Review

Ultrasonographic Measures of Subacromial Space in Patients with Rotator Cuff Disease: A Systematic Review

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ABSTRACT: *Purpose.* Recently sonography (US) has been used to measure the subacromial space outlet with a linear measurement of the acromiohumeral distance (AHD). The purpose of this article is to systematically review the literature on the influence of rotator cuff disease (RCD) on AHD using US.

Methods. Computer-aided searches of databases were performed to identify comparative studies that measured US-generated AHD in adults with symptomatic RCD.

Results. Five studies met the inclusion/exclusion criteria.

Conclusions. US images of AHD are smaller in patients with full-thickness tears than healthy individuals and subjects with subacromial impingement. AHD is potentially useful to prognosticate outcome in patients with subacromial impingement. © 2010 Wiley Periodicals, Inc. *J Clin Ultrasound* **39**:146–154, 2011; Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/jcu.20783

Keywords: ultrasound imaging; shoulder; acromiohumeral distance; shoulder impingement syndrome

INTRODUCTION

Rotator cuff disease (RCD) is the most common musculoskeletal shoulder disorder.[1–3] Neer proposed an extrinsic mechanism of RCD with mechanical compression of the rotator cuff tendons under the anterior acromion due to narrowing of the subacromial space (SAS) and termed this subacromial impingement.[4] Compression has also been described on the articular side of the rotator cuff tendons between the posterior glenoid rim and the humeral head, termed internal impingement, and is common in overhead athletes.[5–8] In contrast, evidence of an intrinsic mechanism of RCD also exists, described as intrasubstance tendon breakdown perpetuated by avascularity and repetitive loading.[9–12] In some individuals, extrinsic and intrinsic mechanisms may not be mutually exclusive. The etiology of RCD appears to be multifactorial and remains controversial. Treatment of RCD can be optimized when the underlying contributing mechanisms are addressed. Studies examining the effect of extrinsic and intrinsic mechanisms on the SAS can advance the understanding of the mechanisms of RCD and treatment for patients with RCD.

The SAS is the region between the inferior aspect of the acromion of the scapula and the head of the humerus that contains the tendons of the rotator cuff muscles and subacromial bursa. The SAS has been studied in patients with RCD using MRI[13–15] and radiographs[15–19] with a linear measurement of the distance (in mm) between the inferior acromion and humerus, termed the acromiohumeral distance (AHD). In healthy individuals with the arm resting at the side, the mean AHD is between 10 and 15 mm measured on radiographs.[20] An AHD of less than 7 mm with the arm at rest is indicative of a large RCT and a less than satisfactory outcome with surgery.[16,21] However, in patients with subacromial impingement, AHD was not reduced when measured on radiograph images with the arm at rest[22] and, therefore, may have limited clinical utility in this population. Deficits in AHD related to muscle

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weakness are more likely to be detected during active arm elevation. During active arm abduction, greater narrowing in AHD measured from MRI images has been shown in patients with subacromial impingement than in healthy shoulders.[13,14]

However, not all subjects with RCD may demonstrate narrowing of the AHD because likely not all patients with RCD have an extrinsic compression mechanism.[23] By measuring SAS in patients with RCD, subgroups with a compression mechanism with narrowing of AHD may be identified. To date, the AHD imaged with the arm at rest in patients with RCD has been used in clinical decision-making for the surgical treatment and prognosis of rotator cuff tears.[16,21] However, this is not routine in patients with subacromial impingement as the diagnosis is traditionally based on clinical examination findings. There may be clinical utility of AHD measures during active arm elevation in patients with primary or secondary subacromial impingement to direct treatment and establish a prognosis for conservative surgical treatment and outcome. Currently, the usefulness of sonography (US)-generated AHD measures with active elevation in patients with subacromial impingement is unknown.

