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Increased preoperative greater tuberosity angle does not affect patient-reported outcomes postarthroscopic rotator cuff repair



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Background: The greater tuberosity angle (GTA) is a newly described radiological parameter identified in a 2018 study by Cunningham et al that sought to investigate the effect of GT morphology on cuff tears. Increased GTA has been conceptualized to affect rotator cuff pathology through both extrinsic and intrinsic mechanisms. $GTA > 70^\circ$ was highly predictive of a degenerative rotator cuff tear. This study seeks to examine if increased GTA predicts for worse functional outcomes 2 years postoperatively after arthroscopic rotator cuff repair.

Methods: Between May 2010 and December 2016, 169 patients who underwent arthroscopic rotator cuff repair with subacromial decompression were included in this study. GTA was measured on preoperative radiographs. These patients were evaluated preoperatively and at 3 months, 6 months, 1 year, and 2 years postoperatively. Outcomes were assessed with the Visual Analog Scale Pain score, Constant Shoulder Score, and the Oxford Shoulder Score. Power analysis was performed based on the minimal clinically important difference of the Constant Shoulder Score. Statistical analysis was performed by dividing patients into two groups based on GTA: 1) ≤ 70 (control GTA); and 2) >70 (increased GTA) and comparisons were made between the 2 groups.

Results: The patients' demographics were comparable between both groups. All 169 patients had statistically significant improvements in all functional scores at 2 years postoperatively. There were no statistically significant differences between the two groups of patients in Visual Analog Scale and functional scores at 3 months, 6 months, 1 year, and 2 year postoperatively. The changes in functional scores from their preoperative baseline were also tabulated, and there were no statistically significant differences between the 2 groups. Finally, there was no significant correlation between GTA with CSS or Oxford Shoulder Score at 2 years follow-up.

Conclusion: This study represents the largest single series available investigating the influence of GTA on midterm functional outcomes after arthroscopic rotator cuff repair. Although GTA remains a reliable radiographic predictor of rotator cuff tears, the authors conclude that increased GTA does not negatively influence midterm functional outcomes. As there is also no statistical significance between increased GTA vs. control in relative functional gain 2 years postoperatively, corrective tubero-plasty may not be mandatory during arthroscopic repair of cuff tears. Standard arthroscopic double-row rotator cuff repair with subacromial decompression can still be offered as a suitable treatment option.

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Centralized Institutional Review Board approval (CIRB 2019/2777) was obtained for this study.

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Rotator cuff pathology is a common musculoskeletal condition and can vary from tendinosis to partial or full-thickness tears.²⁶ Often rotator cuff tears cause atrophy and fatty degeneration of rotator cuff muscles that leads to painful functional limitations of the shoulder joint.^{15,17}

The shoulder girdle consists of a dynamic interplay between structural bony anatomy, tendons, ligaments, and muscle. As surgeons search for factors contributing to the development

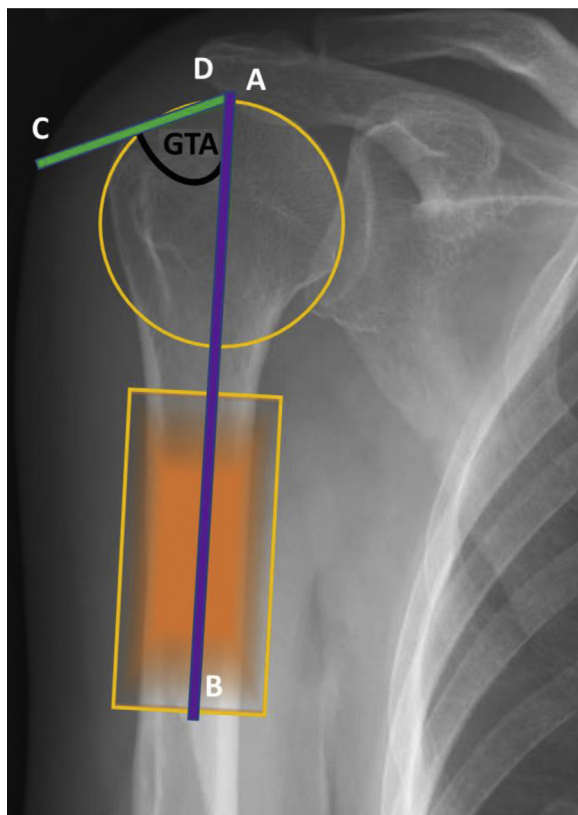


Figure 1 Measuring GTA. Line A-B represents a line parallel to the diaphyseal axis of the humerus that crosses through the humeral head center of rotation. Line C-D connects the superolateral edge of the greater tuberosity to the superior border of the humeral head. The GTA is the measured angle between these 2 lines.

