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Long-term follow-up of patients with a high critical shoulder angle and acromion index: is there an increased retear risk after arthroscopic supraspinatus tendon repair?

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Background: The effect of the acromion index (AI) and critical shoulder angle (CSA) on the short-term healing rate after arthroscopic repair of the supraspinatus tendons is already known. Long-term effects have not been published yet.
Purpose: Long-term evaluation of the effect of the AI and CSA on the postoperative healing rate and clinical results after arthroscopic repair of the supraspinatus tendon.
Methods: Patients with a symptomatic, single-tendon, full-thickness supraspinatus tear in whom nonoperative management had failed were treated with an arthroscopic repair. Preoperative radiographs were used to measure CSA and AI. Eight years postoperatively, magnetic resonance imaging (MRI) studies were performed and evaluated on repair integrity. Patient-reported outcome measurements were collected pre- and postoperatively.
Results: Thirty-one patients were evaluated 8 years postoperatively. The mean age at the time of surgery was 61 ± 9 years. MRI evaluation showed that 20 patients (65%) had an intact repair and 11 (35%) had a full-thickness retear. No significant differences were found between the intact and retear groups regarding age ($P = .605$), initial tear size ($P = .485$), retraction grade ($P = .439$), and all PROMs. The mean CSA for the intact group (33° ± 1°) was significantly lower than the CSA in the retear group (38° ± 1°; $P = .004$). Eighteen patients (58%) had a CSA ≥35°, and 9 (50%) among them had a retear and 9 (50%) had an intact repair.
The mean AI for the intact group (0.72 ± 0.11) was significantly lower than the AI in the retear group (0.81 ± 0.08 ; $P = .021$). Seventeen patients (55%) had an AI ≥0.75, and 9 (53%) among them had a retear and 8 had an intact repair. If the AI was ≥0.75, the odds ratio of having a retear was 6.19 ($P = .045$). No progressive worsening of PROMs and clinical results could be demonstrated related to a higher CSA or AI during the entire follow-up.
Conclusion: At long-term follow-up, a higher CSA has the tendency to have an increased rate of retear after arthroscopic supraspinatus tendon repair, but this was not significant. A higher AI significantly increased the retear risk. A higher CSA and AI did not impair the clinical results over time. An AI ≥0.75 was associated with a 6-fold increase in risk of retear after arthroscopic supraspinatus tendon repair.

Rotator cuff tears (RCTs) are regularly encountered in daily orthopedic practice. These RCTs can result in decreased mobility and strength of the upper limb, sleep quality, and other symptoms.[11,20] Treatment of these RCTs can be both conservative and surgical.[21] Surgical repair is associated with high failure rates.[18] Some risk factors are already known. Patient's age is one of the most important risk factors.[7,13,24] Other important risk factors are initial tear size and fatty infiltration.[12,35] Anatomic risk factors are also reported. Neer[30] was the first to describe the influence of the intrinsic anatomy of the scapula, specifically the role of the acromion-anatomy and the correlation with disability and degenerative tears of the rotator cuff (RC). Other studies mentioned the influence of the lateral extension of the acromion[31] and the inclination of the glenoid fossa.[17,42] Taking these factors into account, radiographic measurements were developed to evaluate these factors: among these, the acromial index (AI) and the critical shoulder angle (CSA)[28,31] are commonly used.

This prospective study was approved by the Ethical committee of AZ Delta hospital at Roeselare (Belgium). Written consent was obtained from all participants. (Belgium Clinical Trial Number: B117201836044).

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Recent studies have shown the relationship of the CSA and the AI and their role in the incidence of RCTs.[10,25] They state that an increasing CSA and AI are associated with an increasing incidence of RCTs.[15,38] Some studies question the value and clinical importance of the CSA and the AI.[8,27] They often state that the reliability of measuring the CSA and AI is low. Nevertheless, assessing the CSA and AI could be helpful during diagnostic evaluation of patients with shoulder pain and can help predict the pathology.