More recently US has been used to study the SAS in patients with RCD. US is less costly than MRI,[24] does not have the ionizing radiation effects of radiographs, and has the potential to be a cost-effective clinical tool to measure SAS at the outlet via the AHD. The purpose was to systematically review the literature on measures of AHD and the influence of RCD on AHD as measured with US. Measurement of AHD in patients with RCD using US may provide a cost-effective method to identify the presence of a contributing extrinsic mechanism and potentially be used to guide treatment and establish a treatment prognosis or outcome based on AHD findings.

METHODS

Study selection criteria were established a priori including study population, study design, methodology, and AHD measurement outcomes. The population was defined as adult patients ($\geq$18 years of age) with shoulder pain of any duration related to RCD, impingement, rotator cuff tear, tendinitis, tendinosis, subacromial impingement syndrome, and subacromial bursitis. Studies of both primary and secondary impingement were included due to the multifactorial nature of RCD and potential influence of secondary impingement on the AHD. Studies that used clinical diagnostic criteria to define RCD were included. Studies of only healthy individuals or those with no known pathology were excluded. Studies of participants with other conditions including neurologic disorders such as hemiplegic shoulders, systemic inflammatory conditions such as rheumatoid arthritis, fracture, postoperative shoulder pain, and pain the shoulder region related to cervical, myofascial, and regional pain involving the neck were also excluded. Due to the relatively recent use of US to study AHD, all comparative studies of the defined population to either the uninvolved shoulder or a healthy group were included such as cross-sectional study designs, randomized controlled trials (RCTs), controlled clinical trials, observational cohort studies, and observational case-control studies. To be included, the study must have described the use of US to quantify AHD or acromiohumeral interval as a dependent variable.

Citation Search Strategy

Computer-aided searches of the following databases since their inception up to June 2009 were performed unless otherwise specified: the Cochrane Central Register of Controlled Trials (CENTRAL), PubMed (1966 to June 2009), the Physiotherapy Evidence Database (PEDro), and a combined search of Medline, CIHAHL Plus, and SPORTDiscus using EBSCO Host. Studies included were those published in the English language and available electronically. Abstracts and conference proceedings were not included. Forward searches of relevant studies using the Science Citation Index (SCISEARCH) through Web of Science were also performed. Personal communication with content experts was made. A search strategy that utilized specified combinations of the following keywords in the basic text field index was performed to identify potentially relevant studies: ultrasonography, ultrasound, rotator cuff, rehabilitation, acromiohumeral interval, acromio-humeral distance, acromiohumeral distance, shoulder impingement, subacromial space, and shoulder pain. These keywords were combined using the "AND" and "OR" operators in the following combinations: subacromial space AND ultrasound, acromion humeral distance OR acromiohumeral distance, ultrasonography AND rotator cuff, ultrasonography AND rotator cuff AND rehabilitation, ultrasonography AND shoulder impingement, ultrasonography AND shoulder impingement with limiters set for a comparative study type.

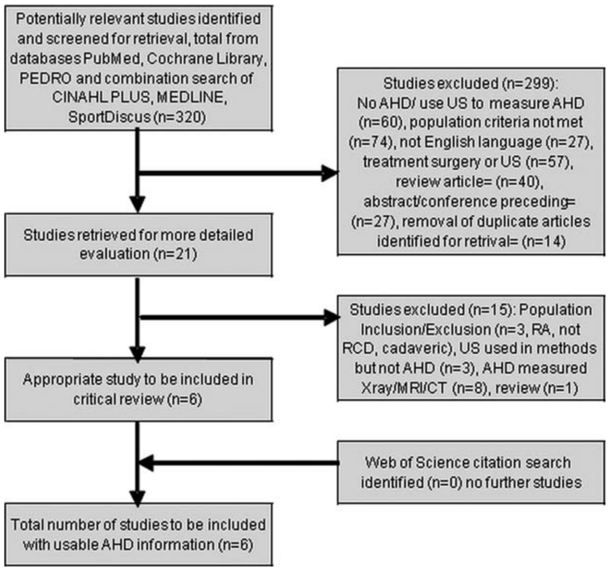

FIGURE 1. Flow diagram of literature search results.