degenerative rotator cuff tears, studies have investigated on anatomical radiographic predictors of rotator cuff tears such as acromial index, critical shoulder angle, and most recently, the greater tuberosity angle (GTA).^{1,7,19} In 2018, the GTA was introduced in a study by Cunningham et al and sought to investigate the effect of greater tuberosity (GT) morphology on rotator cuff tears. The GTA is measured by the angle between a parallel line to the humerus diaphysis through the humeral head center of rotation and a line that connects the superior humeral head border to the superolateral edge of the GT (Figure 1). GTA > 70° is highly predictive of a degenerative rotator cuff tear and this increased GTA has been conceptualized to affect rotator cuff pathology through both extrinsic and intrinsic mechanisms via early impingement of the GT against the undersurface of the acromion and changing the force vector of the supraspinatus tendon, respectively.¹⁹

Previous studies have investigated the effect of preoperative radiographical markers such as critical shoulder angle or acromial index on the outcomes after rotator cuff repair. Docter et al have shown that a higher critical shoulder angle increases risk of retear postoperation, whereas other studies from Lee et al and Gürpınar et al have concluded that such angles do not appear to influence functional outcomes. Until now, there is no clear consensus with regard to the true impact of these radiographical parameters on outcomes.^{13,14,18,19}

The association between GTA and patient-reported outcomes after rotator cuff surgery has not been studied. This study is designed to examine if increased GTA predicts poorer functional outcomes 2 years postoperatively after arthroscopic rotator cuff repair.

Materials and methods

The study was conducted with approval from the Centralized Institutional Review Board at our institution, CIRB: 2019/2777, with waiver of informed consent based on ethical consideration.

Patient recruitment

Between May 2010 and December 2016, patients who underwent arthroscopic double-row rotator cuff repair with subacromial decompression by a fellowship-trained shoulder surgeon in a single institution were reviewed. Our inclusion criteria involved those that had a full set of preoperative and 2 years postoperative functional outcomes data, along with preoperative shoulder radiographs taken within 1 year before surgery. All patients had documented atraumatic full-thickness rotator cuff tear. Patients who underwent surgery for traumatic rotator cuff injuries or multiple tears were excluded.

Data collection

An independent reviewer measured the GTA on preoperative plain radiographs using standardized, true anteroposterior shoulder radiographs as per the described method by Cunningham et al. On identification of the humeral head center and marking it electronically, the angle measurement function on our clinical imaging computerized system was used to establish the degree in between 2 drawn lines—1 line that was parallel with the humerus diaphysis and cut through the marked humeral head center, and another line that connected the superior humeral head border to the superolateral GT edge. An illustration was shown in Figure 1. The measured angle was then rounded off to 1 decimal place.

All patients were evaluated preoperatively and were prospectively followed up at 3 months, 6 months, 1 year, and 2 years postoperatively. The Visual Analog Scale (VAS) for pain score was collected. Functional outcomes were assessed with the Constant Shoulder Score (CSS) and Oxford Shoulder Score (OSS). These scores have been consistently used in several rotator cuff outcome studies and have been shown to provide an accurate assessment of shoulder function with respect to qualities such as pain, range of motion, and overall management of activities of daily living.^{5,12,16}

The VAS pain scoring system is a pain rating scale marked out of a range of 0 to 10, with 0 being “no pain” and 10 being the “worst pain”. It is often depicted via a paper-based assessment of a 10-cm scale denoting each pain level at each centimeter mark, and it is used to track pain improvement progression for patients between multiple spatial points in time of follow-up.¹⁰

The CSS was first presented in 1987 and has since been widely used as a tool to evaluate shoulder function in different pathologies. It evaluates pain, function, range of motion, and strength in the shoulder and the score ranges from 0 to 100 points, with the higher score denoting a better function.²² For patients with rotator cuff tears, a minimal clinically important difference (MCID) for CSS of 6.3 points was previously determined for attainment of treatment effectiveness.²⁴