Interestingly, the CSA and AI are also associated with the outcome of rotator cuff repair. Most literature, however, reports a maximum follow-up of 3 years.[14,25,35] A high CSA and AI may be associated with an increasing retear rate following arthroscopic repair.[10,14,25,35,36] However, most studies only evaluated the short-term correlations between these radiographic measurements and the risk of retear after rotator cuff repair. The purpose of this study was to evaluate the long-term effect (±8 years) of CSA and AI on the postoperative healing and clinical evolution throughout time. More specifically, Is there a further impairment between 3 and 8 years postoperatively? Our hypothesis was that an increased CSA or AI would be associated with a progressive risk of retear and ongoing deterioration of clinical outcomes throughout time.

Methods

Patient selection

The patients in this prospective study were recruited from the study of De Roo et al[9] in which 130 patients were included. All patients between 40 and 75 years at the time of surgery were invited to participate. In order to reduce variables, inclusion criteria were a single tear of the supraspinatus tendon repaired in a consistent way with no history of surgery on the same shoulder. Patients were excluded if they had a concomitant disease such as acromioclavicular (AC) arthritis in need of acromioclavicular resection or other tendon involvement. After application of these strict inclusion criteria, a homogeneous subgroup of 37 patients could be included. Of these 37 patients, 31 could be reached for full clinical and technical workup, all of whom were investigated at final follow-up. None of these patients had responded to nonoperative management, including a trial of physical therapy.

Surgical technique

One surgeon (S.M.) performed all operations. The patient was seated in a beach chair position. An arthroscopic double-row technique with 1 or 2 medial screw anchors (ALLthread; Biomet, Warsaw, IN, USA) and 1 or 2 lateral-row plug anchors (Poplock; Linvatec, Largo, FL, USA) was performed. In all patients, an anterior subacromial decompression was performed according to Bigliani et al: postoperation, all patients had a Bigliani type 1 acromion.[4] As no massive tears were included, all patients received immediate passive mobilization therapy under supervision of a physiotherapist. An abduction pillow was worn for at least 4 weeks. Active assisted therapy was started after 6 weeks. Strengthening exercises of the RC muscles were started at 8 weeks postoperatively.

Clinical scores

Preoperative as well as postoperative outcome measures after 8 years of surgery on average were assessed. The Simple Shoulder Test, Shoulder Pain and Disability Index, the University of California at Los Angeles Shoulder Score (UCLA Shoulder Score), and Constant-Murley Score were used.

Radiographic assessment

Preoperative anteroposterior radiographs were used. They all suited the criteria for correct anteroposterior radiographs to measure the CSA and AI.[40] On these anteroposterior radiographs, the CSA and AI were measured by 2 independent residents (G-J.O. and L.V.) The CSA was measured as the angle between a line connecting the upper and lower margin of the glenoid and a line from the inferior margin of the glenoid to the most inferolateral point of the acromion.[28] The AI was defined as the ratio of the distance from the glenoid plane to the acromion to the distance from the glenoid plane to the lateral aspect of the humeral head[31] (Fig. 1).

The magnetic resonance imaging evaluation was on average performed 8 years postoperatively. An independent radiologist evaluated the quality of healing of the rotator cuffs. First, the radiologist evaluated the integrity of the repair using the classification of Sugaya et al.[39] Type IV and V according to the Sugaya classification were considered as full-thickness retear.[25] The others (I-III) were classified as intact repair.

Statistical method

All analyses were performed with SPSS, version 26 (IBM, Armonk, NY, USA). The data were summarized using mean and standard deviation. Patients were grouped according to repair integrity. The first group had an intact repair on radiographic assessment. In the second group, the repair was not intact any more. The independent Student *t* test was used for comparing differences between the groups regarding age, initial sagittal tear size, retraction grade, and clinical outcome scores. Spearman correlation coefficient was used to evaluate repair integrity with CSA and AI. The odds ratios for risk of failure with a CSA cutoff of 35° and those with AI cutoff of 0.75 were calculated using logistic regression. Patient-reported outcome measurements were compared using paired samples *t* test and 1-way analysis of variance. Statistical significance was defined as a *P* value <.05. Results were reported as mean ± standard deviation.