TABLE 1
Standardized Criteria Used for Methodological and Quality Assessment

Criteria List for Methodological Quality Assessment			
A	Were the groups similar at baseline?	Yes	No
B	Is the RCD group specifically defined and valid?	Yes	No
C	Were assessors blinded to group/ side allocation?	Yes	No
D	Defined method for measuring AHD consistent w/previously defined methods?	Yes	No
E	Is the reliability of the AHD measurement method provided?	Yes	No
F	Are the patients described in detail to determine if all eligibility criteria met?	Yes	No
G	Are values for AHD provided separately for each group/ subgroup?	Yes	No

Abbreviations: AHD, acromiohumeral distance; RCD, rotator cuff disease.

Study Selection

With this method, 158 articles were identified for screening in the combined search of Medline, CIHAHL Plus, and SPORTDiscus using EBSCO Host and 162 articles in a separate search of PubMed. No relevant articles were identified in a search of the Cochrane Library or the PEDro database. The titles and abstracts of the potentially 320 relevant articles were then examined. Duplicates, articles not related to the proposed question, population, and methodology were excluded. Articles for which the title, abstract, and keywords provided insufficient information for a decision on selection were obtained. There were 21 studies retrieved for a detailed evaluation, with a total of six articles that met inclusion criteria for this review. A forward search using Web of Science of the six articles identified no additional references suitable for inclusion. Figure 1 depicts the flow diagram of search results.

Data Extraction and Synthesis

The extracted data included subject characteristics (age, gender), the population from which they were sampled, number of subjects, inclusion and exclusion criteria for RCD and comparison groups, methodology for AHD measurement, AHD measurement point estimate and estimate of precision for all groups, and reports of reliability and validity of the AHD measurement.

Studies were reviewed by two independent assessors for methodological quality, homogeneity of methods used to measure AHD, and homogeneity of subject characteristics in RCD and comparison groups using a standardized checklist (Table 1). Studies were not excluded based on these results of qualitative assessment; however, these were considered to derive the conclusion of the primary research question. Last, mean AHD values for the RCD study population and control groups were summarized and synthesized.

RESULTS

Table 2 summarizes the articles included in this systematic review. All were observational case-control studies. Two articles by Azzoni et al[25,26] published in separate journals reported the results of the same study as confirmed by communication with the author. Therefore, this review refers to these two articles by Azzoni et al[25,26] as the results of one study, thus reducing the total number of actual studies in this review to five. Subject characteristics for each group or subgroup are shown in Table 3. One of the five studies explicitly included subjects with secondary impingement,[27] but results were not reported separately from primary impingement. One of the five studies[28] excluded subjects with secondary impingement and multidirectional instability. The subjects in the RCD groups were older than the control groups in the studies by Azzoni et al[25,26] and Desmeules et al.[29] The proportion of males in the RCD and control group(s) was similar in studies by Azzoni et al and Cholewinski

TABLE 2
Summary of Studies Included in Systematic Review

Author	Year	Study Design	N	Primary Population Sampled
Azzoni	2004	Case-control prospective	200	Consecutive patients from orthopedic department (Milan, Italy)
Desmeules	2004	Case-control prospective	20	Patients with SAIS referred to rehabilitation (Canada) Healthy group was sample of convenience
Girometti	2006	Case-control	20	Professional basketball players (Milan, Italy)
Wang	2005	Case-control	70	Nonathletic group sample of convenience university Participants or those in training for the 2001 Collegiate National Baseball World Cup (Taipei, Taiwan)
Cholewinski	2007	Case-control	93	Patients with SAIS from orthopedic outpatient clinic Control group were patients and staff of internal medicine department (Katowice, Poland)

Abbreviation: SAIS, subacromial impingement.

