Frontiers in Health Informatics
ISSN-Online: 2676-7104
www.healthinformaticsjournal.com

Role of Dynamic High-Resolution Ultrasound in Comparison with MRI in Assessment of Shoulder Impingement Syndrome

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Cite this paper as: Mostafa Abdelraheem Abdelshafey Ali, ElSayed Said, Ahmed Okasha (2024) Role of Dynamic High-Resolution Ultrasound in Comparison with MRI in Assessment of Shoulder Impingement Syndrome . *Frontiersin Health Informatics, 13* (3), 5570-5581

Abstract
Subacromial impingement is a prevalent cause of shoulder pain, responsible for up to sixty percent of all shoulder-related symptoms. Impingement syndrome may arise from several circumstances categorized into structural and functional causes. Shoulder joint injuries are prevalent. The distinctive anatomy of the shoulder joint renders it more susceptible to dislocation. Various etiologies of shoulder discomfort are observed, with shoulder impingement being the predominant condition influenced by multiple variables. One is functional, whereas the acromion, acromioclavicular (AC) joint, rotator cuff, bursa, coracoid process, and humerus are structural. MRI is useful for examining shoulder pain; however, it only provides a static image of the shoulder joint. A number of disorders affecting musculoskeletal structures, such as painful shoulder syndrome, can be effectively evaluated using dynamic ultrasonography. Rotator cuff tendon diseases represent the predominant category of ailments impacting the shoulder joints. Diagnostic radiological techniques, including magnetic resonance imaging (MRI), ultrasonography (US), as well as magnetic resonance arthrography (MRA), furnish valuable insights that assist doctors in formulating appropriate treatment strategies for individual patients.

***Key words**: Dynamic High-Resolution Ultrasound, MRI, Shoulder Impingement Syndrome*

Introduction
Shoulder joint injuries are prevalent. The distinctive anatomy of the shoulder joint renders it more susceptible to dislocation (1).
Shoulder impingement, which can be caused by a number of different things, is the most common kind of painful shoulder.
There are structural factors that are associated with the AC joint, coracoid process, rotator cuff, bursa, and humerus, and there are functional factors that are related to other structures (2).
Diagnostic imaging is used to guide management decisions, whether surgical or non-surgical. For imaging to be really effective in reducing needless surgical intervention, the false positive rate must be manageable while the genuine positive rate must be substantial (3).
The advantages of ultrasonography, such as its low cost, accessibility, as well as the ability to provide real-time high-resolution imaging for dynamic assessment in addition to needle guidance, have recently enabled its increasing use (4).
The objective of the research was to identify whether dynamic high-resolution ultrasonography is more effective than static testing in detecting a variety of shoulder joint abnormalities in people with shoulder impingement syndrome. We will be comparing this to MRI in order to establish a standard for our cases.

Anatomy of Shoulder

The clavicle and scapula form the shoulder girdle, which fastens to the upper limb's proximal humerus. The shoulder has 4 joints: the glenohumeral joint, AC joint, scapulothoracic joint, in addition to sternoclavicular joint (5).

A synovial saddle joint, the sternoclavicular joint is the only connection between the axial skeleton and the upper limb. It is also known as the sternoclavific joint. This ligament, known as the costoclavicular ligament, is responsible for providing support and connecting the clavicle to the manubrium of the sternum. The term "acromioclavicular joint" describes the synovial attachment between the scapula and the clavicle (6).

The inferior and superior AC ligaments provide secondary stability, whereas the coracoclavicular ligament provides primary stability. Although it seems like a joint, the scapulothoracic joint is actually just the scapula gliding along the back of the thoracic cage (7).

The main movements of the glenohumeral joint involve (8)**:**

Abduction: The humerus moves laterally upward and away from the body, following the scapula's plane.

Adduction: The humerus moves laterally toward the body as it descends from abduction, along the scapular plane.

Flexion: The straight anterior movement of the humerus

Extension: The straight posterior movement of the humerus

External rotation: as the humerus rotates laterally about its own long axis, away from its own midline

Internal rotation: as it moves along its length axis, the humerus moves towards the midline.

Horizontal adduction (transverse flexion): the humerus's motion in a transverse or horizontal plane towards and across the chest

Horizontal abduction (transverse extension): Movement of the humerus away from the chest in a horizontal or transverse plane

Shoulder Impingement Syndrome

Introduction

MRI is regarded as a useful method for assessing various etiologies of shoulder discomfort, albeit its primary limitation is the static assessment of the shoulder joint. Dynamic US is an advantageous method for assessing many conditions impacting musculoskeletal structures, including uncomfortable shoulder syndrome (9)

The shoulder joints are most commonly affected by a set of illnesses known as rotator cuff tendon opathies. Clinicians can utilize the valuable information provided by diagnostic radiological methods like MR arthrography (MRA), ultrasonography (US), and to develop the most appropriate treatment strategy for each patient (10)

Neer Classification

The impingement syndrome can be categorized utilizing multiple approaches. Neer was the first person to describe rotator cuff impingement in 1972. This condition is brought on by the application of mechanical pressure to the rotator cuff tendon, which is located beneath the antero-inferior section of the acromion. When the shoulder is internally rotated and bent forward, this pressure is extremely intense that it is difficult to move.

The following three phases in the spectrum of rotator cuff impingement are described by Neer (11)**:**

Stage 1 is frequently observed in patients under the age of 25, and it is defined by acute inflammation, edema, as well as hemorrhage in the rotator cuff. Non-operative treatment is typically effective in reversing this stage, which is frequently linked to an overuse injury.

Stage 2 frequently impacts patients among the ages of twenty-five and forty, and it is a continuation of stage 1. The progression of fibrosis and tendonitis in the rotator cuff tendon usually does not respond to non-operative treatments, and surgical intervention becomes necessary.

Stage 3 is frequently experienced by patients who are over the age of 40. As this condition advances, it may result in the formation of osteophytes along the anterior acromion and variations in the coracoacromial arch, as well as mechanical disruption of the rotator cuff tendon. Deterioration, or Stage III, is the last stage of long-term tendinitis and fibrosis. Performing rotator cuff repairs and anterior acromioplasty are common surgical needs.

