Do Acromiohumeral Centre Edge Angle and Greater Tuberosity Angle Correlate With the Full-Thickness Degenerative Supraspinatus Tear?

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Abstract

Background: Many radiographic parameters associated with the extrinsic cause of supraspinatus tear have been proposed. The aim of this study was to correlate the relationship between full-thickness degenerative supraspinatus tear (FTDST) and the patient's radiographic parameters, including the acromiohumeral centre edge angle (ACEA) and the greater tuberosity angle (GTA).

Methods: A retrospective study was conducted. We included 116 patients who had undergone shoulder arthroscopic surgery at our institute. The case group included FTDST patients, while the control group also included patients without evidence of supraspinatus tear. In each patient, the ACEA and GTA values were measured and analysed by two independent observers. Intra-inter observer reliability was assessed. Multivariate regression analysis was performed.

Results: The ACEA values were significantly higher in FTDST, with a mean of 26.44°± 9.83° compared with 16.81° ± 7.72° in the control group ($P < 0.001$). Multivariate regression analysis also showed that higher ACEA values were associated with a FTDST (odds ratio 1.16 per degree, $P = 0.01$). Meanwhile, for GTA values, a statistically significant difference was found with a mean of 70.92° ± 6.64 compared with 67.84° ± 5.56 in the control group ($P = 0.02$). However, Stepwise regression analysis rejected GTA as a predictor for FTDST.

Conclusions: Our study demonstrated that the presence of higher ACEA values is an independent significant risk factor for the presence of FTDST. Consequently, GTA values may be less helpful in assessing the risk of FTDST, especially in this specific population.

Background

Rotator cuff tear (RCT) is a common cause of chronic shoulder pain and disability (1). Extrinsic causes for RCT are usually associated with subacromial impingement (2), defined by the supraspinatus (SSP) tendon becoming entrapped between the acromion process and the greater tuberosity. As concern about SSP pathology increased, many previous studies focused on excessive lateral acromial coverage and confirmed that it is associated with a higher incidence of RCT (3-5). Regardless, the complex interlinkage of these acromial morphology parameters with RCT is still under extensive exploration. Recently, Singleton et al. (6) introduced the acromiohumeral centre edge angle (ACEA), a new measurement to be used with true AP shoulder radiography. The lateral projection of the acromion coverage humeral head, as a valid measurement with good reproducibility, has an accuracy comparable to measurement using a computed tomography scan. The results showed that the ACEA value was significantly higher in patients with RCT. However, because the Singleton et al. study only included acute traumatic RCT, the usefulness of ACEA in predicting degenerative RCT is still questionable. Furthermore, the subacromial impingement process necessarily comprises two sides of the bony structure, making evaluation of both bony sides, the acromion, and the greater tuberosity (GT) equally important. GT morphology still plays an important role in subacromial impingement. Some studies report that a displaced malunion GT was related to the worst outcome (7) and that the tuberosity procedure may provide a satisfactory result for irreparable massive rotator cuff tear (8). Additionally, the greater tuberosity angle (GTA), a new radiographic marker that evaluates the GT's position proposed by Cunningham et al., has been advocated as a reliable predictor marker for RCT. They suggested that the development of degenerative RCT (9) was associated with a higher GTA values. However, their study group included both participants with partial-thickness RCT and participants with full-thickness RCT. According to a recent study (10), some acromion parameters are associated with full-thickness but not with partial-thickness RCT. For this reason, the specific full-thickness degenerative supraspinatus tear (FTDST) subgroup correlation with these parameters should be determined. Hence, no previous study has considered any of these values, including ACEA and GTA, as a specific tool to be used with patients with FTDST. Moreover, the literature contains limited information about these parameters, especially those pertaining to a Southeast Asian population. Certain authors have attempted to evaluate the correlation of both parameters to the incidence of FTDST and analyse any association of both parameters with patients' demographic data and arthroscopic findings. The primary objectives of our study were (1) to evaluate the presence of significant differences regarding the ACEA and the GTA values among patients with or without FTDST and (2) to assess the association between any of these parameters with other variables, such as age, sex, and SSP tear retraction. The hypothesis was that higher values for ACEA and GTA would be associated with a higher likelihood of detecting FTDST.

