Original Research

Different types of rotator cuff tear morphology do not affect post-repair clinical outcomes in large to massive tears

Mark H.X. Yeo, Shawn J.S. Seah, Merrill Lee, Denny Tjiauw Tjoen Lie

Department of Orthopaedic Surgery, Singapore General Hospital, 1 Outram Road, Singapore, 169608, Singapore

ARTICLE INFO

Keywords: Rotator cuff Tear morphology Arthroscopic Repair Large Shoulder

ABSTRACT

Objectives: The primary aim of this current study is to evaluate the effects of rotator cuff tear morphology on clinical outcomes in large to massive tears, using a modified version of the existing classification system, with specific focus on tear symmetry and use of margin convergence.

Methods: Patients who underwent arthroscopic repair of large to massive, full thickness rotator cuff tears were retrospectively analysed. The tear pattern was classified at the time of surgery as Type IA, Type IB, Type IIA, and Type IIB according to tear symmetry and direction of maximum tear diameter, with Type I being symmetrical and Type II being asymmetrical. Type IA (U-shaped) had greater mediolateral (ML) than anteroposterior (AP) diameter while Type IB (crescent shaped) had greater AP than ML diameter. Type IIA tears have an anterior extension towards the rotator interval while IIB tears have a posterior extension into the infraspinatus, similar to AP L-shaped tears established in the literature. Type I tears were typically repaired from medial to lateral while Type II tears were repaired diagonally. All types were repaired using double row technique, with the addition of margin convergence for Types IA and IIB, which had larger tears in the medial and lateral directions. Primary outcome measures were Oxford Shoulder Score, Constant Shoulder Score, University of California at Los Angeles Shoulder Score followed-up at 6, 12, and 24-months as well as retear rates at latest follow-up.

Results: In total, 109 patients were included in the study with a mean age of 65.5 ± 9.4. The prevalence of each tear morphologies from Type IA to IIB was 22.0 %, 34.9 %, 27.5 %, and 15.6 %, respectively. All four groups showed statistically significant improvement from pre-operative scores in all 3 outcome measures at 24 months (p < 0.001 for all). No significant difference in primary outcome measures or retear rates was detected between all 4 groups.

Conclusion: This study found that different types of cuff tear morphology, despite affecting surgical repair technique, does not influence clinical outcomes post-arthroscopic rotator cuff repair at mid-term follow-up. Level of evidence: Retrospective Cohort study, Level III.

What are the new findings?

- Using the classification system described in this study, no significant difference in primary outcome measures or retear rates were detected between 4 different types of tear morphology post-operatively
- All 4 different tear morphologies showed significant improvement from pre- to post-operative scores in all outcome measures
- This study highlights that different types of cuff tear morphology, despite affecting surgical repair technique, does not influence clinical outcomes post-arthroscopic rotator cuff repair at mid-term follow-up

* Corresponding author. 1 Outram Road, 169608, Singapore.
E-mail address: denny.lie.t.t@singhealth.com.sg (D.T.T. Lie).

https://doi.org/10.1016/j.jisako.2023.10.014
Received 13 August 2023; Received in revised form 28 October 2023; Accepted 30 October 2023
Available online xxxx
2023 The Authors. Published by Elsevier Inc. on behalf of International Society of Arthroscopy, Knee Surgery and Orthopedic Sports Medicine. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Please cite this article as: Yeo MarkHX-oHX et al., Different types of rotator cuff tear morphology do not affect post-repair clinical outcomes in large to massive tears, Journal of ISAKOS, https://doi.org/10.1016/j.jisako.2023.10.014
1. INTRODUCTION

Predictive factors for rotator cuff outcomes have been widely studied. One important factor in successful rotator cuff repair is the identification of rotator cuff tear morphology and its corresponding repair technique. Rotator cuff tears were first classified by McLaughlin et al. into vertical splits, transverse tears, and retracted tears [1]. Subsequently, Davidson and Burkhat et al. established the 3-dimensional (3D) geometric classification system, based on tear patterns determined pre-operatively (on magnetic resonance imaging [MRI]) or intra-operatively (at arthroscopy), to better guide treatment technique [2]. This has since been adapted and used in the current literature on tear morphology, where in essence the tear morphologies are grouped into 4 main patterns: crescent-shape, U-shape, and anterior/posterior L-shape [2–6].