Etiology

It is important for clinicians to distinguish between internal and exterior impingement while treating shoulder pain. The rotator cuff is the most basic clinical distinction among the two types; it determines the anatomic boundary between the internal and exterior forms (12).

Typically, manual laborers or overhead throwers are the ones who suffer from this second form of injury, which manifests as glenohumeral internal rotation deficit (GIRD), articular-sided rotator cuff illness, or superior labrum anterior posterior (SLAP) rips. This type of damage is caused by recurrent impingement (13).

The painful disease known as external impingement (or "shoulder impingement" among medical professionals) develops when the subacromial region becomes inflamed, irritated, and deteriorated due to trauma to the orthopaedic structures located there. In the past, shoulder impingement syndrome was thought to be an isolated diagnosis; however, today, doctors see it as a group of symptoms and anatomical features (14).

Shoulder impingement discomfort is the consequence of the compressive force exerted by the humeral head on the rotator cuff, the subacromial bursa, or both structures (15).

Constriction of the subacromial space is caused by the rotator cuff tendons, which are inflamed and damaged. However, it is not yet known whether tendon inflammation is caused by the reduced subacromial space or by the repetitive pathological compression, degeneration, as well as fraying of the tendons (16).

The two main ways to classify shoulder impingement syndrome are by the kind of impingement that is causing it (primary or secondary impingement) and by where the impingement is located (external or internal) (17).

The condition known as external or subacromial impingement occurs when the subacromial space is invaded, either physically or mechanically, by soft tissue. Internal impingement occurs when the rotator cuff tendons stick out between the glenoid rim and the humeral head. The tendons of the supraspinatus and infraspinatus are the most frequent sites of internal impingement (18).

The structural constriction of the subacromial space is a hallmark of primary impingement. One kind of primary shoulder impingement syndrome is caused by a swollen soft tissue or an atypical acromion, like a hooked class III acromion.

Impingement occurs during shoulder movement, even though the anatomy is normal at rest; this could be because the rotator cuff weakens, allowing the humeral head to translate superiorly uncontrollably. This condition is known as secondary shoulder impingement syndrome (19). The subacromial space is further reduced and the scapula's ability to elevate and rotate externally during abduction of the upper limb is restricted, leading to secondary impingement syndrome if the trapezius and serratus anterior muscles are weak (20).

Shoulder impingement was ranked by Neer into three severe phases. Edema, hemorrhage, or both are the main causes of impingement in stage I, which is typically caused by mechanisms of overuse. In Stage II, the tendon changes are permanent and the fibrosis is worse. When shoulder impingement syndrome reaches stage III, a tendon rupture or tear can occur as a consequence of persistent fibrosis (21).

EPIDEMIOLOGY

Shoulder pain ranks second in prevalence, following lower back pain, within the general population. According to research, SIS accounts for around 30–35 percent of shoulder illnesses and is thus the leading cause of shoulder pain. Nevertheless, the epidemiologic estimates may differ based on the definition of SIS (22).

Pathophysiology

A debate exists over the causes of Shoulder Impingement Syndrome. Nonetheless, a combination of extrinsic compression and intrinsic degeneration occurs in SIS. Repetitive compression and micro-trauma of the rotator cuff are widely recognized as primary causes (23).

The Supraspinatus tendon is the predominant Rotator Cuff tendon involved in Shoulder Impingement. Typically, when arm abduction exceeds 60 degrees and internal rotation exceeds 45 degrees, the subacromial space narrows, resulting in compression of the supraspinatus tendon by the acromion (24).

The symptoms appear to be alleviated by external rotation of the arm, as the subacromial space expands to its maximum extent. Sixteen Rotator cuff irritation and tendinopathy may result from repetitive abduction of the arm and internal rotation, such as painting or cleaning windows. Research has demonstrated that the presence of inflammatory cells in the rotator cuff tendons is negligible (25).

Extrinsic Mechanism

Extrinsic rotator cuff compression can be caused by a number of different sources, that involve AC joint, the coracoacromial ligament (CAL), as well as the inferior region of the acromion.

The anatomical shape of the acromion appears to play a crucial role in the onset of Shoulder Impingement Syndrome (24).

The development of SIS can be attributed to any injury that impacts the AC joint's arthrokinematic motion. In particular, the subacromial space shrinks and the scapula cannot rotate upwards during humeral elevation due to the clavicle's restriction of superior and posterior rotation. Shoulder impingement syndrome can develop in part because of the CAL (26).

Degeneration of both the Rotator Cuff tendon and the CAL occurs as a result of continuous contact between the two. This causes the CAL's collagen fibers to harden.

Degeneration of the rotator cuff tendon might develop because to the increasing pressure between CAL and the tendon caused by its increased stiffness. In addition, impingement of the rotator cuff happens and the subacromial space narrows. Deposition of amorphous debris, infiltration of fatty acids, and collagen fiber disintegration have all been revealed by histological investigation of the tendon (27).

Intrinsic Mechanism

The intrinsic mechanism encompasses all the factors that contribute to the degeneration of the Rotator Cuff tendon. Some of the variables include aging, impaired blood flow, changed biology, hereditary components, trauma, overload, and excessive use. Tendon degeneration, stiffness, loss of elasticity, and fibrosis are all symptoms of aging. Each of these lesions has the potential to impair shoulder mobility and produce pain (28).

Numerous studies have revealed that the deterioration of the supraspinatus tendon typically begins around the age of 40. Histological studies of the supraspinatus tendon in healthy older adults reveal degenerative lesions and tendon calcification. The tendon also shows a reduction in glycosaminoglycans and proteoglycans. Collagen type 3 to type 1 is also extremely high (29).

Diagnosis

History and Physical

Shoulder impingement syndrome can only be diagnosed after a comprehensive patient history and physical examination. When people come in, they usually report that it hurts when they elevate their affected arm or lie on that side. They could say that they can't move about much or that they can't sleep because of the agony they experience at night. Aside from the pain, stiffness and weakness are common side effects (30).