Results

Descriptives

Thirty-one patients were evaluated 8 (±1) years postoperatively. Twenty-three were women (74%) and 8 were men (26%). The mean patient age at the time of surgery was 61 years (±9 years). Preoperatively, 3.2% of the patients had a retraction grade of 0 (Patte et al[33]), 64.5% had grade 1, and 32.3% had grade 2. The mean preoperative tear size was 3.13 cm (±0.72 cm) in the sagittal plane.

Radiographic assessment 8 years postoperatively showed that 20 (65%) had an intact repair (Sugaya types I-III) and 11 (35%) had a retear (Sugaya types IV and V). The preoperative fatty infiltration was not measured as not all patients consistently got computed tomography / magnetic resonance imaging preoperatively. The postoperative fatty infiltration of the supraspinatus muscle was also evaluated and classified according to Goutallier classification.[37] There were no significant differences between any of the groups (Table I).

No significant differences were found between the group with an intact repair and those with a retear regarding age ($P = .605$), initial tear size ($P = .485$), and retraction grade ($P = .439$). No significant correlation was found between outcome and age ($P = .716$), initial tear size ($P = .485$), and retraction grade ($P = .468$).

Clinical outcome scores

There were no significant correlations between the CSA (Table II) and all the clinical outcome measures; furthermore, no

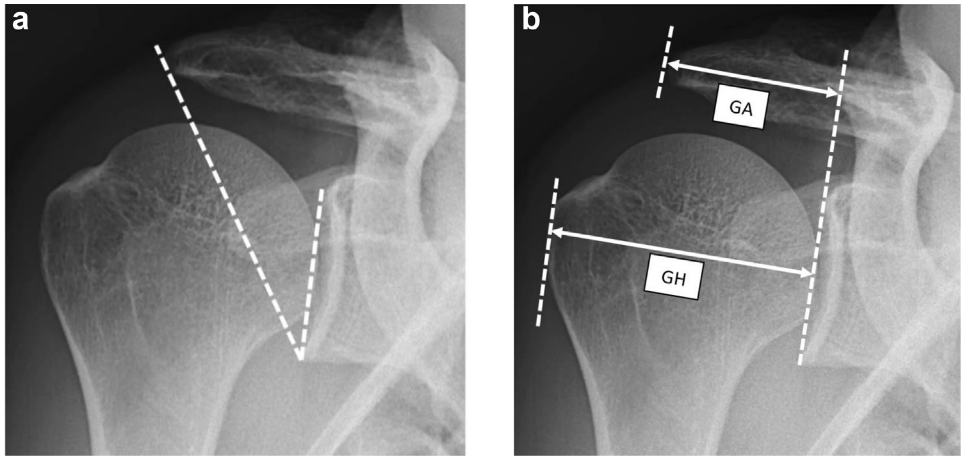

Figure 1 Overview of the radiologic parameters assessed in the study. (**a**) Critical shoulder angle: The angle between a line connecting the upper and lower margin of the glenoid and a line from the inferior margin of the glenoid to the most inferolateral point of the acromion. (**b**) Acromion index: ratio of the distance from the glenoid plane to the acromion (GA) to the distance from the glenoid plane to the lateral aspect of the humeral head (GH).

Table I
Postoperative fatty infiltration in function of CSA and AI according to Goutallier classification

	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4		Grade 0	Grade 1	Grade 2	Grade 3	Grade 4	*P*
CSA <35°						CSA ≥35°						
FI supraspinatus	3	8	2	0	0	FI supraspinatus	4	8	5	1	0	.645
FI infraspinatus	5	8	0	0	0	FI infraspinatus	5	8	2	3	0	.230
FI teres minor	9	4	0	0	0	FI teres minor	11	5	1	1	0	.672
FI subscapularis	9	4	0	0	0	FI subscapularis	12	6	0	0	0	.880
AI <0.75						AI ≥0.75						
FI supraspinatus	4	8	1	0	0	FI supraspinatus	3	7	6	1	0	.228
FI infraspinatus	4	9	0	0	0	FI infraspinatus	6	6	2	3	0	.135
FI teres minor	9	4	0	0	0	FI teres minor	11	4	1	1	0	.638
FI subscapularis	10	3	0	0	0	FI subscapularis	11	6	0	0	0	.469

CSA, critical shoulder angle; *AI*, acromion index; *FI*, fatty infiltration.