TABLE 3
Summary of RCD and Control Group Subject Characteristics

	RCD Group					Control/Comparison Group				
			Mean Age	Gender			Mean Age		Gender	
Study Author	N	Population with Subgroups	(yr)	M	F	N	Comparative Groups	(yr)	M	F
Azzoni	54	Tendinopathy	55	32	22	70	Healthy	47.5	32	38
	20	PT-RCT	64	6	14					
	26	FT-RCT	63.2	16	10					
Desmeules	7	SAIS referred for rehabilitation	44 ± 3.8			13	Healthy	34 ± 9.0		
Girometti	4	Professional basketball				10	Healthy nonathletic	21.6		
		players with 1° and 2° SAIS	20.4							
	6	Asymptomatic players[a]								
Wang		Injured elite college baseball athletes				16	Healthy nonathletic	21.4 ± 1.2		
	42		20.6 ± 1.8			12	Healthy baseball athletes	20.5 ± 1.4		
Cholewinski	57	Unilateral SAIS >6-mo duration	56	23	34	36	Healthy	57	14	22
						57	Uninvolved shoulder	56	23	34

Mean and standard deviation in years provided for ages when available.
Abbreviations: PT-RCT, partial thickness rotator cuff tear; FT-RCT, full-thickness rotator cuff tear; SAIS, subacromial impingement syndrome; M, male; F, female.
[a]Subject characteristics of asymptomatic and symptomatic players could not be extracted separately.

TABLE 4
Results of Quality Assessment

Criteria List for Methodological Quality Assessment	Azzoni	Desmeulus	Girometti	Wang	Cholewinski
A Were the groups similar at baseline?	No	No	Yes	Yes	Yes
B Is the RCD group specifically defined and valid?	Yes	Yes	No	No	Yes
C Were assessors blinded to group/side allocation?	No	Yes	No	No	No
D Defined method for measuring AHD consistent w/previously defined methods?	Yes	Yes	No	Yes	No
E Is the reliability of the AHD measurement method provided?	Yes	Yes	No	Yes	No
F Are the patients described in detail to determine if all eligibility criteria met?	No	Yes	Yes	No	Yes
G Are values for AHD provided separately for each group/subgroup?	Yes	Yes	No	No	Yes
Total Quality Score	4/7	6/7	2/7	3/7	4/7

et al, while subject gender was not provided in the other three studies.[27,29,30] The results of the quality assessment are shown in Table 4. Methods used to measure AHD on captured US images (Figure 2) are described in Table 5. As shown in Figure 3, the acromion and humeral head were the anatomical landmarks visualized on the US image used to measure AHD in three of the five studies.[25,26,29,30] As shown in Table 5, the reliability of AHD measurements using these landmarks were good. The other two studies[27,28] using the anatomical landmarks of the acromion and greater tuberosity or the humeral head and superior border of the supraspinatus tendon did not provide estimates of reliability. Standardized placement of the US probe with respect to the acromion was described in only two of the studies[29,30]; the probe was placed within 1 cm of the most anterior aspect of the acromion[29] or the midportion of the acromion.[30] All studies measured AHD with the arm positioned at rest; one study included active abduction at 45° and 60°,[29] and one study included passive 90° abduction.[30] Mean/median AHD measurements of all studies are shown in Table 6. Statistically significant differences were reported between groups in AHD in the studies by Azzoni ($p < 0.05$),[25,26] Cholewinski et al ($p < 0.001$),[28] Wang et al ($p < 0.008$),[30] and Girometti et al ($p < 0.05$)[27]; however, AHD values could not be pooled due to methodological differences in AHD measurement and RCD study samples.