Patients frequently report being unable to pinpoint a specific trauma or event that precipitated the pain, and the onset is often slow and sneaky, taking place over the course of weeks or months. Many people report that the pain radiates from the lateral mid-humerus and originates over the lateral acromion. It is important for clinicians to gather information about the patient's shoulder discomfort, including when it started, how bad it is, what causes it to become worse or go away, what treatments have been tried so far, how the patient is responding, and any history of injuries to the afflicted arm or shoulder (31).

Specifically, the clinician should inquire about repetitive activities and overhead activities. Rest, anti-inflammatory medications, as well as ice may provide relief; however, symptoms frequently recur upon the return to activity (17).

Palpation, inspection, range of motion (both passive and active), in addition to strength tests (both for the shoulder and neck) should all be performed in a bilateral fashion during a comprehensive physical examination. All of these tests should be performed on both sides of the body. There is a high incidence of individuals exhibiting weakness in abduction and/or external rotation on the side that is affected.

For the anterior apprehension test, the patient is positioned in a supine position with their shoulder in external rotation and at ninety degrees of abduction. The next step is for the doctor to support the proximal shoulder as they perform a little but noticeable increase in external rotation. The evaluation is effective when the individual reports sensation as though a subluxation or dislocation is imminent (32).

Relocation test: A positive result on the anterior apprehension test is necessary for this evaluation of shoulder instability. When a patient experiences the symptoms of dislocation or subluxation, as mentioned earlier, the doctor can alleviate their pain by applying a push that is applied posteriorly to the anterior humeral head (33).

Evaluation

The physical examination is purported to have a diagnostic sensitivity of ninety percent; however, imaging studies are frequently conducted to confirm the diagnosis and exclude other conditions.

To assess potential anatomical differences and exclude other pathologies, for example arthritic changes or calcific tendinitis, radiographs should be obtained bilaterally, rather than solely on the afflicted side, if the decision to obtain them is made (17).

Two views are included in standard normal radiographs of the shoulder: anteroposterior (AP) and lateral/scapular

Y. The AP view of the shoulder, which encompasses the angle of the glenoid and the degree of lateral covering afforded by the acromion, can be utilized to evaluate the CSA. In impingement syndrome, the probability of rotator cuff involvement increases as critical shoulder angles exceed thirty-five degrees. Rotator cuff disorders and anomalies can be identified with the assistance of measurements such as the acromiohumeral distance (AHD). Measurement of the distance between the inferior edge of the acromion to the humeral head is carried out in order to ascertain the acromion height (AHD). According to the normative range, the range for boys is around seven to fourteen millimeters, while the range for females is seven to twelve millimeters. A decreased anterior humeral distance (AHD) is an indication of rotator cuff disease. For the purpose of determining the location of the humeral head in relation to the glenoid, the scapular Y view is an advantageous perspective. The morphology of the acromion will be effectively demonstrated and evaluated by supplementary plain radiographs with the outflow view (17)**.**

Treatment

Non-Operative Treatment

Many individuals with shoulder impingement syndrome ultimately recover through nonoperative treatment, as evidenced by a 1997 literature review conducted by Bigliani and Levine. The most frequently employed non-operative treatment modalities are subacromial steroid injections, physical therapy protocols, non-steroidal anti-inflammatory medications, in addition to activity moderation (34)**.**

In comparison to patients aged 21–40, those aged 20 and under, as well as those aged 41–60, had superior outcomes. A worse result was observed in people older than 60 years. Results were better for those with type-I acromion than for those with type-II or type-Ill (35)**.**

Operative treatment

Operative treatment is frequently implemented by surgeons when conservative treatments are unsuccessful in alleviating discomfort. The two most common procedures are anterior acromioplasty and CAL excision.

There are two main approaches to anterior acromioplasty: the open technique first described by Neer and the arthroscopic procedure described by Ellman. By removing bone spurs and soft tissue, other surgeons can perform arthroscopic subacromial decompression, a procedure that relieves pressure in the subacromial area. (11)**.**

Open acromioplasty has been found to be effective in 73% to 93% of individuals, in accordance with various publications. Additionally, arthroscopic acromioplasty has been described by a number of writers as a successful procedure (36)**.**

According to Hawkins et al., the outcomes of arthroscopic acromioplasty were the worst. After following up with patients for at least two years, they looked at the outcomes of 110 successive arthroscopic acromioplasties.

Only 46 percent of individuals had satisfactory outcomes. Open decompression, in accordance with the authors, produces better outcomes (37)**.**

Complications of Arthroscopic Acromioplasty

Arthroscopic acromioplasty has a minimal risk of complications, that vary from 0.76 percent to 6.5%. A revision procedure has been necessary due to insufficient bone removal, which has been the most prevalent consequence. Complications such as acromion fracture have also been documented (38)**.**

Arthroscopy of the shoulder has an infection rate that varies from 0.04 percent to 3.4 percent. It is possible to injure the median, ulna, musculocutaneous nerve, or radial nerve while doing shoulder arthroscopy (39)**.**

The beach chair position has been related to tragic outcomes in a few of shoulder arthroscopy cases. An individual died and three others suffered from serious brain damage after arthroscopic shoulder surgery, according to a report by Pohl and Cullen. Additionally, reports have indicated ophthalmoplegia, stroke, brain death, and vision loss (40)**.**

Evaluation of Shoulder Symptoms and Function

The symptoms and function of the shoulder were evaluated with the Shoulder Pain and Disability Index (SPADI), which has two subscales with a total of thirteen items: one measuring disability and the other measuring pain. A 100-point scale is generated by adding up the scores of each item, which range from zero (no pain/disability) to ten (maximum pain/disability). All individuals were asked to report a zero on the SPADI for both of their shoulders in this research (41)**.**

ROLE OF DYNAMIC HIGH-RESOLUTION ULTRASOUND

Abduction or flexion of the shoulder joint, with the probe positioned at the acromion's end in either the coronal or sagittal planes, allows for dynamic examination. If you suspect subacromial impingement, you should look for two things: depression of the humeral head and impingement of the tendon or bursa. During the second half of the shoulder abduction cycle, the humeral head center usually moves inferiorly. This is necessary to create enough room for the rotator cuff to slide beneath the acromion, which in turn requires humeral head depression (42).