Materials And Methods

Sample

A retrospective study was conducted in Ramathibodi Hospital, Mahidol University, Thailand. The medical records of all patients who had undergone shoulder arthroscopic surgery between April 2016 and July 2018 were collected. All pre-operative true AP shoulder radiographs were analysed. The patients selected were divided into two groups. The case group consisted of individuals presenting with a clinical diagnosis of FTDST, which was confirmed by history, preoperative-magnetic resonance imaging (MRI) scans, and intraoperative arthroscopic findings. The control group consisted of those with shoulder pain without any finding of RCT based on history; physical examination; preoperative-MRI scans; and arthroscopic findings, such as labral injury, shoulder instability, and primary adhesive capsulitis. Patient demographic data included age, gender, bicep pathology, fatty degeneration of the SSP by Goutallier staging (11), and SSP tear retraction in the frontal plane grading by Patte classification (12).

Inclusion criteria&exclusion criteria

The inclusion criteria were that the patients had a pre-operative true AP shoulder radiograph with the proximal humerus in an acceptable rotation of the affected shoulder. The exclusion criteria included partial-thickness RCT, any history of traumatic event to exclude any potential traumatic aetiology, previous surgery, fractures, and/or dislocation around the shoulder, congenital shoulder deformity, shoulder tumours, or infection. Patients with any evidence of osteoarthritis change in the glenohumeral joint were also excluded due to the possibility of producing outliers of these parameters.

Patients meeting the inclusion and exclusion criteria were recruited. Therefore, the final sample comprised 116 patients who were enrolled into the study. The case group included 84 patients, and the control group included 32 patients. The studied population was Thai and exclusively Southeast Asian. This study was ethically approved by our hospital's institutional research board committee (IRB number MURA2018/837). All methods in the study were carried out in accordance with the Helsinki guidelines and relevant CIOMS guidelines.

Data collection & outcome measurement

ACEA and GTA measurements were determined on true AP shoulder radiographs and described, as shown in Fig. 1. The ACEA is defined as the angle between a line drawn superiorly from the centre of the humeral head parallel to the glenoid and a line from the centre of the humeral head to the acromion's outer edge (Fig. 1B) (6). The GTA represents the angle between a line parallel to the humerus diaphysis passing through the centre of rotation of the humeral head and a line connecting the upper edge of the humeral head to the most superolateral edge of the GT (Fig. 1C) (9). All measurements were performed by two independent assessors: an orthopaedic surgeon specializing in the shoulder and a radiologist specializing in musculoskeletal imaging) using a goniometer tool in the Picture Archiving and Communication System (PACS). Both were blinded from intra-operative findings. Then a repeated measurement was performed with one-month interval. Inter-observer and intra-observer reproducibility was determined.

In an effort to avoid the effect of the rotation of the proximal humerus, the parameters were measured on the true AP shoulder radiograph. Each patient was placed in a supine position with the arm adducted to the side and in a neutral position. Rotation in the axial plane was accepted up to ± 20. This protocol was due to unchanged ACEA and GTA parameters in this rotation range according to previous studies (6, 9).

Statistical analysis

Statistical analyses were calculated using Stata 16 software (StataCorp, College Station, TX, USA). The difference in the ACEA and GTA of the case and control groups was determined using independent t-tests. Correlations between parameters and age were assessed with the Pearson correlation coefficient method. Receiver operating characteristic (ROC) analysis curves were devised to determine the diagnostic ability of these parameters. Multivariate adjusted analysis by logistic regression analysis was used to determine each factor for the occurrence of FTDST with respective odds ratios. A Bonferroni post-hoc test was performed to evaluate if there was any significant difference among the subgroup analysis based on the SSP's tear retraction grading. The limits of agreement between two assessors were examined with Bland-Altman plot analysis. The intra-rater reliability and inter-rater reliability were assessed using the intraclass correlation coefficient (ICC). The ICC was interpreted as follows: 0 to 0.40, poor; 0.41 to 0.60, moderate; 0.61 to 0.80, good; and 0.81 to 1.00, excellent (13).

Results

Patient demographic data

The total number of recruited samples was 116 shoulders. The case group included 84 shoulders representing shoulders with FTDST, while the control group (without evidence of SSP tear) included 32 shoulders. The mean age was 64.19 ± 7.67 years (range, 46–81 years) for the case group and 35.81 ± 14.13 years (range, 15–65 years) for the control group.

In every shoulder, we identified the presence of SSP tear, SSP tear retraction, and biceps pathology. In our series, 61.9% had biceps pathology in the case group compared to 12.5% in the control group. There were 42 patients with SSP retraction grade 1 (50%), 33 patients with SSP retraction grade 2 (39%), and 7 patients with SSP retraction grade 3 (8%). All patient characteristics are listed in Table 1.