The OSS evaluates a patient’s perception of shoulder pain and the degree of disability.²⁰ It is a patient-based questionnaire that is simple to complete, sensitive to clinical change, and has had several cross-cultural adaptations as well for implementation worldwide.^{4,12,25} The OSS was earlier introduced in 1996 by Dawson et al and our study enlisted the application of the original scoring system where point weightage was given in each category of the 12-part questionnaire to give rise to an eventual score range of 12 to 68, with 12 being the best possible score denoting better outcomes,

Table I
Baseline demographics data

| | Control group | Increased GTA | P value |
|--------|---------------|---------------|---------|
| Age | 61.3 ± 9.5 | 62.3 ± 9.5 | .536 |
| Gender | 0.3 ± 0.5 | 0.5 ± 0.5 | .744 |
| BMI | 25.3 ± 4.4 | 25.5 ± 4.5 | .119 |

BMI, body mass index.

and 68 being the worst possible score indicating poorer outcomes.^{8,28}

Surgical method

All procedures were performed by a fellowship-trained shoulder surgeon from our institution. The procedure was carried out with patients placed in a beach chair position under general anesthesia.

A standard posterior portal was created first and the relevant shoulder anatomy identified via a diagnostic arthroscopy with a 30-degree arthroscope. Next, an anterior portal was placed in the rotator interval lateral to the coracoid process. An additional lateral portal was made to assist with visualization during the rotator cuff repair and an accessory lateral portal was occasionally created to allow for suture instrumentation and suture anchor placement at appropriate points of the glenohumeral head. The footprint for the suture anchor on the GT was prepared using an arthroscopic shaver. A double-row rotator cuff repair was used for all patients in our study, with usage of suture anchors for both the medial and lateral rows.

Postoperative rehabilitation

Postoperatively, all patients were referred to physiotherapy and these sessions were commenced on the same day as their surgery, as per our institution’s standard protocol regime after arthroscopic rotator cuff repair. Some patients were discharged on the same day after a physiotherapy session, whereas others remained in hospital for 1 night for observation, before getting discharged the next day after physiotherapy review. The first phase of physiotherapy rehabilitation involved placing patients on an arm sling, with gradual progression to pendular shoulder exercises and passive limited range of motion during the first 4 weeks postoperation. This was followed by active range of motion therapy which was commenced during week 4 to 6. On good recovery progress, patients were then trained on strengthening exercises for the shoulder as well.

Statistical analysis

Power analysis was performed based on the MCID of the CSS. The MCID of CSS was reported to be 6.3 points.²⁴ To detect a difference of 7 points in CSS from a baseline mean score of 72 with a standard deviation of 12 at a power of 0.80, a sample size of at least 48 patients in each group would be required. This calculation was done for a 2-sided test with a type 1 error of 0.05.

Table II
Preoperative functional scores (based on GTA)

| | Group 1 (n = 59) | Group 2 (n = 110) | P value |
|------------------|------------------|-------------------|---------|
| Preoperative CSS | 34 ± 19 | 41 ± 18 | .024 |
| Preoperative OSS | 35 ± 12 | 31 ± 10 | .018 |

GTA, greater tuberosity angle; CSS, Constant Shoulder Score; OSS, Oxford Shoulder Score.

Table III
Preoperative and postoperative VAS scores (based on GTA)

| | Control (n = 59) | Increased GTA (n = 110) | P value |
|----------|------------------|-------------------------|---------|
| VAS | | | |
| Pre-op | 7 ± 2 | 6 ± 3 | .083 |
| 3 months | 4 ± 3 | 3 ± 3 | .627 |
| 6 months | 3 ± 3 | 2 ± 2 | .094 |
| 1 year | 2 ± 3 | 1 ± 2 | .181 |
| 2 years | 2 ± 3 | 1 ± 2 | .172 |

GTA, greater tuberosity angle; VAS, Visual Analog Scale.