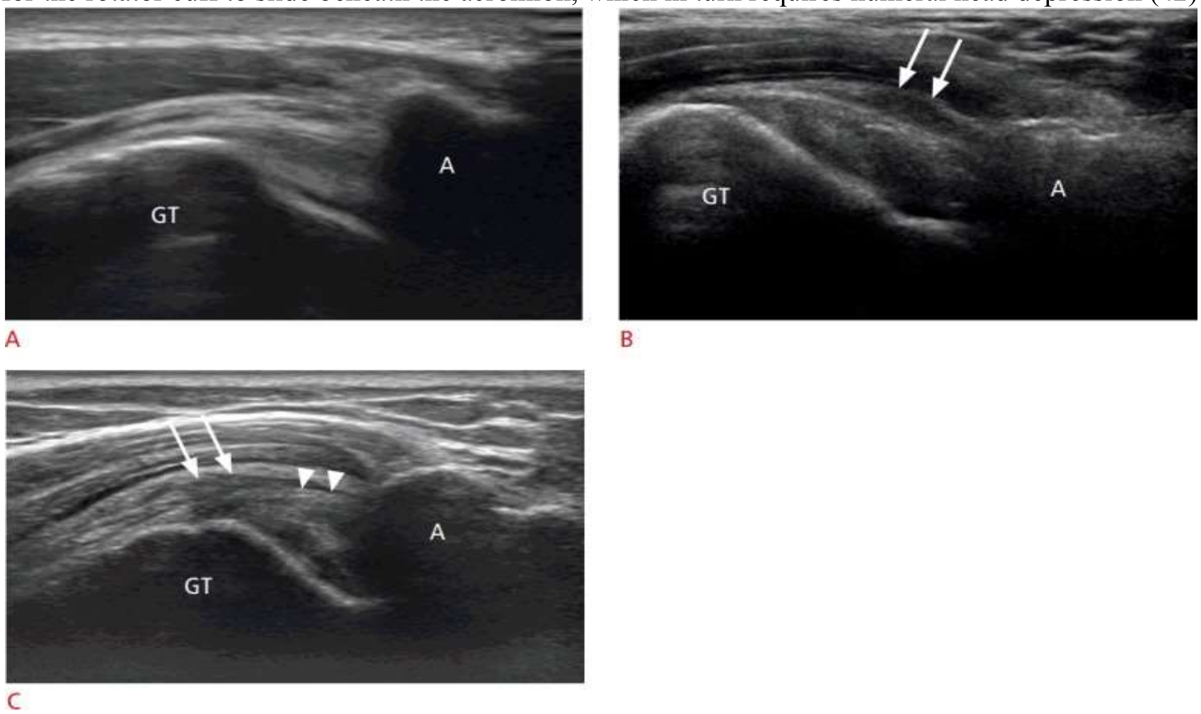

Figure 6. Dynamic evaluation of subacromial impingement. A 31-year-old man's normal dynamic US is displayed. No evidence of osseous or soft tissue impingement was observed during shoulder flexion. The subacromial impingement was classified as grade 2, and the patient was a 45-year-old female. When the shoulder is abducted, the bursa located between the acromion and the subdeltoid muscles thickens above the supraspinatus tendon and accumulates outside the acromion (arrows). A fifty-year-old woman presented with symptoms of grade three subacromial impingement. Because of its position between the acromion and the greater tubercle of the humerus, the supraspinatus tendon has sustained significant damage. Underneath the acromion, the subacromial-subdeltoid bursa and the supraspinatus tendon are not crossed by the humeral head because it does not drop low enough. Acromion and larger tubercle surround the humerus, and the arrowheads and arrows show the tendon and bursal tissues that protrude superficially and put pressure on the humerus (43).

One structure that has recently attracted ultrasonographic attention is the CAL, which is an integral part of the coracoacromial arch and a main culprit in cases of subacromial impingement (44).

The CAL can be seen by positioning the instrument such that one end is at the acromion and the other tip is at the coracoid process.

From the long-axis view of the CAL, which is slightly anterior to the acromion, rotate the probe through a 90-degree angle in the direction of the supraspinatus tendon to reveal subacromial impingement beneath the ligament (42).

Subacromial impingement syndrome participants and healthy individuals have identical CAL thickness and length; however, when the shoulder is abducted and rotated internally, the CAL is much more displaced to the front (45).