While previous studies have extensively investigated the correlation between clinical outcomes and the various tear morphologies, there is a paucity of evidence surrounding tear morphologies in large to massive tears, even though failure rates and clinical outcome remain suboptimal in this group [7–9]. To date, only Park et al. has reported outcomes of tear morphology in large tears, specifically comparing mobile tears and chronic U-shaped tears [4].

Moreover, biomechanical studies have shown that the site and direction of a tear have potentially significant clinical implications [10]. This is also an important consideration in pre- and intra-operative planning as it affects the direction in which the cuff is pulled to bone during surgical repair [11,12]. Asymmetrical tears are hypothesized to have greater instability and potentially worse outcomes [13], but the evidence for this remains unclear as there is currently no study comparing outcomes based on the symmetry of tear morphology.

Another consideration in the identification of tear morphologies is whether margin convergence is required in certain morphologies, such as U-shaped tears. Margin convergence, which entails a side-to-side repair of an anteroposterior split, has been found to reduce strain on the tendon-to-bone repair by decreasing the mediolateral length of the tear [6,14]. However, the benefits of margin convergence remain widely debated and some surgeons still prefer a more anatomic repair, such as repair of a U-shaped tear with a mobile posterior leaflet [7,12,15]. Nonetheless, recent evidence has shown comparable results with and without the use of it across various tear morphologies [5].

Given the limitations in the existing literature on rotator cuff tear morphology, the primary aim of this study was to investigate the effect of rotator cuff tear morphology on clinical outcomes and retear rates of large to massive tears. Rotator cuff tear morphology assessed in this study was adapted and used in the current literature on tear morphology, where in essence the tear morphologies are grouped into 4 main patterns: crescent-shape, U-shape, and anterior/posterior L-shape [2–6]. Type I tears were further subdivided based on the anteroposterior (AP) and mediolateral (ML) diameter of the tears. Type IA (U-shaped) has greater ML than AP diameter while Type IB (crescent shaped) has greater AP than ML diameter. Type II tears were also divided into Type IIA and IIB, where IIA tears have an anterior extension towards the rotator interval while IIB tears have a posterior extension into the infraspinatus, similar to anterior/posterior L-shaped tears established in the literature. The 4 types of rotator cuff tear morphologies and corresponding repair techniques (described below) are shown in Figs. 1–4.

To further improve the accuracy of intra-operative classification of tear morphologies, pre-operative imaging (US or MRI) was reviewed independently by two of this study's authors as further evidence of tear morphology, using the authors’ institution's picture archiving and communication system. On MRI, T2-weighted coronal and sagittal views were used to evaluate the greatest AP and ML dimensions of the tear in to predict 3D cuff tear pattern, similar to Davidson et al.’s methods [2]. Similarly, sonographic measurements of the above dimensions were evaluated on US imaging.

Interobserver reliability between the two authors demonstrated concordance in the classification of tear morphology (100%).

2. METHODS

2.1. Study design

This study conducted a single-centre, retrospective cohort study of patients who underwent arthroscopic rotator cuff repair by the senior author at a single high-volume tertiary institution between 2013 and 2017. This study was approved by the institutional review board.

The inclusion criteria were patients aged 21 years or older with full-thickness, large to massive rotator cuff tear documented on pre-operative shoulder imaging (ultrasonography [US] or MRI). The tear size was classified according to the rating system by DeOrio and Cofield, whereby <1 cm is small, 1–3 cm is medium, 3–5 cm is large, and >5 cm is massive [16]. The exclusion criteria were (1) small and medium tears; (2) partial thickness tears; (3) isolated subscapularis tears; (4) previous rotator cuff surgery on affected shoulder; (5) concomitant glenohumeral instability or osteoarthritis in the affected shoulder; (6) concomitant labral repair.

Baseline demographic data were collected, including age, sex, body mass index (BMI), operation side, and time from radiological diagnosis (via US/MRI) to surgery.