TABLE 1: Patient demographic characteristics

Demographic characteristics	Study population	
	Case group (n = 84)	Control group (n = 32)
Age (years)∞		
Mean ± SD	64.19 ± 7.67	35.81 ± 14.13
Genderμ		
Male	33 (39.3%)	23 (71.9%)
Female	51 (60.7%)	9 (28.1%)
Bicep pathologyμ	52 (61.9%)	4 (12.5%)
Goutallier(11) classificationμ		
Grade0	20 (23.8%)	32 (100%)
Grade1	51 (60.7%)	0 (0%)
Grade2	12 (14.3%)	0 (0%)
Grade3	1 (1.19%)	0 (0%)
Patte(12) classificationμ		
Normal	0 (0%)	32 (100%)
Grade1	42 (50%)	0 (0%)
Grade2	33 (39.3%)	0 (0%)
Grade3	7 (8.3%)	0 (0%)
∞: value presented as mean ± standard deviation		
μ: value presented as the number of volunteers with that condition (percentage)		

Radiographic interpretation

The ACEA and GTA were accessible in 116 shoulders. The average ACEA value was 23.79° ± 10.22°, and the average GTA value was 70.07° ± 6.49°. Comparing both parameters with the presence of FTDST, we found that both angles had a statistically significant association with the presence of SSP tear. The means of the ACEA and GTA variables in the case group were 26.44° ± 9.83° (95% CI, 24.31°–28.57°) and 70.92° ± 6.64 (95% CI, 69.48°–72.36°), respectively. In the control group, the means of the ACEA and GTA variables were 16.81° ± 7.72° (95% CI, 14.03°–19.60°) and 67.84° ± 5.56 (95% CI, 65.84°–69.85°) respectively. Statistically significant associations between both variables and FTDST were found as shown in Table 2.

TABLE 2: Comparison of the parameters between patients with or without full-thickness degenerative supraspinatus tear (FTDST).

Parameters	Group	Statistics			
		N	Mean (°)	SD (°)	p-value
ACEA	Case group	84	26.44	9.83	< 0.001**
	Control group	32	16.81	7.72	
GTA	Case group	84	70.92	6.64	0.02*
	Control group	32	67.84	5.56	

*Significant at level 0.05

**Significant at level 0.01

For the assessment of any correlation between age and these parameters among total populations, a small positive strength of association (coefficient < 0.3) was found between age and both parameters. However, the results showed no statistical differences between these parameters within each group, as seen in Table 3.

TABLE 3: Correlation analysis between parameters and age in the total population and in each of both groups.

Parameters	Total (n = 116)		Case group (n = 84)		Control group (n = 32)	
	Pearson correlation	p-value	Pearson correlation	p-value	Pearson correlation	p-value
ACEA	0.29	0.001**	-0.22	0.045	0.18	0.324
GTA	0.25	0.006**	0.27	0.014	-0.05	0.772

**Significant at level 0.01

Comparing both parameters in correlation with patient gender, Table 4 showed that female gender had a statistically significant higher ACEA value compared to male gender in total populations. Meanwhile, no statistically significant difference in correlation with patient gender was found regarding GTA value.

TABLE 4: Comparison of parameters by gender among the total population and in each of both groups.

Parameters	Total (n = 116)				Case group (n = 84)				Control group (n = 32)			
	N	Mean (°)	SD (°)	p-value	N	Mean (°)	SD (°)	p-value	N	Mean (°)	SD (°)	p-value
ACEA												
Female	60	25.83	10.78	0.025**	51	27.24	10.69	0.36	9	17.89	7.69	0.63
Male	56	21.59	9.18		33	25.21	8.33		23	16.39	7.87	
GTA												
Female	60	70.88	7.31	0.16	51	71.08	7.6	0.783	9	69.78	5.59	0.224
Male	56	69.19	5.4		33	70.67	4.89		23	67.09	5.49	

**Significant at level 0.01

The ROC curves were designed to evaluate the ability of both angles to predict FTDST.

The curves showed that an ACEA was a good predictor for FTDST with an area under curve as 0.78. For a GTA value, the area under the curve was 0.67, which is interpreted as a fair predictor for FTDST (Figure 2). To determine the cut point, an ACEA value of 18° was a good predictor for full-thickness SSP tear, which had 85% sensitivity and 50% specificity, while a GTA value of 68° had 77% sensitivity and 44% specificity. This finding indicated that the ACEA value is a more accurate diagnostic test than is the GTA value. The differences in the cut-off values of ACEA and GTA are reported in Table 5.

TABLE 5: Different ACEA and GTA cut-off values (PPV: positive predictive value, NPV: negative predictive value).