Statistical analysis was performed by dividing the patients into 2 groups based on GTA: 1) $\leq 70^\circ$ (control GTA); and 2) $>70^\circ$ (increased GTA). Student’s unpaired t-test was used to compare VAS scores and the functional scores between the 2 groups of patients. The paired t-test was used to compare changes in functional scores within the 2 groups of patients. The Pearson correlation test was used to assess the relationship between GTA with CSS and OSS at 24 months postoperatively. Statistical significance was deemed as P -value ≤ 0.05 . Statistical analysis was carried out using SPSS version 23.0 (IBM, Armonk, NY, USA).

Results

In total, 169 patients met the inclusion criteria for patients undergoing arthroscopic double-row rotator cuff repair for atraumatic degenerative rotator cuff tears performed between 2010 with 2016. About 110 patients had increased GTA (GTA > 70 deg), whereas 59 patients were in the control group (GTA ≤ 70 deg).

The patients’ demographics were comparable between both groups and there was no significant difference in body mass index, age, and gender (Table I). Average GTA for all 169 patients was 71.8 ± 6.6 deg. The average GTA within the control group was 64.6 ± 3.9 deg, whereas the increased GTA group had an average of 75.7 ± 3.8 deg.

There was a statistically significant difference in preoperative CSS and OSS between both groups of patients (Table II). For the CSS functional assessment, both groups scored poorly preoperatively, with the increased GTA group having a significantly better CSS scores. Meanwhile, for OSS scores, patients in the control group have significantly better functional OSS scores than those in the increased GTA group.

In terms of VAS scores, there was no significant difference between the 2 groups at each interval follow-up (Table III).

Both groups of patients had statistically significant improvements in all functional scores (CSS, OSS) at 2 years postoperatively (Table IV).

There were no significant differences between the 2 groups of patients in functional scores at 3 months, 6 months, 1 year, and 2 years postoperatively (Table V). The changes in functional scores from their preoperative baseline to 2 years postoperation were also tabulated, and there were no significant differences in the changes in functional scores between the 2 groups of patients (Table VI). Finally, there was no significant correlation between GTA with CSS or OSS at 2 years follow-up ($r = -0.028, P = 0.713$; $r = -0.026, P = 0.739$, respectively).

Discussion

Many studies researching on rotator cuff tears and pathology have previously focused extensively on the impact of scapular/acromion morphology. As discussed by Cunningham et al, with the high variability present in the anatomy of the humeral head, the role of GT morphology cannot be ignored given its intricate

Table IV
Change in functional scores from preoperative baseline to 2 years post-op (for all patients)

| Pre-op vs. 2 years | Paired differences | | | | t | df | Sig (2-tailed) | |
|--------------------|--------------------|---------------|-----------------|-----------------------|--------|--------|----------------|-----------------------|
| | Mean | Std deviation | Std. Error Mean | Interval of the Lower | | | | Interval of the Upper |
| CSS | -32.20 | 18.2 | 1.40 | -34.96 | -29.44 | -23.02 | 168 | 0.00 |
| OSS | 16.9 | 10.9 | 0.84 | 15.33 | 18.64 | 20.27 | 168 | 0.00 |

CSS, Constant Shoulder Score; OSS, Oxford Shoulder Score.

Table V
Postoperative functional scores (based on GTA)

| | Group 1 (n = 59) | Group 2 (n = 110) | P value |
|----------|------------------|-------------------|---------|
| CSS | | | |
| 3 months | 38 ± 16 | 40 ± 15 | .415 |
| 6 months | 52 ± 16 | 58 ± 15 | .037 |
| 1 year | 66 ± 15 | 68 ± 14 | .343 |
| 2 years | 70 ± 14 | 72 ± 12 | .544 |
| OSS | | | |
| 3 months | 30 ± 11 | 28 ± 10 | .233 |
| 6 months | 22 ± 10 | 20 ± 7 | .130 |
| 1 year | 17 ± 7 | 16 ± 6 | .181 |
| 2 years | 16 ± 8 | 15 ± 6 | .248 |

GTA, greater tuberosity angle; CSS, Constant Shoulder Score; OSS, Oxford Shoulder Score.