DISCUSSION

This systematic review identified differences in SAS between individuals with RCD and asymptomatic individuals as measured via the AHD using US. Differences in the AHD measured with the arm resting at the side were found between RCD and healthy shoulders in four of the five studies.[25–28,30] Consistent with AHD measures from MRI[15] and radiographs,[15–19] AHD measures from US-generated images taken with the arm at rest are smaller in subjects with severe RCD, in particular, full-thickness rotator cuff tears (8.6 mm), compared with healthy controls (10.5 mm)[25,26]; however, there is significant variation in mean AHD values reported for both the RCD (5.6–22.2 mm) and the healthy (8.6–22.7 mm) subjects. Measurement of AHD using US allows for evaluation of SAS with active arm elevation, without exposure to ionizing radiation and more cost-effective than MRI, thus is advocated as a method to detect deficits that exist in patients with less severe RCD, such as subacromial impingement.[29,31] Trends ($p = 0.06$) of greater narrowing of the AHD over multiple angles of active arm elevation were found in the subacromial impingement patients compared with the healthy subjects,[29] consistent with results from previous studies using MRI to measure AHD.[13,14]

The quality assessment (Table 4) specifically addressed issues related to homogeneity and validity of the RCD study population and control group assignment (criteria A, B, and F), methods to control measurement bias including blinding,

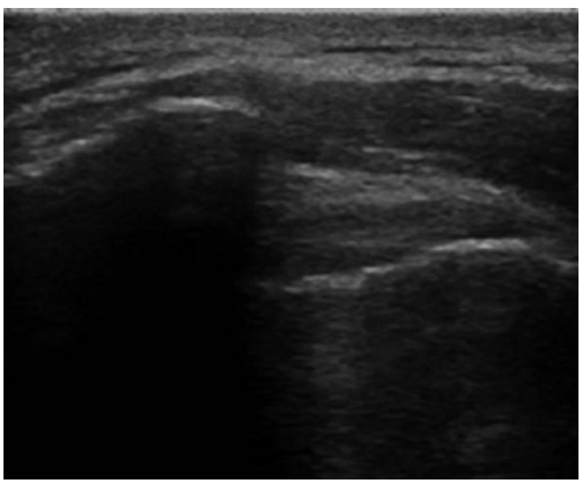

FIGURE 2. Ultrasound image for AHD measurement.

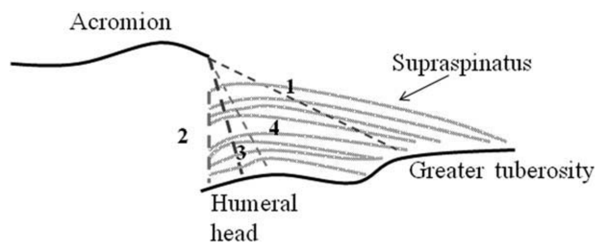

FIGURE 3. Different acromiohumeral distance (AHD) measurement techniques on ultrasound-generated images: **1.** Cholewinski et al[30] measurement using acromion to greater tuberosity of humerus; **2.** Girometti et al[27] measurement using point of entry of tendon into acoustic shadow to humeral head; **3.** Desmeules et al[27] measurement of tangential distance from humeral head to tip of acromion; and Azzoni et al[25,26] measurement from inferior external margin of acromion to nearest aspect of humeral head; **4.** Wang et al[29] measurement from lateral acromion identified by acoustic shadowing to highest point on humerus.

TABLE 5
Summary of AHD Measurement Methods

Author	AHD Landmarks Used for Measurement	Arm Positions	Reliability of Method
Azzoni	Inferior external margin acromion to nearest aspect humeral head	0°	Interrater correlation coefficient $r = 0.80$ ($p < 0.05$)
Desmeules	Tangential distance between humeral head and tip of acromion	0°, active 45°, 60°	Interrater ICC = 0.86 (rest), 0.91 (45°), and 0.92 (60°)
Girometti	Point of entry of tendon to humeral head	0°	
Wang	Lateral acromion at point of acoustic shadowing to highest point on humerus	0°, passive 90°	ICC 0° = 0.91, ICC 90° ABD = 0.81
Cholewinski	Acromion to greater tuberosity of humerus	0°	

Abbreviations: ICC, intraclass correlation coefficient; ABD, abduction.