Cut-off value	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
ACEA					
15°	90.5	31.3	77.6	55.6	74
16°	86.9	40.6	79.3	54.2	74
17°	84.5	40.6	78.9	50.0	72
18°	84.5	50.0	81.6	55.2	75
19°	79.8	59.4	83.8	52.8	74
20°	77.4	59.4	83.3	50.0	72
21°	73.8	65.6	84.9	28.8	72
GTA					
65°	83.3	28.1	75.3	39.1	68
66°	81.0	31.3	75.6	38.5	68
67°	79.8	37.5	77.0	41.4	68
68°	77.4	43.8	78.3	42.4	67
69°	73.8	43.8	77.5	38.9	66
70°	67.9	59.4	81.4	41.3	66
71°	60.7	71.9	85.0	41.1	64

The multivariate analysis showed that the ACEA parameter was the only parameter that was found to be statistically significant. A higher ACEA value indicated an increased risk of FTDST with an odd ratio of 1.16 per degree (P = 0.01). However, there was no statistical significance for the GTA parameter (P = 0.10) (Table 6). The risk factor for FTDST was increased age (odd ratio of 1.26 per year; p < 0.001). Our findings also showed that while the mean ACEA and GTA values of the FTDST group were larger than those of the control group, the means of the parameters among subgroups categorized by Patte classification did not show a significant difference. A comparison of both parameters is shown in Figure 3.

TABLE 6: Multivariate analysis by logistic regression analysis for each factor associated with the presence of full-thickness degenerative supraspinatus tear (FTDST).

Factor	Odd ratio	95% Confidence interval		p-value
ACEA, per degree	1.16	1.04	-1.3	0.01**
GTA, per degree	1.13	0.98	-1.32	0.10
Age, per year	1.26	1.13	-1.43	< 0.001**
Gender, female to male	0.92	0.17	-5.01	0.93

**Significant at level 0.01

Reliability testing for the ACEA and GTA values showed that the mean ACEA difference and the mean GTA difference were -0.94 ± 3.2 and 0.60 ± 2.0, respectively. The ICC values for the ACEA and GTA measurements were 0.95 and 0.94, respectively (Table 7). Interobserver reproducibility between both assessors was excellent for corresponding to previous reports (6, 9). The Bland–Altman plot of the mean difference between the repeated measurements is shown in Figure 4.

TABLE 7: Summary of intra-rater and inter-rater reliability of ACEA, GTA (LOA: limits of agreement, ICC: intraclass correlation coefficient).

Parameters	Intra-observer reliability			Inter-observer reliability		
	Mean ± SD (°)	95% LOA (°)	ICC (%)	Mean ± SD (°)	95% LOA (°)	ICC (%)
ACEA	-0.94 ± 3.2	-7.16 to 5.27	95	-0.27 ± 4.37	-8.84 to 8.283	91
GTA	0.60 ± 2.0	-3.34 to 4.53	94	-0.77 ± 2.75	-6.15 to 4.61	89

Discussion

RCT is one of the most common causes of chronic shoulder pain, leading to decreased functionality, declined quality of life and escalated utilization of health care resources (14). Due to its cost effectiveness and accessibility, the standard shoulder series is typically the first line of investigation for the patients suspected RCT (15) to provide additional information and needs of advanced images as MRI of the shoulder (16). This study aims to correlate between the radiographic parameters, as ACEA and GTA, from the standard shoulder radiographs and FTDST in those patients who presented with shoulder pain underwent arthroscopic surgery.

Our results showed that the mean ACEA parameter was 26.44° ± 9.83° in the case group compared to 16.81° ± 7.72° in the control group, with a statistically significant difference between the groups. Female gender had a statistically significant higher ACEA value when comparing to male gender in the total population. Pearson correlation was used to identify whether any correlation was present between age and ACEA among this study's total population. We found a negligible correlation between ACEA value and age (17). According to logistic regression analysis, an increased ACEA has an independent risk of FTDST, with an odds ratio of 1.13 per degree. In addition to higher ACEA values, the analysis manifested that increased age was a risk factor in FTDST. Our results regarding patient age aligned with those of prior studies, which revealed that the prevalence of RCT positively correlated with patient age (18). The results of in the present study with FTDST are comparable with those in the study by Singleton et al., which reported a positive correlation between ACEA and acute traumatic RCT (23.9 vs. 16.6, $p < 0.001$) (6). However, they did not consider RCT size and mentioned that implementation of ACEA parameter on the chronic degenerative tear is still doubtful. With our results, we certified that ACEA could be generalized to a FTDST population and used as a reliable measurement tool for detecting FTDST on standard shoulder plain radiographs. The association between higher ACEA values and rotator cuff pathology could be clarified in the same way that it has been for other parameters, such as the Acromial index (AI) and critical shoulder angle (CSA). This was explained by the vertical force vector of the middle fibre of the deltoid muscle, where the pull, influenced by the lateral extension of the acromion, was directed upward, lead plausibly to SSP impingement and consequence tear due to a compression effect causing a degeneration tear of the rotator cuff, as stated in previous literature (19, 20).