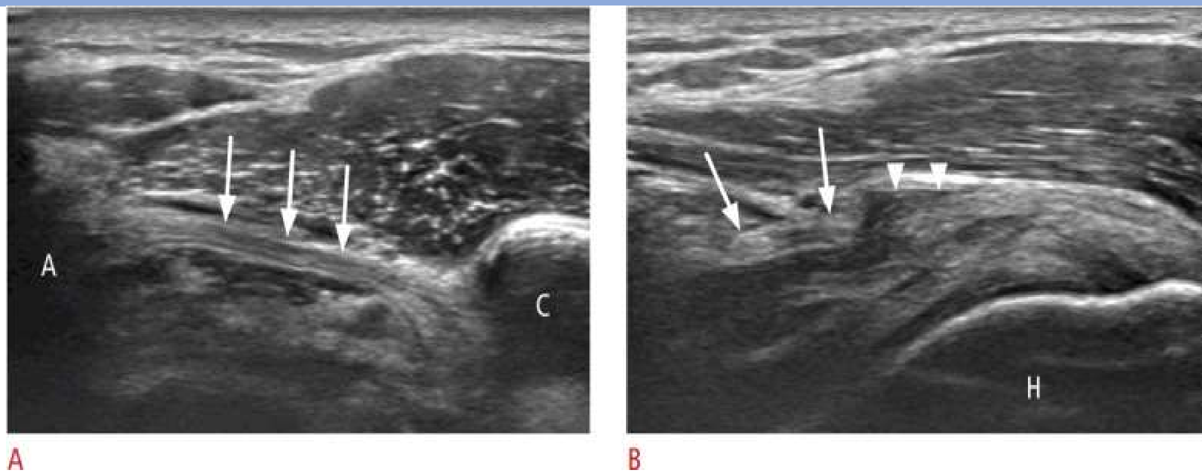

Figure 8. A 19-year-old male diagnosed with subacromial impingement syndrome attributed to the CAL. A. The CAL (arrows) joins the acromion (A) with the coracoid process (C) in the long-axis view; it is inserted into an oblique coronal plane at the anterolateral shoulder. B. In the short-axis view (arrows), the supraspinatus tendon and the plate-like subacromial bursa are covered by the CAL. Raising the arm to a position midway between a flexed and abducted shoulder generated pain and swelling of the supraspinatus tendon and the subacromial bursa (arrowheads) (43).

Shoulder Ultrasound Examination

A scout was utilized to perform a detailed examination of the long head of the biceps, the supraspinatus, the infraspinatus, and the subscapularis tendon. A short-axis imaging of the supraspinatus tendon was utilized in order to investigate the subacromial-subdeltoid bursa when the shoulder was in the internal rotation position (46).

The hypoechoic stripe was visible as it stretched between the deep hyperechoic peribursal fat and the superficial hyperechoic fat.

A subacromial-subdeltoid bursa thickness exceeding two millimeters was deemed aberrant. This thickness is the sum of the hypoechoic stripe depth in addition to the superficial peribursal fat (47).

The diagnostic criteria for pathology were derived from prior research, and individuals having tears of any of the specified tendons were excluded from this investigation (48).

The individuals were asked to sit with their arms naturally resting at their sides during the active examination. The arm that was being examined had a smartphone fastened to it, just below the middle deltoid muscle insertion.

The smartphone was programmed to measure the angle of abduction when the arm was raised utilizing the GPS Status and Toolkit application, version 8.4.177 (Hungary, 1,033 Budapest, Hévízi u. 5.) (49) (50).

Because of the placement of a linear ultrasonic transducer (5-18 MHz; HI VISION Ascendus, Hitachi) along the scapular plane, the humeral head, supraspinatus tendon, and acromion were all able to be observed with great clarity. The transducer's midpoint was located on the lateral margin of the acromion.

The people involved were instructed to passively abduct their arm to the level underneath the acromion after the bigger tuberosity had rotated to that spot, and then to naturally return it to its original position. It was recommended that they rapidly raise and lower their arms as they aim to touch an item overhead (50) (51).

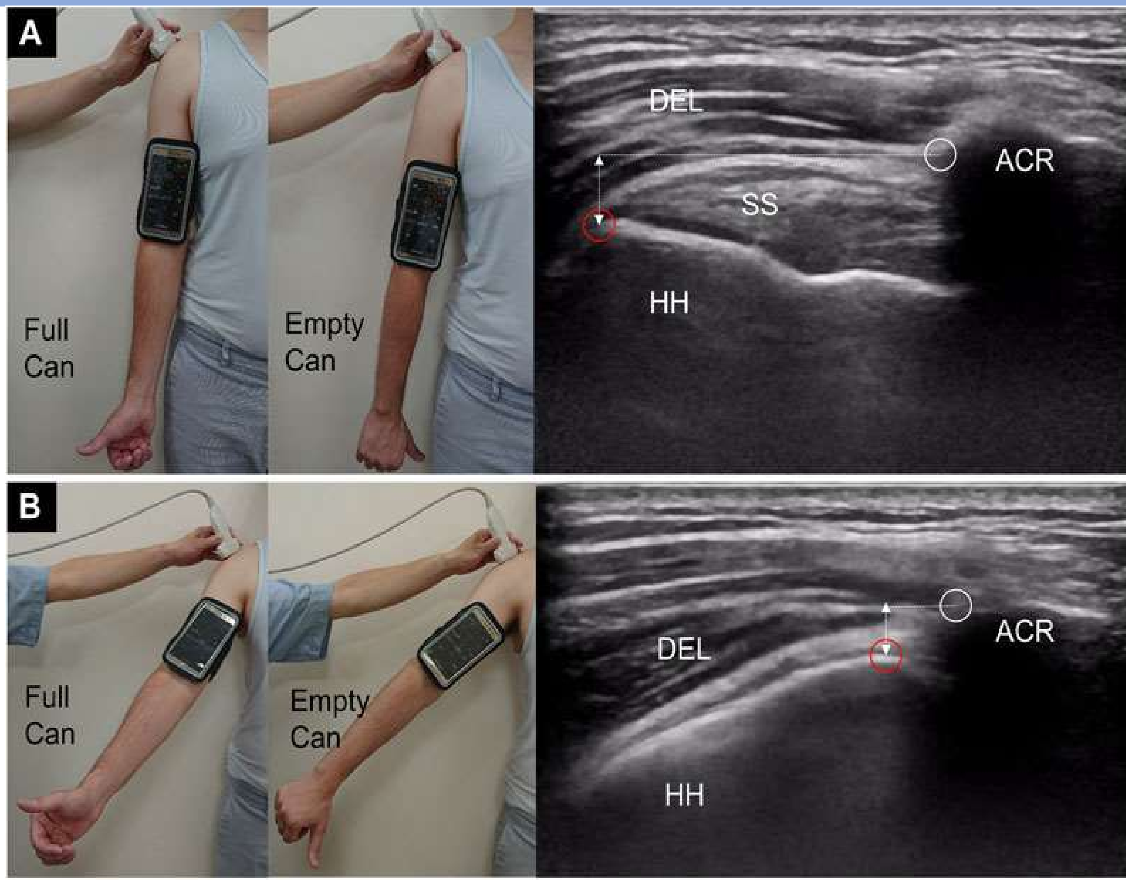

FIGURE 9. The subacromial region and the upper limb's posture can be imaged using ultrasound in both the abducted (B) and beginning (A) positions. In (B), the larger tuberosity is about to pass the lateral acromial margin, which is represented by the white circles. humeral head (HH), supraspinatus tendon (SS), and acromion (ACR) are all shown by the vertical dashed line (46)**.**

