears and tendinopathy. Ultrasound exam in conjunction with plain film radiographs may be sufficient to capture a majority of shoulder pathology subsequently leading to reducing cost and expediting both diagnosis and treatment. Further imaging with MRI may be warranted depending on the clinical scenario. For example, one might consider getting an MRI for surgical planning purposes. When evaluating the infraspinatus, begin with resisted external rotation test and the external rotation lag sign as both yield adequate sensitivity (84 and 97%, respectively). The external rotation lag sign also showed high specificity (93–97%) for infraspinatus tears. This test may also be combined with Patte's test, which held a specificity of 95% for infraspinatus tears. Taken in combination (resisted external rotation, Patte's test, and external rotation lag sign), a positive result should prompt a consideration of a focused ultrasound exam of the infraspinatus to specifically characterize pathology. Finally, when considering pathology of the subscapularis, the lift-off test, belly press test, and belly-off test all yield strong sensitivity and specificity for both tears and tendinopathy. A positive result for at least two of these tests should indicate further consideration of investigation with ultrasound of the subscapularis.

Finally, the evidence-based approach of adhesive capsulitis begins with physical exam demonstrating loss of external and internal rotation. If there is clear limitation in range of motion without technical limitations of the exam due to pain interference, the diagnosis does not need further imaging to support it. However, an adequate examination of many shoulders with suspected adhesive capsulitis is limited by pain, and imaging

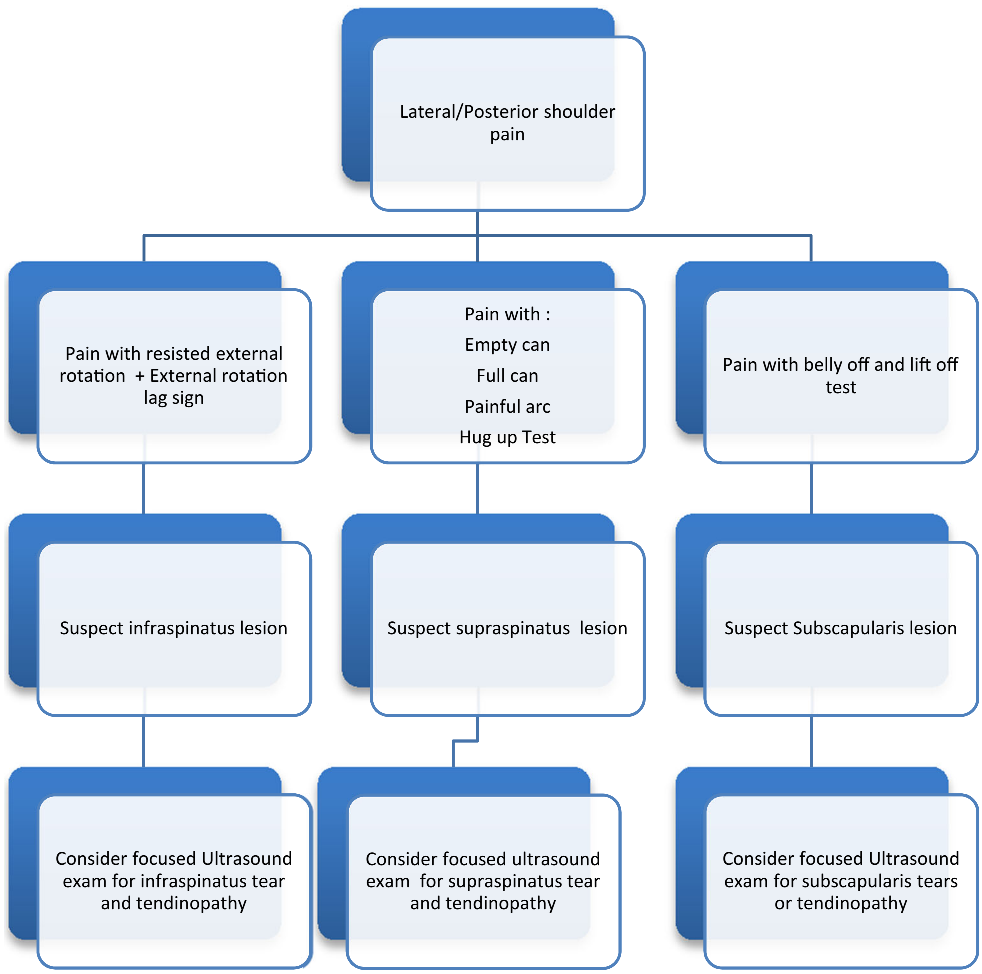


Fig. 2 Evidence-based approach to the diagnosis of rotator cuff pathology

can be used in these situations to confirm the diagnosis. MSK-US should be used to look for coracohumeral ligament thickening, increased signal on power Doppler, and hypoechoic areas within the soft tissues of the rotator interval. The rotator cuff should also be evaluated to exclude pathology confounding the clinical picture. The clinician should also classify the stage of adhesive capsulitis to help guide management and gauge expectations of the patients for understanding the length of recovery.

Conclusion

Shoulder pain can be a diagnostic challenge due to the structural and biomechanical complexity surrounding the glenohumeral joint. Developing an evidence-based approach to the evaluation of shoulder pain helps to focus the physical exam, imaging, and eventual management. The current body of literature shows a mixed landscape of evidence with no single exam maneuver being highly sensitive and specific for differentiating pathology. Utilizing multiple physical exam tests that individually provide either high sensitivity or specificity in combination may yield a more accurate diagnosis, though even this approach leaves a great deal of diagnostic uncertainty. Incorporating MSK-US as a routine extension of the physical exam can expedite diagnosis and allows for the timely initiation of appropriate treatments. MSK-US may also be used by clinicians for needle guidance when performing diagnostic injections to suspected pain-generating structures. Continued research is needed to further validate and standardize protocols of combined exam maneuvers and MSK-US for diagnosing shoulder pain.

Compliance with Ethical Standards

Conflict of Interest Michael F. Saulle and Alfred Gellhorn declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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