TABLE 6
Mean and Standard Deviations of Acromiohumeral Distance (AHD)

Author	Group	AHD Values (in millimeters) Passive 0° ABD (in mm)	Active 45° ABD	Active 60° ABD	Passive 90° ABD
Azzoni	Normal	10.5; range 6.9–16.6			
	Tendinopathy	14.4; range 9.6–17.4			
	PT-RCT	10.8; range 6.5–13.1			
	FT-RCT	8.6; range 6.1–12.9			
Desmeules	Healthy	9.9 ± 1.5	8.3 ± 1.9	7.6 ± 1.7	
	SAIS	12.0 ± 1.9	9.5 ± 2.7	9.6 ± 2.3	
Girometti	Nonathletic	8.6 ± 0.83 R; 8.49 ± 0.86 L			
	1° or 2° SAIS[a]	7.19 ± 1.59 R; 7.70 ± 1.46 L			
	Asymptomatic	6.08 ± 1.03 R; 6.63 ± 0.81			
Wang	Nonathletic	5.6 ± 1.5 D; 5.9 ± 2.1 N			6.2 ± 1.6 D; 7.3 ± 2.3 N
	Hx injured[b]	7.8 ± 2.8 D; 8.1 ± 2.7 N			9.6 ± 3.1 D; 9.6 ± 3.3 N
	Uninjured	8.8 ± 3.5 D; 7.9 ± 2.5 N			8.7 ± 3.4 D; 8.7 ± 3.7 N
Cholewinski	SAIS	Median 22.7; range 18.3–29.4			
	Healthy	Median 22.2; range 16.4–34.2			
	Uninvolved	Median 19.4; range 11.2–31.2			

Means and standard deviations provided unless otherwise specified.
Abbreviations: AHD, acromiohumeral distance; mm, millimeters; ABD, abduction; PT-RCT, partial thickness rotator cuff tear; FT-RCT, full-thickness rotator cuff tear; SAIS, subacromial impingement syndrome; L, left shoulder; R, right shoulder; D, dominant shoulder; N, nondominant shoulder; Hx, history.
[a]Symptomatic side consisted of three right shoulders and one left shoulder.
[b]History of injury occurred in the dominant shoulder all but 3 and 27/43 are those with RCD.

consistency of methods for measuring AHD among studies (criteria D), the reliability of these measures (criteria E), and the ability to extract AHD data representing the RCD group (criteria G). The minimum quality score for a study considered in the conclusion of this review was 4/7 total points.

Misclassification Bias: Homogeneity and Validity of RCD and Control Groups

The study sample was evaluated for validity of RCD and control group criteria and assessment of group characteristics for misclassification bias and control of potential confounders (criteria A, B, and F). As shown in Table 3, three studies identified the primary study population as those with RCD[25,26] or impingement syndrome.[28,29] Azzoni et al[25,26] used results of diagnostic US to assign symptomatic subjects into one of three groups: rotator cuff tendinopathy (subacromial impingement), partial-thickness rotator cuff tear, or full-thickness rotator cuff tear. This method of diagnoses using US has been shown to have high sensitivity (97–98%) and moderate specificity (67–80%) when used to diagnose partial- and full-thickness rotator cuff tears when compared with MRI or arthroscopy as the gold standard.[24,32] In studies by Desmeules et al[29] and Cholewinski et al,[28] the primary study population was defined as those with subacromial impingement using the history and physical exam findings to confirm the diagnosis that is consistent with the literature, thus providing face validity to the RCD group selection. However, only the study by Cholewinski et al[28] excluded subjects with secondary impingement and multidirectional instability. For healthy subjects, it was limited to no verification of the absence of RCD.