2.2. Classification of rotator cuff tear pattern

Intra-operative findings of the procedure were documented in the institution's electronic health record system. Tear morphology at the time of repair was described intraoperatively by the primary surgeon after proper debridement of the lesion and classified into 4 types. As one of the study's primary objectives is to assess the effect of tear symmetry on postoperative clinical outcomes, the patients were broadly classified into Type I (symmetrical) and Type II (asymmetrical) tears. In Type I tears, the apex is at the centre of the base of the tear and there is no preferential extension of the tear anteriorly or posteriorly while Type II tears detach from the greater tuberosity in an asymmetrical manner and extend anteriorly or posteriorly [3]. Type II tears have a more mobile anterior or posterior leaf, which can be pulled more easily towards the corresponding direction (posterior or anterior, respectively) to the bone bed or other leaf in a diagonal fashion. Type I tears were further subdivided based on the anteroposterior (AP) and mediolateral (ML) diameter of the tears. Type IA (U-shaped) has greater ML than AP diameter while Type IB (crescent shaped) has greater AP than ML diameter. Type II tears were also divided into Type IIA and IIB, where IIA tears have an anterior extension towards the rotator interval while IIB tears have a posterior extension into the infraspinatus, similar to anterior/posterior L-shaped tears established in the literature. The 4 types of rotator cuff tear morphologies and corresponding repair techniques (described below) are shown in Figs. 1–4.

To further improve the accuracy of intra-operative classification of tear morphologies, pre-operative imaging (US or MRI) was reviewed independently by two of this study's authors as further evidence of tear morphology, using the authors’ institution's picture archiving and communication system. On MRI, T2-weighted coronal and sagittal views were used to evaluate the greatest AP and ML dimensions of the tear in to predict 3D cuff tear pattern, similar to Davidson et al.’s methods [2]. Similarly, sonographic measurements of the above dimensions were evaluated on US imaging.

Interobserver reliability between the two authors demonstrated concordance in the classification of tear morphology (100%).

2.3. Surgical repair

All surgeries were performed by the senior author. Surgery was performed under aseptic precautions, with patients under general anaesthesia in a beach chair position. Standard arthroscopic portals (anterosuperior, posterior, anterolateral, and lateral) were established. Torn edges of the rotator cuff tendons were debrided until stable. Bursectomy and subacromial decompression was performed. Diagnostic arthroscopy was then performed to visualise the lesion and the intra-operative findings of tear size, morphology, and degree of retraction/delamination were noted. Tendon manoeuvrability was assessed using the arthroscopic tendon grasper and mobilization was performed if necessary. Suture repair technique utilised was based on the type of tear in each case and was at the discretion of the surgeon. The tendon is only repaired if the cuff tissue demonstrates sufficient mobility and reduction does not cause...
excessive tension. The anatomic footprint of the supraspinatus was debrided in preparation for the anchor placement.

All tendon-to-bone repairs were performed via the double-row repair technique, consisting of medial and lateral row anchors while margin convergence was performed via side-to-side suture. While the number of anchors depended on bone quality and exact tear size, there was minimal variation as this study only included large to massive tears. Across the repairs, 2–3 anchors were used in the medial row and 3–4 anchors in the lateral row, which is consistent with existing evidence on double-row repair [17,18]. The direction of pull for a Type I lesion was typically from medial to lateral while that of a Type II lesion was typically diagonal in nature.

Fig. 1. Type IA: (a) symmetrical tear where ML > AP; (b) margin convergence followed by medio-lateral mobilisation and double-row tendon-to-bone repair. ML = mediolateral dimension; AP = anteroposterior dimension; ISP = infraspinatus; SSP = supraspinatus; Subscap = subscapularis; LHBT = Long head of biceps tendon.
In Type IA tears, the margin convergence technique was utilised to reduce tension at the free margin. The converged margin was then mobilised in the medial-to-lateral direction and repaired to bone (Fig. 1). In Type IB tears, tendon at the medial apex of the tear was mobilised medio-laterally and directly repaired to bone (Fig. 2).

In Type IIA tears, the posterior leaf was mobilised in the oblique-anterior direction and directly repaired to the anterior bone bed, re-establishing the rotator interval (Fig. 3). In Type IIB tears, margin convergence with the infraspinatus was first performed for tears with excessive longitudinal split. The anterior leaf was then mobilised in the oblique-posterior direction and repaired to the posterior bone bed (Fig. 4).