Table II
Functional outcome scores preoperatively and 4 months and 8 years postoperatively

	Preop	4 mo postop		8 yr postop		*P* (preop vs. 8 yr postop)
	Mean (SD)	Mean (SD)	*P* (preop vs. 4 mo postop)	Mean (SD)	*P* (4 mo vs. 8 yr postop)	
CSA <35° (n = 13 patients)						
Constant-Murley	64.17 (23.76)	68.55 (26.85)	.349	89.41 (8.30)	.020	.007
Simple Shoulder Test	5.92 (2.87)	9.00 (2.98)	.008	9.73 (2.94)	.586	.012
Shoulder Pain and Disability Index	48.42 (29.68)	17.11 (15.35)	.014	33.43 (23.77)	.083	.663
UCLA score	17.33 (6.43)	26.80 (6.88)	.002	28.91 (7.13)	.570	.006
CSA ≥35° (n = 18 patients)						
Constant-Murley	70.67 (15.75)	72.28 (22.72)	.765	87.96 (13.91)	.030	.010
Simple Shoulder Test	6.72 (3.20)	9.12 (2.62)	.013	10.50 (2.28)	.121	.000
Shoulder Pain and Disability Index	45.67 (16.82)	21.80 (21.66)	.002	25.83 (30.93)	.500	.115
UCLA score	18.17 (5.07)	25.59 (6.56)	.000	26.39 (11.18)	.932	.010
All patients (n = 31)						
Constant-Murley	68.55 (19.13)	75.57 (13.87)	.473	88.53 (11.86)	.001	.000
Simple Shoulder Test	6.51 (2.85)	9.23 (2.36)	.000	10.21 (2.53)	.118	.000
Shoulder Pain and Disability Index	60.79 (24.80)	19.96 (19.84)	.000	19.43 (26.65)	.227	.123
UCLA score	19.32 (5.14)	26.71 (5.60)	.000	27.34 (9.78)	.714	.000
P (between the groups)						
Constant-Murley	.374	.692		.759		
Simple Shoulder Test	.488	.916		.434		
Shoulder Pain and Disability Index	.748	.576		.584		
UCLA score	.695	.653		.511		

CSA, critical shoulder angle; *UCLA*, University of California at Los Angeles Shoulder Rating Scale; *preop*, preoperative; *SD*, standard deviation; *postop*, postoperation.

significant correlations were found for the AI (Table III) and all the clinical outcome measures. In addition, none of the clinical outcome measures were significantly different between the no-tear group and the retear group.

All mean functional outcome scores, except the Shoulder Pain and Disability Index, improved significantly at an average follow-up of 8 years compared with the preoperative scores. This significant improvement is already seen 4 months postoperatively. No

Table III
Functional outcome scores preoperatively and 4 months and 8 years postoperatively compared between patients with AI <0.75 and those with AI ≥0.75

	Preop	4 mo postop		8 yr postop		*P* (preop vs. 8 yr postop)
	Mean (SD)	Mean (SD)	*P* (preop vs. 4 mo postop)	Mean (SD)	*P* (4 mo vs. 8 yr postop)	
AI <0.75 (n = 14 patients)						
Constant-Murley	58.33 (24.67)	65.91 (25.39)	.195	91.55 (8.12)	.004	.003
Simple Shoulder Test	5.42 (3.55)	8.20 (3.05)	.035	10.63 (2.16)	.031	.000
Shoulder Pain and Disability Index	55.00 (27.01)	21.80 (18.61)	.009	21.17 (22.99)	.846	.118
UCLA score	16.17 (6.58)	24.70 (7.53)	.012	29.18 (9.76)	.307	.001
AI ≥0.75 (n = 17 patients)						
Constant-Murley	74.24 (11.48)	73.94 (23.98)	.953	86.31 (13.64)	.089	.027
Simple Shoulder Test	7.00 (2.62)	9.81 (2.32)	.003	9.82 (2.79)	.879	.009
Shoulder Pain and Disability Index	41.25 (17.98)	18.54 (21.22)	.004	32.08 (30.33)	.138	.476
UCLA score	18.76 (4.71)	27.00 (6.20)	.000	25.71 (9.94)	.552	.035
P (between the groups)						
Constant-Murley	.027	.405		.282		
Simple Shoulder Test	.178	.139		.420		
Shoulder Pain and Disability Index	.110	.704		.447		
UCLA score	.225	.405		.371		