With regard to subject ages, studies by Choleswinski et al[28] and Desmeules et al[29] did not have comparable ages between groups; the mean age of the subjects with RCD was greater than the healthy subjects. The proportion of males in each group was not similar in two studies[25,26] or was not specified.[29] In the two remaining studies, by Wang et al[30] and Girometti et al,[27] subjects with RCD were a subgroup of the primary study population. Wang et al[30] studied elite male college baseball athletes with subgroups of uninjured and injured athletes, comparing them to a control group of asymptomatic subjects with no previous history of shoulder pain or injury. The control subjects were not participating in sports at a professional level or studying physical education, and the injured athlete subgroup contained those who had suffered shoulder sports injuries or pain. Using this inclusion criterion for the injured group, there is potential for misclassification bias because athletes who were asymptomatic at the time of the study would be included in the injured group. Moreover, Wang et al[30] reported 27/43 shoulder injuries were given a diagnosis of RCD; however, the authors did not specify the methods used to establish the RCD diagnosis. The results of AHD measurements provided for the injured athlete group in this study[30] have potential to represent other diagnoses than RCD. With misclassification bias of this nature, there is potential for regression toward the null when examining differences between injured and healthy groups.

Girometti et al[27] compared AHD in professional basketball players with subgroups of players with shoulder pain and players without shoulder pain. Symptomatic players were diagnosed with primary or secondary impingement based on physical examination findings that were not defined, while asymptomatic players did not have musculoskeletal alterations due to previous shoulder trauma or systemic musculoskeletal diseases, or took steroids or nonsteroidal anti-inflammatory drugs. In this study and the study by Wang et al,[30] the athletes' AHD was examined bilaterally but not reported separately for the involved versus uninvolved shoulder. Therefore, specific AHD measures that represent only the involved shoulder of RCD groups in these studies were not reported.

The varying methodologies used for group classification of the study populations did not allow pooling of the results. To answer the primary research question, two[27,30] of the five studies were not used due to the potential misclassification bias of the RCD groups and thus the inability to extract AHD measurement data of the involved RCD group shoulder. Results of this review include RCD secondary to instability since only one study[28] explicitly excluded this population. Using the remaining studies, there is limited evidence that subjects with full-thickness RCT have reduced AHD as measured with US when compared with healthy individuals. In patients with less severe RCD, specifically subacromial impingement, there is evidence of greater AHD with the arm at rest at the side[25,26,28,29] and trends of excessive reduction in AHD with active arm abduction (45° and 60°)[29] compared with healthy subjects.

Methodology of AHD Measurement, Reliability, and Validity

The US units used were not consistent across all studies; however, all studies used a linear array transducer with frequencies between 5 and 12.5 MHz. The probe placement relative to the anterior, middle, or posterior aspect of the acromion was specified in two[29,30] of the five studies with an anterior probe placement on the acromion in one study[29] and a mid-acromion probe placement in the other.[30] One study[29] reported blinding assessors to the involved shoulder for AHD measurement; however, no study reported blinding assessors to group assignment.

As shown in Table 5, the method of measuring AHD among studies varied with respect to anatomical landmarks used to define the subacromial space. The lack of a consistent standardized method to measure AHD may be another reason for the lack of homogeneity and large variance in AHD measurements among the studies (Table 6). Cholewinski et al[28] reported the greatest AHD values of all studies (median 19.4–22.7), as the AHD measurements were made from the tip of the acromion to the greater tuberosity of the humerus (Figure 3.1). This was the only study that used the greater tuberosity as a bony landmark, which is both inferior and lateral to the humeral head. All the other studies used the humeral head as the distal landmark, which is directly inferior to the acromion as shown in Figure 3.2–4. Interestingly, the greater tuberosity landmark method also had greater variability in the measure and the reliability was not reported. The acromion was used in all studies except that by Girometti et al, who used the superior aspect of the tendon as the superior landmark (Figure 3.2). This method does not account for space available between the superior aspect of the tendon and the inferior margin of the acromion and thus does not truly represent a measurement of the SAS. The remaining three studies by Azzoni et al,[25,26] Desmeules et al,[29] and Wang et al[30] reported similar methods using the same bony landmarks, the acromion, and humeral head (Figure 2.3–4), and the reliability reported was good.