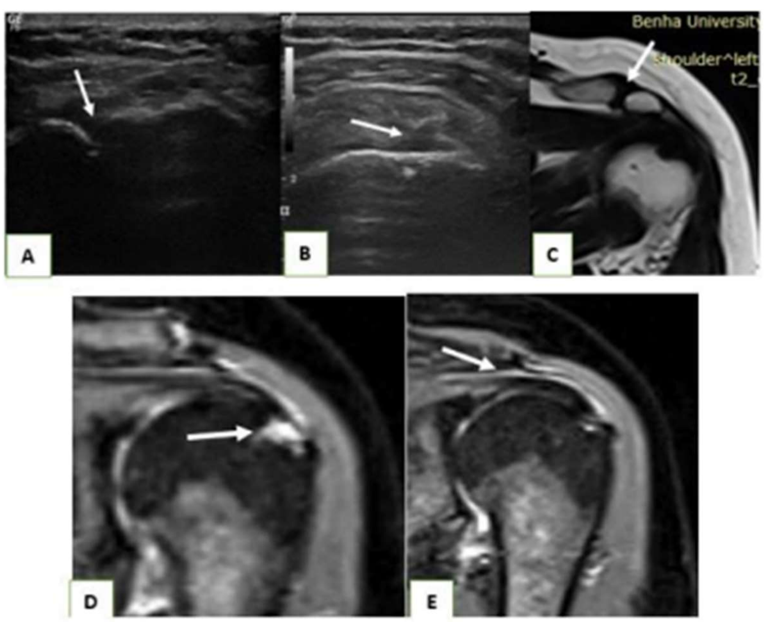

Figure 13: A: The ultrasound picture indicated the presence of AC osteoarthritis (arrow). Ultrasound of the shoulder revealed a partial thickness rip of the supraspinatus tendon on the articular surface, as indicated by a focal

hypoechoic defect at the articular aspect of the tendon fibers (arrow). It was found that the subacromial bursa contained fluid. Coronal T2-weighted MRI images revealed cartilage damage at the AC joint (arrow) and acromial offset, which made it difficult to see the peritendinous fat planes underneath. D: MRI, coronal STIR wide-field images: fluid signal at the supraspinatus tendon's articular surface, indicating a partial thickness fracture of that surface (arrow). Coronal STIR WIs on the MRI revealed minor subacromial bursitis (arrow) as well as joint effusion (52).

ROLE OF MRI in SHOULDER IMPINGEMENT SYNDROME

An MRI scan was conducted using a magnet unit from Philips Intera that has a high field system of 1.5 Tesla. The supine position with the patient's head oriented towards the scanner bore is advised. The patient's arm should be maintained in a neutral or slightly externally rotated position. The coils that encircle and adapt to the anatomical region of interest are referred to as surface coils, also known as flexible coils. A preliminary investigation was conducted utilizing sagittal, coronal, as well as axial scout localizers (53).