Despite the high variability of GT morphology (21), the GTA parameter was first proposed in 2018 for a new reliable radiographic marker of degenerative RCT. However, the precise relationship between GTA's high values and the incidence of RCT is not yet understood. In the present study, GTA was found significantly between groups with a small size difference; the mean in the case group was 70.92° ± 6.64, compared to 67.84° ± 5.56 in the control group. However, multivariable analysis showed no statistically significant correlation between GTA and FTDST. Hence, stepwise multiple regression analysis rejected GTA as a predictor for FTDST. The result of the present study contrast with those reported by Cunningham et al., who noted that the mean GTA parameter was 72.5° ± 2.5° in the RCT group compared to 65.2° ± 4.1° in the control group and concluded that degenerative RCT in the European population was associated with GTA values of more than 70°(9). In addition, Yoo et al. reported that high GTA values accompanied RCT in the Korean population, based on MRI results (22). This discrepancy between results could be explained by the population-based anatomic variation that may exist in a Southeast Asian population, such as the Thai population. A recent study has documented that the Asian population exhibits a smaller humeral head compared to the Western population (23); these findings could possibly explain why the GTA effect is larger in Asians than in Europeans (22). Moreover, previous studies examined the GTA effect on individuals with partial- or full-thickness supraspinatus tears, but our study examined the GTA effect only on FTDST; partial tears were not taken into consideration. Recent studies (5, 10) demonstrated a dissimilarity association between acromial parameter and type of RCT tear (full thickness vs. partial thickness). Additionally, Seo et al. (24) reported that the mean GTA values for bursal-side partial RCT tended to be larger than those for full-thickness RCT. Therefore, the different populations' characteristics could affect the magnitude of the parameter and may have produced different findings among studies as well

This study was the first to evaluate these angles based on arthroscopic findings for their usefulness in determining the risk of FTDST. The most important finding was that ACEA was shown to have a statistically significant, high association with FTDST. Stepwise logistic regression analysis demonstrated that between ACEA and GTA, only ACEA appears to be valid in correlation with FTDST: GTA was rejected as a factor in predicting FTDST. No previous study has performed logistic regression to assess the effects of these parameters on FTDST. We summarized that ACEA could be used as an independent factor to assess the risk of FTDST in our study. As such, we also concluded that GTA could not be utilized to assess the risk of FTDST in the Southeast Asian population, particularly in the Thai population. Nevertheless, a positive correlation was not found between a higher value and SSP tear retraction grading. Thus, these parameters cannot be used to differentiate the severity of tear retraction of SSP. Although the possibility of type II errors should be considered, further biomechanics study is essential for specific assessment of the influence of these parameters on tear retraction.

The present study had several limitations. First, due to limitation of retrospective study nature and arthroscopic based study design, some patient's demographic data might have a difference between the groups. FTDST patients tend to be females who are older than patients with labral injury and shoulder instability, even adhesive capsulitis, which is mainly included in the control group. Despite this variation, the statistically significant difference still endured for the ACEA parameter after multivariable analysis. Second, our study has relatively small sample size compared to previous studies. However, a statistical power analysis was performed for sample size estimation, with alpha = .05 and power = 0.80. The sample size needed with this effect size was approximately 25 samples within each group. These were sufficient for detecting a difference of 5° between groups if the standard deviation of each group was 7.7., despite the fact that our proposed sample size was more than adequate for this study's primary objective. Third, the difference of ACEA and GTA between the patients with and without FTDST was approximately

9.6° and 3.1°, respectively; these results were within their SD range. Although the findings were statistically significant, careful interpretation is essential to determining the clinical application of these parameters

Conclusion

The presence of higher ACEA values is a significant independent risk factor for the presence of full-thickness, degenerative SSP tear. The measurement of ACEA could be a useful tool to determine additional advanced images such as MRI to confirm diagnosis of this condition in a patient with chronic shoulder pain. Consequently, GTA values may be less helpful in assessing the risk of full-thickness, degenerative SSP tear, especially in the Southeast Asian population.