Concurrent validity of AHD measures using the acromion and humeral head landmarks was demonstrated by Azzoni et al, with high correlations (r = 0.80–0.85, $p < 0.05$) between the mean AHD measures using radiographs and those from US in the normal, tendinopathy, and partial-thickness RCT groups.[26] There is good reliability and concurrent validity of AHD measures with radiographs.[25] Two-dimensional measures of SAS, such as AHD measures with radiographs or US, do not represent the entire volume of the SAS. Moreover, two-dimensional images of SAS have been criticized due to potential errors induced with scaling, projection, and superimposition of the humerus and acromion[33,34]; however, it has been demonstrated that standardization of a two-dimensional measure of AHD can yield reliable results.[35,36]

Of the three studies[25,26,29,30] using a reliable method of AHD measurement, two[25,26,29] did not have threats of misclassification bias within RCD groups and provided values of AHD measures separately for the involved shoulder. Azzoni et al[25,26] reported statistically significant differences in AHD among the four various levels of RCD ($p < 0.05$) with the arm at rest; AHD was smaller in subjects with full-thickness rotator cuff tears (mean AHD = 8.6 mm) compared with subjects with impingement (mean 14.4 mm) and healthy controls (10.8 mm). Desmeules et al[29] found that despite increased AHD at rest in the subjects with subacromial impingement, there were trends of excessive narrowing when the arm was elevated to 45° and 60° of abduction compared with the healthy controls ($p = 0.06$). These results were underpowered to provide statistical significance; however, a sample size of n = 18 would have provided adequate statistical power. Findings of excessive narrowing of AHD in subjects with subacromial impingement are consistent with previous literature.[13,14,37] Additionally, Desmeules et al found that subjects with subacromial impingement who did not demonstrate excessive narrowing of the AHD with active arm elevation did not demonstrate improvements in pain and function following rehabilitation. Patients who demonstrated excessive narrowing of the AHD (>2.5 ± 1.1 mm) had significant improvements in function with rehabilitation; thus, the AHD may have the potential to identify patients with subacromial impingement most likely to benefit from rehabilitation.

We are unable pool data from the five studies, thus limiting the strength of the conclusions. However, US appears to have the potential to be a reliable and useful method to measure AHD in patients with RCD. The measurement of AHD via US-generated images can potentially be used to further define the mechanism of RCD as to whether an extrinsic mechanism is present. US is less costly than MRI,[24] does not involve ionizing radiations, and has the potential to be a cost-effective clinical tool to measure SAS at the outlet via the AHD. US imaging can be used repeatedly without risk to the patient, thus US-generated measures of AHD may be clinically useful in patients with subacromial impingement to monitor and prognosticate the outcome of treatment. Consistent with other imaging studies,[13,14] this review suggests AHD measured via US-generated images is altered in patients with RCD. Further study is necessary to determine the usefulness of US for clinical decision-making in patients with subacromial impingement to guide treatment, establish prognosis, or monitor outcome.

CONCLUSION

Studies using US to quantify SAS via AHD measurements in patients with RCD suggest RCD does influence the AHD.[25–30] US-generated AHD measurements taken with the arm at rest are smaller in patients with full-thickness RCT, compared to healthy controls or subacromial impingement.[25,26] Patients with less severe RCD, specifically subacromial impingement, demonstrate trends of greater narrowing of the AHD when the arm is actively elevated compared to healthy controls.[29] Further study of AHD with active arm elevation in patients with RCD is warranted to further determine optimal treatment (conservative versus surgical) and potentially predict treatment outcome.

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