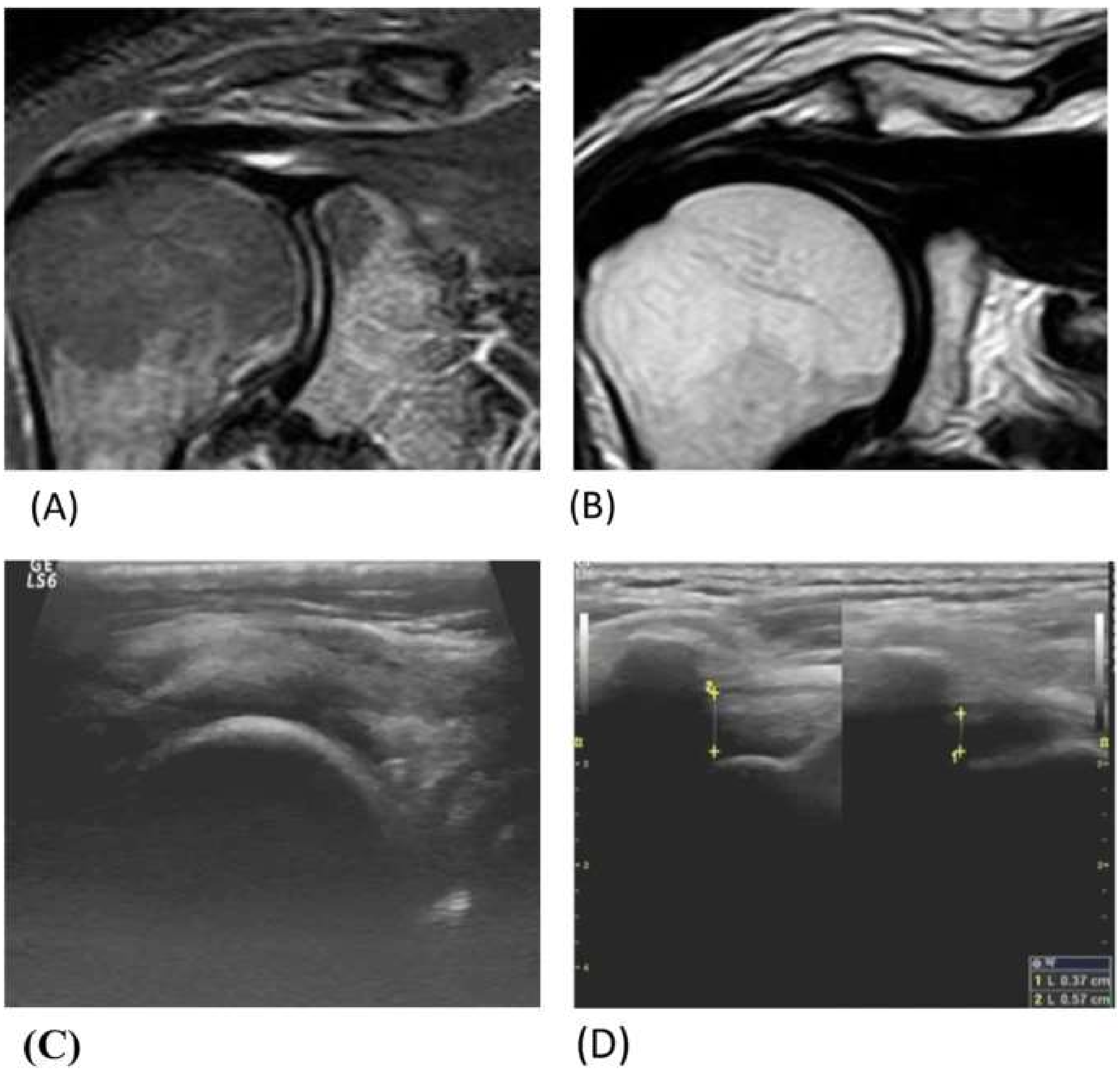

Figure 16. fluid signal observed at the articular surface of the musculo-tendinous junction of the supraspinatous tendon (arrow) on an MRI scan with sagittal STIR WIs. There is no indication of a total fiber interruption. **b** MRI shows acromio-clavicular osteoarthritis on coronal T2WIs of the shoulder. **c** The tendon fibers are interrupted by a hypoechoic linear defect, which is a partial-thickness tear of the humeral surface, as shown in static US pictures

(arrow). d In stress positions, dynamic US revealed a constriction of the subacromial tunnel (54).

References:

[1] Terry GC, Chopp TM. Functional anatomy of the shoulder. J Athl Train. 2000;35(3):248.
[2] Yamaguchi K, Ditsios K, Middleton WD, Hildebolt CF, Galatz LM, Teefey SA. The demographic and morphological features of rotator cuff disease: a comparison of asymptomatic and symptomatic shoulders. JBJS. 2006;88(8):1699–704.
[3] Dinnes J, Loveman E, McIntyre L, Waugh N. The effectiveness of diagnostic tests for the assessment of shoulder pain due to soft tissue disorders: a systematic review. Health Technol Assess (Rockv). 2003;7(29).
[4] Greis AC, Derrington SM, McAuliffe M. Evaluation and nonsurgical management of rotator cuff calcific tendinopathy. Orthop Clin. 2015;46(2):293–302.
[5] Chang LR, Anand P, Varacallo M. Anatomy, shoulder and upper limb, glenohumeral joint. In: StatPearls [Internet]. StatPearls Publishing; 2023.
[6] Olivier T, Kasprzak K, Herteleer M, Demondion X, Jacques T, Cotten A. Anatomical study of the sternoclavicular joint using high-frequency ultrasound. Insights Imaging. 2022;13(1):66.
[7] Epperson TN, Black AC, Varacallo M. Anatomy, shoulder and upper limb, sternoclavicular joint. In: StatPearls [Internet]. StatPearls Publishing; 2023.
[8] Lam JH, Bordoni B. Anatomy, shoulder and upper limb, arm abductor muscles. In: StatPearls [Internet]. StatPearls Publishing; 2023.
[9] Ashir A, Lombardi A, Jerban S, Ma Y, Du J, Chang EY. Magnetic resonance imaging of the shoulder. Polish J Radiol. 2020;85(1):420–39.
[10] Lenza M, Buchbinder R, Takwoingi Y, Johnston R V, Hanchard NCA, Faloppa F. Magnetic resonance imaging, magnetic resonance arthrography and ultrasonography for assessing rotator cuff tears in people with shoulder pain for whom surgery is being considered. Cochrane Database Syst Rev. 2013;(9).
[11] Neer CS. II. Anterior acromioplasty for the impingement syndrome in the shoulder. A preliminary report. J Bone Jt Surg. 1972;54:41–50.
[12] De Yang Tien J, Tan AHC. Shoulder impingement syndrome, a common affliction of the shoulder: a comprehensive review. Proc Singapore Healthc. 2014;23(4):297–305.
[13] Davis DD, Nickerson M, Varacallo M. Swimmer's Shoulder. 2017;
[14] Varacallo M, El Bitar Y, Mair SD. Rotator cuff tendonitis. 2018;
[15] Maruvada S, Madrazo-Ibarra A, Varacallo M. Anatomy, rotator cuff. 2017;
[16] Consigliere P, Haddo O, Levy O, Sforza G. Subacromial impingement syndrome: management challenges. Orthop Res Rev. 2018;83–91.
[17] Garving C, Jakob S, Bauer I, Nadjar R, Brunner UH. Impingement syndrome of the shoulder. Dtsch Arztebl Int. 2017;114(45):765.
[18] Umer M, Qadir I, Azam M. Subacromial impingement syndrome. Orthop Rev (Pavia). 2012;4(2).
[19] Ellenbecker TS, Cools A. Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. Br J Sports Med. 2010;44(5):319–27.
[20] Escamilla RF, Hooks TR, Wilk KE. Optimal management of shoulder impingement syndrome. Open access J Sport Med. 2014;13–24.
[21] Dong W, Goost H, Lin XB, Burger C, Paul C, Wang ZL, et al. Treatments for shoulder impingement syndrome: a PRISMA systematic review and network meta-analysis. Medicine (Baltimore). 2015;94(10):e510.
[22] Juel NG, Natvig B. Shoulder diagnoses in secondary care, a one year cohort. BMC Musculoskelet Disord. 2014;15:1–8.
[23] Bolia IK, Collon K, Bogdanov J, Lan R, Petrigliano FA. Management options for shoulder impingement syndrome in athletes: insights and future directions. Open access J Sport Med. 2021;43–53.