AI, acromion index; *UCLA*, University of California at Los Angeles Shoulder Rating Scale; *preop*, preoperative; *SD*, standard deviation; *postop*, postoperation.

significant further improvement is seen between 4 months and 8 years postoperatively, in general, except for the Constant-Murley score.

If we compare patients with a CSA <35° to those with a CSA ≥35°, no significant differences are found at any time postoperatively for all scores. The outcome scores 8 years postoperatively are almost all significantly better than preoperatively (Table II). An elevated CSA did not cause a progressive clinical deterioration in the long run as compared to a lower one.

All this also applies to the comparison of the patients with an AI <0.75 and those with an AI ≥0.75 (Table III).

Radiographic outcome

The mean CSA for all patients was 35° ± 5°. The average CSA was 33° ± 1° in the no-tear group and 38° ± 1° in the retear group. The mean CSA in the retear group is significantly higher than that for the intact group ($P = .004$) (Table IV). Eighteen patients (58%) had a CSA ≥35°, and 13 (52%) had a CSA <35°. In the group with a CSA ≥35°, 9 patients (50%) had a retear and 9 patients (50%) had an intact repair. In the group with a CSA <35°, only 2 patients had a retear. If the CSA is ≥35°, the odds ratio of having a retear was 5.50, but this was not significant ($P = .059$). A significant positive correlation was found between the CSA and prevalence of retear, but this correlation was low ($r = 0.36$; $P = .049$).

The mean AI was 0.75 ± 0.11. The AI was on average 0.72 ± 0.11 in the no-tear group and 0.81 ± 0.08 in the retear group. The mean AI was significantly higher in the retear group ($P = .021$) (Table IV). Seventeen patients (55%) had an AI ≥0.75, and 14 patients (45%) had an AI <0.75. In the group with an AI ≥0.75, 9 patients (53%) had a retear and 8 patients had an intact repair. In the group with an AI <0.75, only 2 patients (14%) had a retear. If the AI is ≥0.75, the odds ratio of having a retear was 6.19 ($P = .045$). A significant positive correlation was found between the AI and the prevalence of retear, but this was again low ($r = 0.39$; $P = .035$).

Discussion

The overall recurrent tear rate after 8 years of follow-up was 35% in this study. This is similar to previously published studies.[3,14,23,41] They showed retear rates between 17% and 33%.

In this study, the CSA was significantly correlated with the postoperative healing state. Interestingly there was no correlation with retears regarding age of the patient, initial tear size, and retraction grade. The study of Scheiderer et al[35] found similar results. In our study, this might be partly due to the patient selection of our cohort where we opted to choose a homogeneous subgroup to rule out an excess of variables. The accent of this study lies on the long-term relationship between the CSA/AI and the healing rather than the effect of those other variables. Some other studies sufficiently showed that patient's age, initial tear size, and retraction grade, however, significantly influence postoperative healing outcomes.[22,26,34,41] Previous studies showed that a CSA ≥35° leads to a higher chance in developing degenerative tears of the RC.[6,28,32,35,38] Also, Scheiderer et al[35] reported a significant increase in retear risk with a CSA ≥38° and similarly confirmed that the CSA is a predictor of postoperative healing and affects postoperative retear rates. In our study, a CSA ≥35° is associated with a 5-fold increase in risk of retear at 8 years of follow-up, but this was not significant ($P = .059$). Scheiderer et al[35] noted a 4-fold increase in risk of retear 6 months postoperatively in patients with a CSA ≥38°. Another study[14] showed a 14-fold increase in risk of retear even at short-term follow-up with a CSA ≥38°. Our hypothesis that a CSA ≥35° would cause impaired clinical results in the long term as compared to a CSA <35° could, however, not be proven.