Concomitant acromioplasty was performed as deemed necessary by the surgeon. All patients then followed a standard postoperative rehabilitation program.

Fig. 2. Type IB: (a) symmetrical tear where AP > ML; (b) mobilisation of the apex mediolaterally followed by direct double-row tendon-to-bone repair. ML = mediolateral dimension; AP = anteroposterior dimension; ISP = infraspinatus; SSP = supraspinatus; Subscap = subscapularis; LHBT = Long head of biceps tendon.
2.4. Assessment of outcomes

Functional outcome scores such as Oxford Shoulder Score (OSS), Constant Shoulder Score (CSS), and University of California at Los Angeles Shoulder Score (UCLASS) were assessed for each patient by an independent healthcare professional preoperatively and then followed up at 3, 6, 12, and 24 months postoperatively. Both absolute values as well as pre-operative to post-operative change at 24 months were compared across all 4 groups of tear morphology. Furthermore, pre-operative to post-operative improvement was also assessed for

Fig. 3. Type IIA: (a) asymmetrical tear with anterior extension towards rotator interval; (b) oblique-anterior mobilisation of posterior leaf, followed by direct double-row tendon-to-bone repair to anterior bone bed. ML = mediolateral dimension; AP = anteroposterior dimension; ISP = infraspinatus; SSP = supraspinatus; Subscap = subscapularis; LHBT = long head of biceps tendon.
statistical significance in each group. Retears were assessed via US or MRI post-operatively at latest clinical/radiological follow-up. Retear was defined as full thickness tear on US (according to criteria described by Oh et al.) [19], or Sugaya IV-V tears on MRI [20], which is consistent with existing literature evaluating retear rates [19,21].

Apart from evaluation of statistical significance, differences between the groups were compared using MCID reported in the literature [22–24]. Based on the study by Xu et al. [22], the MCID of OSS, CSS and UCLASS was taken as 3.3, 6.7, and 3.0, respectively, at 12 months; 2.7, 6.3, and 2.9, respectively, at 24 months.

Fig. 4. Type IIB: (a) asymmetrical tear with posterior extension towards ISP; (b) margin convergence with ISP followed by oblique-posterior mobilisation of anterior leaf and double-row tendon-to-bone repair to posterior bone bed. ML = mediolateral dimension; AP = anteroposterior dimension; ISP = infraspinatus; SSP = supraspinatus; Subscap = subscapularis; LHBT = Long head of biceps tendon.
2.5. Statistical analysis

Statistical analysis was performed with SPSS statistical software (version 24.0; SPSS, Chicago, Illinois). For continuous variables, parametric data were presented as mean and standard deviation (SD) and analysed via Analysis of Variance and Student’s t test. Non-parametric data were presented as median and range and analysed via Kruskal-Wallis test. Differences between pre-operative and latest follow-up for clinical scores (24 months) were analysed using Paired Student’s t test. Categorical variables were analysed via Fisher’s exact test. The level of significance was taken as p < 0.05 for all analyses.

3. RESULTS

Out of a total of 665 cases of arthroscopic rotator cuff repairs, 556 cases were excluded according to the exclusion criteria accordingly: small and medium tears (n = 365); partial-thickness tears (n = 115); isolated subscapularis tears (n = 5); previous rotator cuff surgery on affected shoulder (n = 22); concomitant glenohumeral instability or osteoarthritis in the affected shoulder (n = 7); concomitant labral repair (n = 42). For overall baseline demographics, the mean age of this study’s population was 65.5 ± 9.4 years, mean BMI was 25.8 ± 4.3 while 54.1 % were females. 71.6 % of the operated side was the right shoulder. The median time from radiological diagnosis to surgery was 10.6 weeks (1–526.4). 86 of the 109 patients completed 12 months’ follow up while 82 of the 109 patients completed the 24 months’ follow up. To evaluate pre-operative prevalence of each tear morphology, patients that were lost to follow-up were included in the study.