[24] Miller MD, Thompson SR. Miller's review of orthopaedics. Elsevier Health Sciences; 2015.
[25] Lin YS, Boninger M, Worobey L, Farrokhi S, Koontz A. Effects of repetitive shoulder activity on the subacromial space in manual wheelchair users. Biomed Res Int. 2014;2014.
[26] Kiel J, Taqi M, Kaiser K. Acromioclavicular joint injury. 2018;
[27] Rothenberg A, Gasbarro G, Chlebeck J, Lin A. The coracoacromial ligament: anatomy, function, and clinical significance. Orthop J Sport Med. 2017;5(4):2325967117703398.
[28] Koukoulithras I, Kolokotsios S, Plexousakis M. Shoulder Impingement Syndrome: From Pathology to Treatment. Available SSRN 3676373. 2020;
[29] McCarthy MM, Hannafin JA. The mature athlete: aging tendon and ligament. Sports Health. 2014;6(1):41–8.
[30] Dhillon KS. Subacromial impingement syndrome of the shoulder: a musculoskeletal disorder or a medical myth? Malaysian Orthop J. 2019;13(3):1.
[31] Varacallo M, Tapscott DC, Mair SD. Superior labrum anterior posterior lesions. In: StatPearls [Internet]. StatPearls Publishing; 2023.
[32] Cotter EJ, Hannon CP, Christian D, Frank RM, Bach Jr BR. Comprehensive examination of the athlete's shoulder. Sports Health. 2018;10(4):366–75.
[33] Lizzio VA, Meta F, Fidai M, Makhni EC. Clinical evaluation and physical exam findings in patients with anterior shoulder instability. Curr Rev Musculoskelet Med. 2017;10:434–41.
[34] Bigliani LU, Levine WN. Current concepts review-subacromial impingement syndrome. JBJS. 1997;79(12):1854–68.
[35] Vakiti A, Mewawalla P. Acute Myeloid Leukemia. StatPearls [Internet]. 2023 Aug 8 [cited 2023 Aug 24]; Available from: https://www.ncbi.nlm.nih.gov/books/NBK507875/
[36] Eraghi AS. Acromioplasty in the surgical operations of partial-thickness rotator cuff tears: A comprehensive review. J Fam Med Prim Care. 2020;9(2):520–5.
[37] Hawkins RJ, Saddemi SR, Moor JT, Hawkins A. Arthroscopic subacromial decompression: a 2-year follow-up study. Arthroscopy. 1992;8(3):409.
[38] Shin JJ, Popchak AJ, Musahl V, Irrgang JJ, Lin A. Complications after arthroscopic shoulder surgery: a review of the American board of orthopaedic surgery database. JAAOS Glob Res Rev. 2018;2(12):e093.
[39] Smith RDJ, Wright CL, Shaw B, Bhai S, Bhashyam AR, O'Donnell EA. Peripheral neuropathies after shoulder arthroscopy: a systematic review. JSES Rev Reports, Tech. 2023;
[40] Pohl A, Cullen DJ. Cerebral ischemia during shoulder surgery in the upright position: a case series. J Clin Anesth. 2005;17(6):463–9.
[41] Yao M, Yang L, Cao Z yuan, Cheng S dan, Tian S lin, Sun Y li, et al. Translation and cross-cultural adaptation of the Shoulder Pain and Disability Index (SPADI) into Chinese. Clin Rheumatol. 2017;36:1419–26.
[42] Coombs P, Ptasznik R, Introcaso J, van Holesbeeck M. Musculoskeletal ultrasound. 2016;
[43] Park J, Chai JW, Kim DH, Cha SW. Dynamic ultrasonography of the shoulder. Ultrasonography. 2018;37(3):190.
[44] Dietrich TJ, Jonczy M, Buck FM, Sutter R, Puskas GJ, Pfirrmann CWA. Ultrasound of the coracoacromial ligament in asymptomatic volunteers and patients with shoulder impingement. Acta radiol. 2016;57(8):971–7.
[45] Wu C, Chang K, Su P, Kuo W, Chen W, Wang T. Dynamic ultrasonography to evaluate coracoacromial ligament displacement during motion in shoulders with supraspinatus tendon tears. J Orthop Res. 2012;30(9):1430–4.
[46] Lin CY, Chou CC, Chen LR, Wu WT, Hsu PC, Yang TH, et al. Quantitative analysis of dynamic subacromial ultrasonography: reliability and influencing factors. Front Bioeng Biotechnol. 2022;10:830508.
[47] Chang KV, Wu WT, Han DS, Özçakar L. Static and dynamic shoulder imaging to predict initial effectiveness and recurrence after ultrasound-guided subacromial corticosteroid injections. Arch Phys Med Rehabil. 2017;98(10):1984–94.

[48] Han DS, Wu WT, Hsu PC, Chang HC, Huang KC, Chang KV. Sarcopenia is associated with increased risks of rotator cuff tendon diseases among community-dwelling elders: a cross-sectional quantitative ultrasound study. Front Med. 2021;8:630009.
[49] Buchner A, Buus T, Evans B, Lambert K, Scheevel L. Comparison of Three-Dimensional Motion of the Scapula during the Hawkins-Kennedy Test and the Sidelying Sleeper Stretch. 2017;
[50] Chang KV, Wu WT, Chen MC, Chiu YC, Han DS, Chen CC. Smartphone application with virtual reality goggles for the reliable and valid measurement of active craniocervical range of motion. Diagnostics. 2019;9(3):71.
[51] Wu WT, Chen LR, Chang HC, Chang KV, Özçakar L. Quantitative ultrasonographic analysis of changes of the suprascapular nerve in the aging population with shoulder pain. Front Bioeng Biotechnol. 2021;9:640747.
[52] Refaat M, Torky A, Salah El Deen W, Soliman S. Comparing Efficacy of Shoulder Ultrasound and Magnetic Resonance Imaging in Shoulder Impingement. Benha Med J. 2021;38(special issue (Radiology)):112–27.
[53] Wood R, Bassett K, Foerster V, Spry C, Tong L. 1.5 tesla magnetic resonance imaging scanners compared with 3.0 tesla magnetic resonance imaging scanners: systematic review of clinical effectiveness. CADTH Technol Overv. 2012;2(2).
[54] El-Shewi IEHAF, El Azizy HM, Gadalla AAEFH. Role of dynamic ultrasound versus MRI in diagnosis and assessment of shoulder impingement syndrome. Egypt J Radiol Nucl Med. 2019;50:1–7.