In addition, the AI is known to be associated with a higher incidence of degenerative RCTs.[2,29,32] Recent studies have shown that the AI also is a predictor of the postoperative healing properties of arthroscopic RC repair.[35,44] This was confirmed in our study: the AI was significantly correlated with the outcome of repair integrity. An AI ≥0.75 was associated with a 6-fold increase in risk for retear at 8 years. Another study[35] showed an almost 2-fold increase 6 months postoperatively. Not all studies, however, support this statement of a wide lateral extension of the acromion as a risk factor for failure after arthroscopic repair.[14,27] Also, for the AI, we could not prove our hypothesis that in the long term clinical results would deteriorate more for the patients with an AI ≥0.75 than those with an AI <0.75.

Table IV
Mean preoperative CSA and AI based on postoperative repair integrity

	Intact group	Retear group	*P* value
	Mean (SD)	Mean (SD)	
CSA (°)	33 (1)	38 (1)	.004
AI	0.72 (0.11)	0.81 (0.08)	.021

CSA, critical shoulder angle; *AI*, acromion index; *SD*, standard deviation.

The CSA is a combination of glenoid inclination and the lateral extension of the acromion. This implies that the CSA's correlation with failure of repair is partially derived from the extension of the acromion. Surgeons can influence the CSA by performing a lateral acromioplasty to reduce the lateral extension of the acromion.[1,19] In the end, one could interpret these studies as a suggestion that the reduction in lateral extension of the acromion reduces the risk of retear after arthroscopic RC repair. This statement was confirmed in several studies.[1,19,35] In our study, we did not perform a lateral resection, only an anterior acromioplasty. But recent studies showed that an anterior acromioplasty does change the CSA. In this manner, an anterior acromioplasty could also prevent the development of degenerative rotator cuff tears.[5,16]

Zakko et al[43] observed differences in rates of retear between compliant (11% retear) and noncompliant (38% retear) patients during rehabilitation. In contrast, in our study, there is a very low probability that differences in compliance of the postoperative rehabilitation would be responsible for the variation in results as these patients were closely followed in view of a previous study on rehabilitation after RC repair.[9]

Limitations

The small size of our study population might certainly be an issue. This is partly due to the limited response of our cohort that has become older, less mobile, and sometimes not willing to have an invasive arthrography. Another reason for the small cohort is that we wanted to have full focus on the long-term effect of the CSA and AI by limiting the large number of variables that influence the outcome of RCT repair. Size of the tear is one of the most important factors that led us to use strict inclusion criteria in order to rule out any effect of size and degeneration of the cuff by choosing a homogeneous isolated supraspinatus repair group without any local morbidity or treatment thereof. An important limitation is that we did not exclude possible confounding variables such as smoking and diabetes. Another remark on our study might be that a long-term follow-up might not add any knowledge, as the risk of retear in a CSA $\geq$35° is already increased at short-term follow-up of a few years. So in the long term, one can indeed expect that this is equally true but we think that our study is even more trustworthy in confirming the specific effect of the CSA and this with long-term risk figures that have not been published before. An additional limitation of long-term follow-up is that retears also could be influenced by normal ageing. A recent systematic review by Saccomanno et al[34] has confirmed this aspect. It is also difficult to prove that the risk of retear would increase progressively in the long term as most other studies show less strict inclusion criteria and therefore are difficult to compare. After all, a retear or a poor clinical outcome might not exclusively be due to the raised CSA or AI alone. Finally, we failed to prove our hypothesis that an elevated CSA or AI would also cause worse clinical outcome in the long run. However, we are the first to publish that there does not seem to be such a long-term clinical consequence even if the structural integrity of the repair might have failed in this elevated CSA/AI population.

Conclusion

At long-term follow-up, a higher CSA has the tendency to have an increased rate of retear after arthroscopic supraspinatus tendon repair, but this was not significant. A higher AI too significantly increases the retear risk. Higher CSA and AI did not impair the clinical results over time. An AI $\geq$0.75 was found to be associated with a 6-fold increase in risk of retear after arthroscopic supraspinatus tendon repair.

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