Of the 109 cases included, the prevalence of the various tear morphologies (Type IA to IIB) at 24 months follow-up are shown in Table 1. There was no significant difference in baseline demographic data and preoperative outcome scores within the groups (Table 1).

3.1. Outcome scores

The postoperative outcomes scores compared across the various tear morphologies (Type IA to IIB) at 24-months follow-up are shown in Table 2. There was no significant difference in absolute postoperative outcome scores between the groups at 6, 12, and 24 months as well as pre-operative to post-operative change at 24 months (p > 0.05 for all). Moreover, all 4 groups showed statistically significant improvement from pre-operative scores as well as improvement which exceeded the MCID in all 3 outcome measures at 24 months (p < 0.001) (Supplementary Table 1).

3.2. Retear

Only patients with persistent or new onset symptoms on follow-up were offered radiological evaluation with either US or MRI. Across all 4 tear morphologies, a total of 20 cases of symptomatic retear (24.4 %) were diagnosed. There were 5 retears in Type IA (26.3 %), 4 retears in Type IB (10.5 %), 6 retears in Type IIA (20 %), and 5 retears in Type IIB (29.4 %). Retear rates did not differ significantly between the different tear morphologies (p = 0.346) (Supplementary Table 2).

3.3. Tear symmetry

Of the 109 cases, 56.9 % (n = 62) were symmetrical (Type I) tears while 43.1 % (n = 47) were asymmetrical (Type II) tears. Postoperative outcome scores of symmetrical versus asymmetrical tears at 24 months follow-up are shown in Supplementary Table 3. There was no significant difference in absolute postoperative outcome scores between the two groups at 6, 12, and 24 months as well as pre-operative to post-operative change at 24 months (p > 0.05 for all). Retear rates did not yield any significant difference as well (p = 0.318) (Supplementary Table 4).

Power analysis was conducted for this analysis for all outcomes analysed. Observed power ranged from 0.114 to 0.517 (Supplementary Table 5).

4. DISCUSSION

Despite differences in repair technique used to manage the various tear types, this study found no difference in clinical outcomes between the 4 types of rotator cuff tear morphology. This does not support this study’s hypothesis that symmetrical tears, especially Type IB, would lead to better clinical outcomes. However, these findings align with the existing literature. Park et al. compared mobile large tears (crescent and L-shape) with U-shaped large tears and found no difference in retear rates as well as clinical scores apart from 12-month Constant Shoulder Score [4]. Moreover, Watson et al. compared clinical outcomes between crescent, U-shape as well as L-shape tears and similarly did not find any difference [5]. This highlights that differences in tear morphology does not lead to differences in clinical outcomes, as long as the appropriate cuff repair technique is utilised.

Furthermore, this study also found that all groups had statistically significant pre-operative to post-operative improvement as well as improvement which exceeded the MCID at 24 months. Additionally, retear rates across all 4 types of tear morphology ranged from 10.5 % to
29.4%, which is lower than reported rates for arthroscopically repaired large to massive rotator cuff tears [7,8,25]. In arthroscopic rotator cuff repair, the identification of tear morphology followed by corresponding repair techniques is crucial in ensuring proper healing and recovery of function post-operatively [3,11,12]. This is especially important in large to massive rotator cuff tears where cuff integrity is often poorer, with retear rates as high as 40% [7,8]. Thus, this study is crucial as it adds to the limited literature on tear morphology in large to massive tear. This study’s findings demonstrate that the current classification framework on tear morphology is feasible in guiding cuff repair technique and can yield good clinical outcomes as long as the surgeon takes appropriate steps to address it. Moreover, a significant strength of this study is all rotator cuff repairs were arthroscopically conducted by a single surgeon from the same tertiary institution, with a focus on large to massive tears, thus reducing heterogeneity in the identification of rotator cuff tear morphology as well as corresponding management.