List Of Abbreviations

FTDST : full-thickness degenerative supraspinatus tear

RCT : rotator cuff tear

SSP : supraspinatus

GT : greater tuberosity

ACEA : acromiohumeral centre edge angle

GTA : greater tuberosity angle

MRI : magnetic resonance imaging

MVA : multivariate regression analysis

ICC : intraclass correlation coefficient

Declarations

Ethics approval and consent to participate

This retrospective study received the written approval by the Institutional Review Boards in Mahidol University (certificate of approval no. MURA2018/837). The Institutional Review Boards in Mahidol University waived the need to obtain consent for the collection, analysis and publication of the retrospectively obtained and anonymized data for this non-interventional study.

Consent for publication

Not applicable.

Availability of data and material

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CV and CK conceptualized and designed the study. CV and PF performed radiographic measurement and helped in the acquisition of data. CV and CK were responsible for analysis and interpretation of data. CV and CK helped to draft the manuscript. SJ and CK helped to revise the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

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Figures

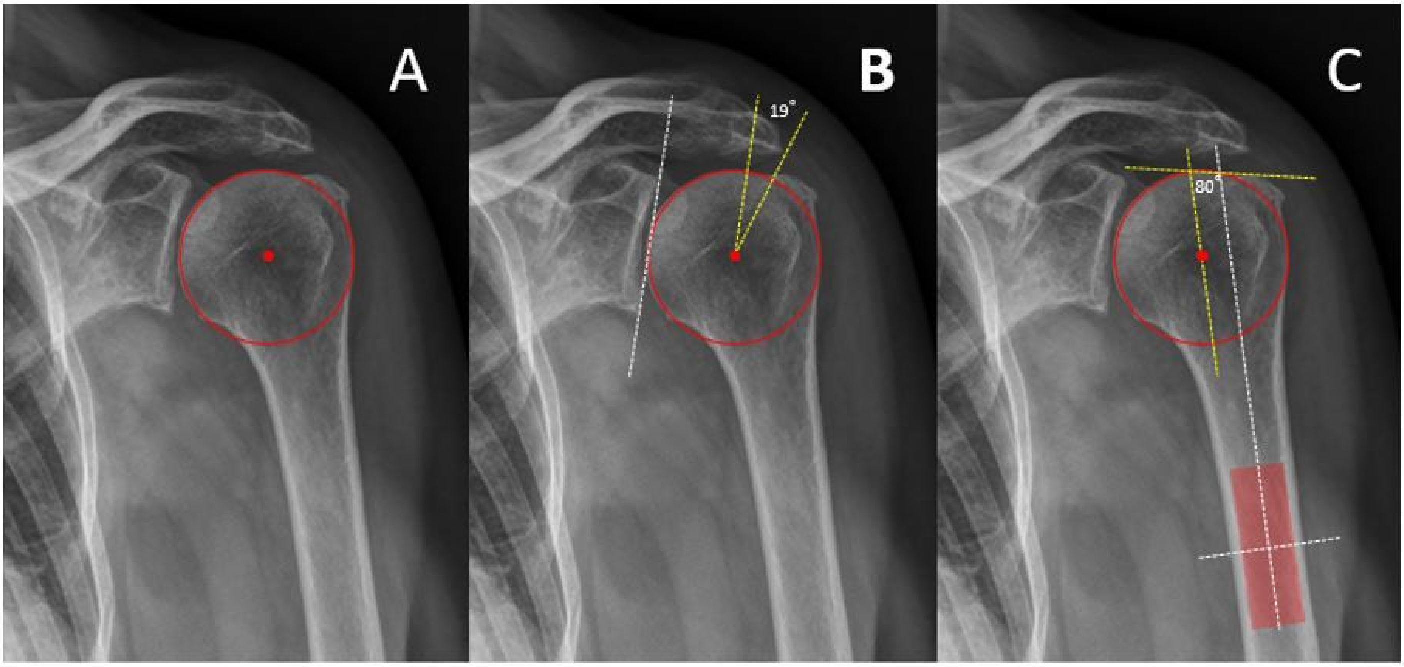

Figure 1

On a true AP glenohumeral X-ray, (A) the humeral head is circled and marked centre of rotation. (B) Measuring the ACEA formed with the first drawn superiorly from the centre of the humerus parallel to the glenoid surface and the second drawn from the centre of the circle to the lateral-most aspect of the acromion edge. (C) Measuring the GTA angle formed by the first drawn parallel to the diaphyseal axis that passes through the humeral head centre of rotation; the second drawn connects the superior border of the humeral head to the superolateral edge of the greater tuberosity.