Table VI
Change in functional scores from preoperative baseline (based on GTA)

| | Group 1 (n = 59) | Group 2 (n = 110) | P value |
|---------------|------------------|-------------------|---------|
| Change in CSS | | | |
| 3 months | 4 ± 21 | -1 ± 21 | .154 |
| 6 months | 18 ± 20 | 16 ± 19 | .668 |
| 1 year | 31 ± 19 | 26 ± 19 | .132 |
| 2 years | 36 ± 18 | 30 ± 18 | .061 |
| Change in OSS | | | |
| 3 months | -5 ± 13 | -3 ± 12 | .320 |
| 6 months | -13 ± 14 | -11 ± 11 | .406 |
| 1 year | -18 ± 11 | -15 ± 10 | .133 |
| 2 years | -19 ± 11 | -16 ± 11 | .129 |

GTA, greater tuberosity angle; CSS, Constant Shoulder Score; OSS, Oxford Shoulder Score.

involvement during movements of the shoulder girdle.⁷ The main findings of our study show that an increased preoperative GTA (>70°) does not predict for worse functional outcomes when compared with those with GTA ≤70°, after standard arthroscopic double-row rotator cuff repair with subacromial decompression.

This study evaluated the association of GTA with preoperative and 2 years postoperative functional scores of arthroscopic degenerative rotator cuff tear repairs. A GTA of greater than 70 degrees has been identified to be strongly predictive of the presence of a rotator cuff tear. Extrinsically, a higher GTA corresponds to a tighter subacromial space and greater impingement of the tendon upon the acromion. The intrinsic component is described as a biomechanical tensile load that is imposed on the supraspinatus tendon in abduction.⁷ Within our study population of patients with rotator cuff tears, most (110 of 169 patients) had an increased GTA of more than 70 degrees, consistent with earlier studies by Cunningham et al and Yoo et al, where larger GTAs were associated with rotator cuff tears.^{7,27}

Over the course of 2 years follow-up postoperatively, both groups of patients noted functional improvements in both CSS and OSS scores. At 2 years postoperatively, all 169 patients' scores improved significantly from preoperative scores. This is consistent with most studies that show patient postarthroscopic rotator cuff

generally quoted improvement in pain, function, range of motion, and satisfaction.^{3,6,9,11,21}

In a similar concept as with subacromial decompression and acromioplasty, the theory of a surgical adjunct measure such as a corrective tuberopecty to decrease the GTA and avoid future impingement had been proposed before, to possibly provide better functional outcomes.⁷ This study showed that at 2 years, there were no significant difference between the control and increased GTA group for both functional scores and VAS scores. Relative functional gain in both scores was not statistically significant as well. This indicates that there may not be a role for corrective tuberopecty during arthroscopic repair of these rotator cuff tears. The degree of GTA does not have an implication toward the algorithm of surgical management and standard arthroscopic double-row repair still provides favorable outcomes, even in patients with increased GTA.

Limitations

This is a retrospective single-surgeon study of patients undergoing arthroscopic double-row rotator cuff repair. Being a single-surgeon study may limit external validity of the results. However, an analysis of a large sample size from a single surgeon will also help to limit surgeon-specific confounders that have previously been identified in the field of surgery.² Our 2 study groups were shown to have significantly different preoperative functional scores and this may affect subsequent interpretation of follow-up data. We have thus added a comparison of relative functional gain (Table VI) to account for their different baseline scores and to strengthen our analysis. Third, our data are collated until 2 years follow-up which represents midterm functional outcomes. Evaluating outcome measures at 5 years or longer will be required for more rigorous analysis on the longer-term outcomes. Additional subjective outcome measures such as the Disabilities of the Arm, Shoulder and Hand questionnaire and American Shoulder and Elbow Surgeons shoulder score were not captured in this study.²³ Collation of these outcomes may allow a more holistic view of patients' functional outcomes from their perspective.

Conclusion

To our knowledge, this is the largest series available that evaluates the influence of GTA on 2-year postoperative functional outcomes after arthroscopic rotator cuff repair. Although GTA remains a reliable radiographic predictor of rotator cuff tears, an increased GTA is not associated with poorer midterm functional outcomes. There were no statistically significant differences between increased GTA vs. control in terms of absolute scores and relative functional gain for all outcome assessments measures over the period of 2 years. Standard arthroscopic double-row rotator cuff repair with subacromial decompression can still be offered as a suitable treatment option and corrective tuberopecty may not be mandatory. Further research is required to shed more light on the clinical impact of this new radiological parameter.

Disclaimer

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