In this study, the margin convergence technique was employed in all Type IA tears as well as Type IIB tears whenever longitudinal split was deemed excessive. Given the absence of cases where margin convergence was not used for Type IA and IIB tears, this study was unable to evaluate the difference in outcomes with versus without the use of margin convergence for these two tear types. Current literature has suggested that there may be no significant difference in the two surgical techniques [4,5]. However, in terms of pre-to post-operative clinical outcomes, this study found clinically significant improvement in groups where margin convergence was used, which highlights that margin convergence can potentially be an effective technique for certain tear morphologies. While the efficacy of margin convergence remains debated, there is growing evidence supporting the biomechanical benefits of tension-free repair that it provides [6,26,27]. In this study, the margin convergence technique was employed in all Type IA tears as well as Type IIB tears whenever longitudinal split was deemed excessive. Particularly, in Type IIB tears, the posterior margin of the torn supraspinatus was repaired to the anterior margin of the infraspinatus before the tendon to bone repair (Fig. 4). This achieves anatomical repair whereby both the supraspinatus and infraspinatus converge to the greater tubercle of the humerus from their respective sites of origin. On the other hand, in Type IIA tears, margin convergence was not employed to converge both the supraspinatus and subscapularis as they separated by the rotator interval, which contains several key tendons and ligaments [28,29]. Thus, for appropriate tear morphologies (namely Type IA and Type IIB), margin convergence can be a useful technique to allow a tension-free tendon-to-bone repair and improve functional outcomes, although this is limited by a lack of evidence to suggest significant benefits over direct tendon-to-bone repair.

In terms of symmetrical (Type I) versus asymmetrical (Type II) tear morphology, this study’s findings did not support the hypothesis that symmetrical tears yield better outcomes post-operatively. Biomechanically, an asymmetrical tear implies that the load along the rotator cable is no longer distributed equally between the anterior and posterior insertions, which causes the cuff to lose its compressive ability on the humeral head and consequently become more unstable [11,13]. Kim et al. found that fatty degeneration was closely associated with an anterior tear location in the supraspinatus in contrast to size and extent of retraction in the infraspinatus [10]. Importantly, the repair technique significantly differs between the two groups in terms of the direction in which the leaves are mobilised [11,12]. In this study, the lack of difference between the two groups can be explained by a few possible reasons. First, evidence has shown that U-shaped tears are less mobile than L-shaped tears [3]. This study hypothesizes that this could have worsened outcomes and displaced any benefits of having a symmetrical repair in Type IA. Second, there is the possibility that chronic Type II tears evolved into a morphology that resembles Type IA tears, making it more challenging to distinguish or classify between the two [4,11].

Lastly, in terms of prevalence, this study found that Type IB tears were the most common, while Type IIB tears were the least common. These findings are concordant with the existing literature in showing that Type IB tears, or tears with greater AP than ML dimensions, are usually more common, while the prevalence of Types IA and II are lower and more variable across studies [3,5,30].

4.1. Limitations

However, this study has a few limitations. First, given the relatively small sample size, observed power was relatively low (<0.8) and there was a possibility of type II error. Second, there still exists substantial heterogeneity within the identification of the tear morphology since this can be very subjective. Third, retear rates could have been underestimated since only patients with persistent or new onset symptoms underwent follow-up US or MRI. Lastly, this study did not directly compare the use of margin convergence versus direct tendon-to-bone repair techniques for Type IA and IIB tears.

5. CONCLUSION

In conclusion, using a modified version of the existing classification system, this current study showed that difference in rotator cuff tear morphology does not affect clinical outcomes and retear rates of large to massive tears, although studies with larger sample size are required to further justify this. Nonetheless, all tear types displayed significant improvement in pre to post-repair outcomes. This study believe that identifying tear morphology via a robust system of classification remains essential in guiding surgical technique, such as the inclusion of margin convergence, and can serve as a basis for communication between orthopaedic surgeons and radiologists.

**Funding**

Singhealth DukeNUS Academic Medicine Research Grant, Grant Number: AM/TP005/2018.

**Ethical approval**

SingHealth CIRB 2019/2777.

**Informed consent**

N/A.

**Authors’ contribution**

Conceptualization and Design: M.Y., S.S., M.L., D.L.
Acquisition of Data: M.Y., S.S.
Analysis and Interpretation of Data: M.Y., S.S.
Writing – original draft: M.Y., S.S., M.L., D.L.
Writing – review & editing: M.Y., S.S., M.L., D.L.

**Conflict of interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Acknowledgements**

None.

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jisako.2023.10.014.
References