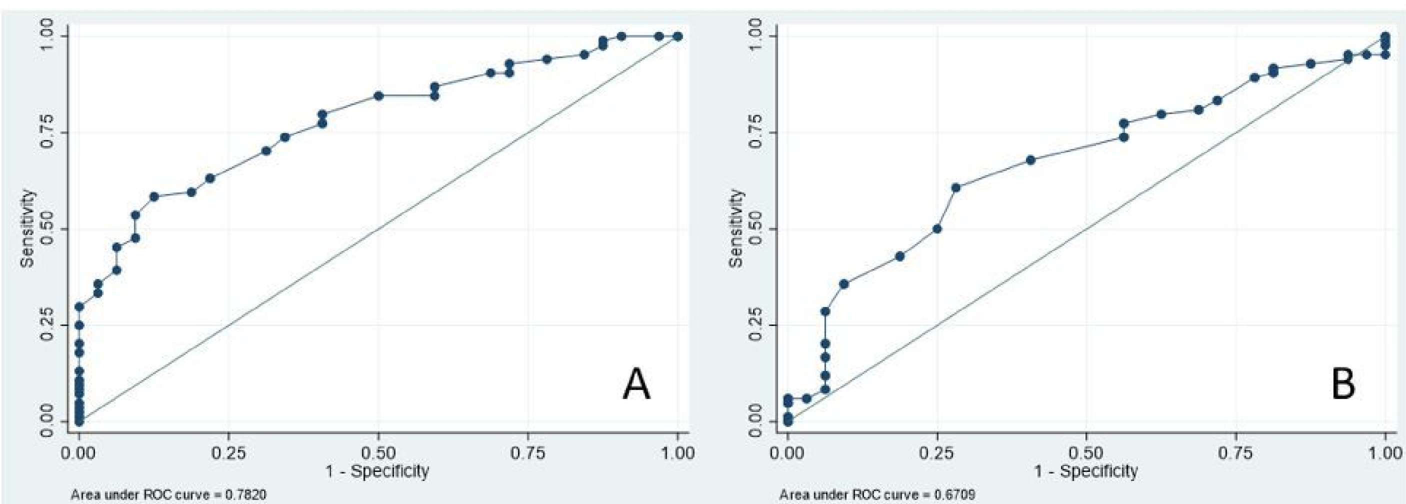

Figure 2

(A) ACEA, (B) GTA. Receiver operating characteristic (ROC) curve, with an area under the ROC curve of 0.78 and 0.67, respectively.

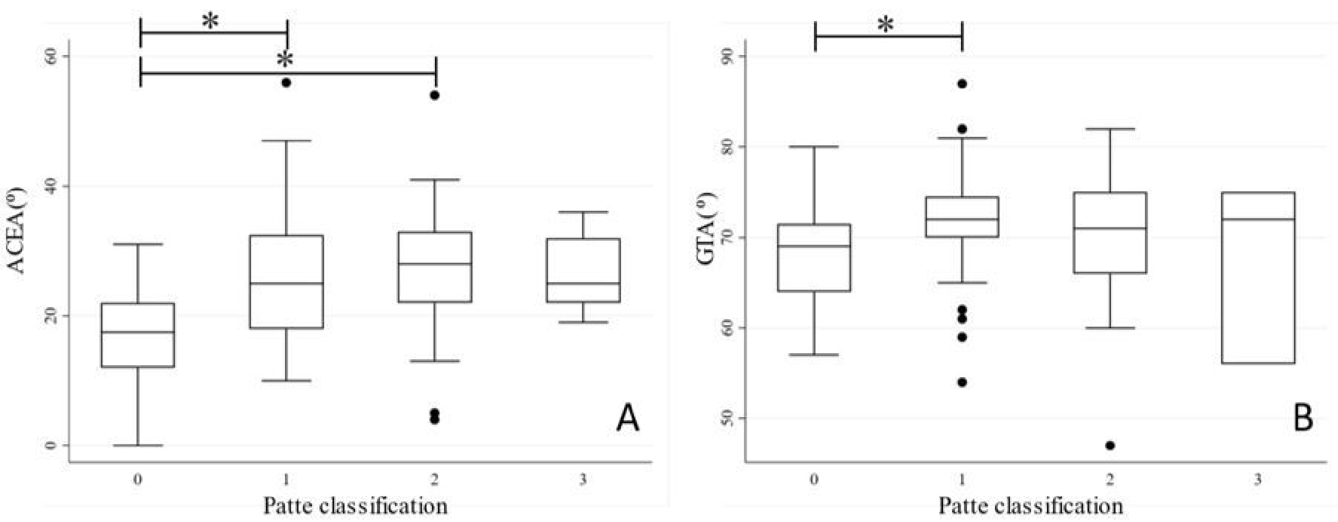

Figure 3

Comparison of parameter (A) ACEA and (B) GTA between the groups graded by Patte classification. Error bars indicate the inter-quartile range (IQR) of the median. Black dots indicate values above the upper fence (1.5*IQR). * above the lines spanning between groups indicated P-values < 0.05. Grade 0 indicates no rotator cuff tear condition.

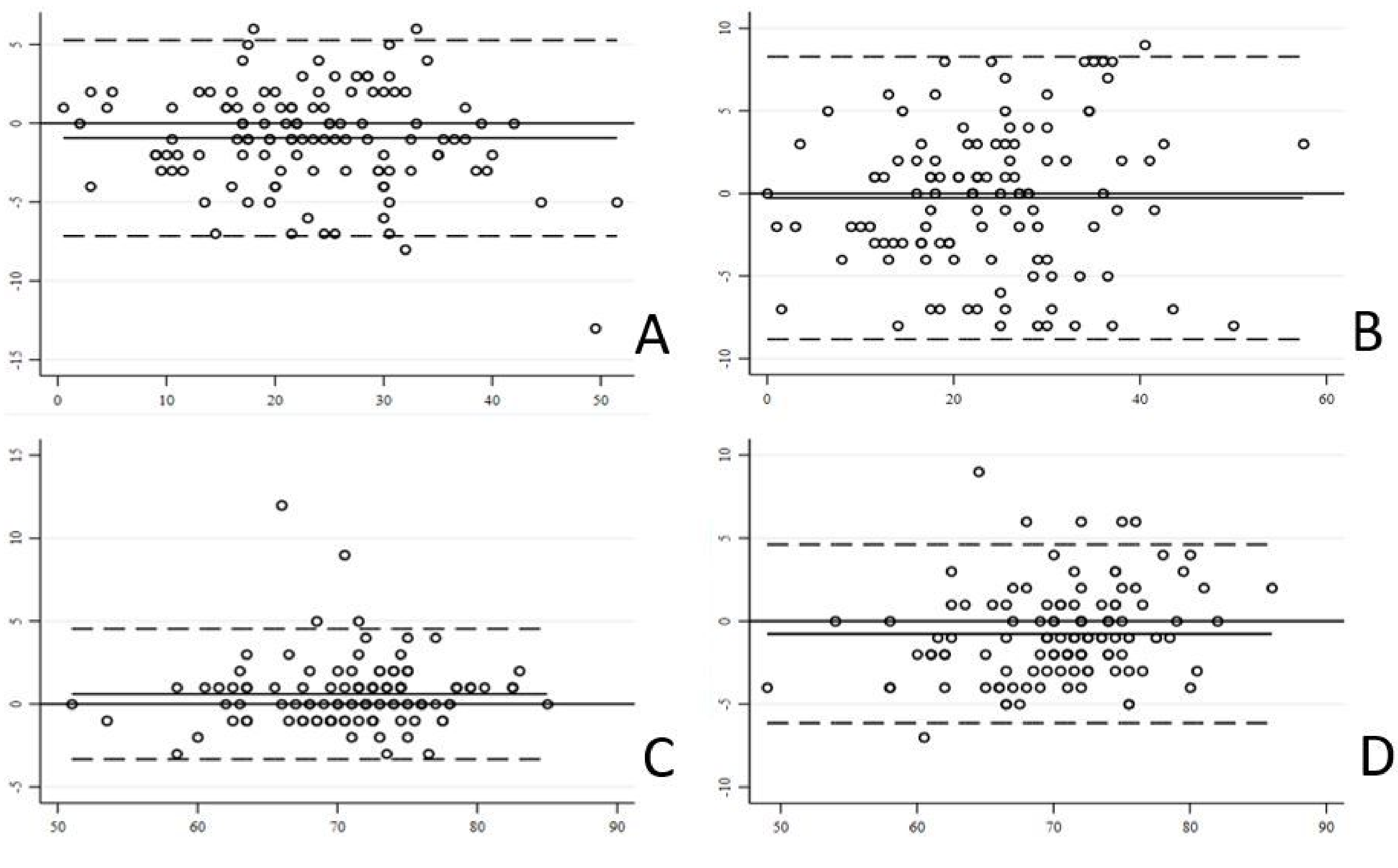

Figure 4

Bland-Altman plot of the mean difference in ACEA measurements between one-month separate time points (A). The mean difference in ACEA measurements between two assessors (B). The mean difference between GTA measurements taken at one-month separate time points (C). The mean difference between GTA measurements of two assessors (D).