CLINICAL ARTICLE

The Use of Autologous Iliotibial Band With Gerdy's Tubercle for Irreparable Rotator Cuff Tears

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Objective: To determine the radiographic and functional outcomes after autologous iliotibial band with Gerdy's tubercle (ITB-GT) interposition in patients with irreparable rotator cuff tears (IRCTs).

Methods: From December 2015 to March 2017, a total of 16 patients who underwent autologous ITB-GT interposition for IRCTs were identified, including 4 males and 12 females. The mean age was 56.1 ± 10.3 years (range, 44–67 years). Functional assessment consisted of active range of motion (ROM), Visual Analogue scale (VAS), American Shoulder and Elbow Surgeons (ASES) score, Constant–Murley score, and patient satisfaction rate. The tendon integrity and acromiohumeral interval (AHI) were assessed by postoperative magnetic resonance imaging (MRI).

Results: The mean duration of follow-up was 25.3 ± 3.5 months. At final follow-up, the patients exhibited significantly improved forward elevation, external rotation, and internal rotation (75.00° ± 13.16° to 159.37° ± 8.51°, t = 26.71, P = 0.001; 17.81° ± 11.54° to 35.31° ± 8.26°, t = 6.57, P = 0.001; 2 to 11, t = 13.10, P = 0.001). Other functional outcomes as measured by VAS score, ASES score, and Constant–Murley score also improved significantly (6.50 ± 1.41 to 1.06 ± 0.93, t = 11.68, P = 0.001; 38.50 ± 8.68 to 81.75 ± 6.80, t = 15.42, P = 0.001; 32.50 ± 8.53 to 77.12 ± 6.72, t = 17.28, P = 0.001). The overall satisfaction rate was 87.5%. The postoperative MRI showed that the tendon integrity was fully intact in 14 patients and partially intact in two patients. The AHI improved significantly from 3.63 ± 1.25 mm preoperatively to 8.37 ± 1.02 mm postoperatively (t = 11.78, P = 0.001).

Conclusion: Autologous ITB-GT interposition was a useful treatment option for patients with IRCTs, which resulted in significant improvements in active ROM, subjective functional outcomes, and AHI with excellent tendon integrity at a minimum 2-year follow-up.

Key words: Graft; Management; Repair; Rotator cuff

Introduction

Although the instruments and techniques of shoulder arthroscopy have developed rapidly during the past decade, the management of irreparable rotator cuff tears (IRCTs) still present a clinical challenge for orthopaedic surgeons[1]. Owing to severe tendon retraction and poor muscle quality, especially advanced fatty infiltration of the rotator cuff tendons, the cuff stump sometimes cannot be repaired primarily to the original footprint despite full mobilization of the tendon, or cuff repair is done but will almost certainly be associated with structural failure. These rotator cuff tears are defined as IRCTs[2].

Historically, limited reliable methods have existed for the management of these tears, and although multiple methods have been described[3–8], many have been insufficient to meet patients' demands (e.g., isolated arthroscopic debridement, partial rotator cuff repair)[3, 4] or are technically demanding and result in difficult rehabilitation (e.g., tendon

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transfers)[5, 6]. These methods have been reported as generally met with unsatisfactory clinical success as a whole.

In recent years, graft interposition has been an implemented method for the management of IRCTs, where the graft is used to bridge the gap between cuff stump and the original footprint[9, 10]. Currently, various graft materials have been used clinically, including allograft, xenograft, and synthetic graft[10–15]. However, many orthopaedic surgeons have concerns regarding the use of these graft materials particularly in terms of foreign material reaction and their tissue induction ability, where there is a shortcoming of not producing a mechanically stable connection over time between the graft and the tuberosity[12–15]. Therefore, orthopaedic surgeons have recently started focusing on autologous graft for interposition. In 2015, Mihara *et al.* was the first to use autologous iliotibial band with Gerdy's tubercle (ITB-GT) for interposition[16]. With ITB-GT, there was no risk of foreign material reaction. Moreover, the bone autograft could provide more reliable healing than soft tissue grafts. However, the study by Mihara *et al.* was a small case series, which included only five patients.

To our knowledge, there is still very limited data in the literature regarding autologous ITB-GT interposition for the management of IRCTs. Therefore, the aims of this study were: (i) to describe the arthroscopic technique of autologous ITB-GT interposition for IRCTs; (ii) to determine the functional and MRI outcomes after autologous ITB-GT interposition in patients with IRCTs; and (iii) to summarize the advantages of autologous ITB-GT interposition for IRCTs. We hypothesized that: (i) this surgical procedure would result in significant improvements in active range of motion (ROM) and subjective functional outcomes with a high patient satisfaction rate; (ii) excellent tendon integrity would be confirmed in the postoperative MRI at a minimum 2-year follow-up.

Methods

Study Design

From December 2015 to March 2017, patients who underwent autologous ITB-GT interposition for IRCTs at our institution were retrospectively identified. The inclusion criteria were as follows: (i) patients diagnosed with IRCTs based on preoperative MRI and arthroscopic examination; (ii) patients who underwent autologous ITB-GT interposition; (iii) patients with Goutallier stage 1, 2, or 3 fatty infiltration assessed by MRI[17]; and (iv) patients with a minimum 2-years follow-up. The exclusion criteria were as follows: (i) previous surgery of the ipsilateral shoulder; (ii) significant glenohumeral osteoarthritis; and (iii) concomitant neurovascular injury.

A total of 16 patients met the inclusion criteria and were enrolled in this study (Table 1). There were 4 males and 12 females with a mean age of 56.1 ± 10.3 years (range, 44–67 years). The dominant side was involved in 10 patients. The mean duration of symptoms was 37.9 ± 14.2 months (range, 12–72 months). Goutallier stage 1 fatty infiltration occurred in one patient, stage 2 in 10 patients, and stage 3 in five patients. This study received approval from our institutional review board. All patients had provided signed informed consent to allow their clinical and radiological data to be used for research programs.

TABLE 1 Patient characteristics (n = 16)

Characteristics	Values
Age, years	56.1 ± 10.3
Sex, male/female	4/12
Dominant side, yes/no	10/6
Duration of symptom, month	37.9 ± 14.2
Goutallier stage, number	
Stage 1	1
Stage 2	10
Stage 3	5
Stage 4	0
Concomitant procedures, number	
Infraspinatus repair	13
Subscapularis repair	7
Biceps tenotomy	15
Biceps tenodesis	1
Duration of surgery, h	1.82 ± 0.67
Duration of follow-up, month	37.9 ± 14.2

The data are shown as mean ± standard deviation.

Surgical Technique

Anesthesia and Position

All the surgeries were performed under general anesthesia combined with an interscalene block. The patients were placed in lateral decubitus position.

Approach and Exposure

A diagnostic glenohumeral arthroscopy was performed through the posterior portal. Biceps tenotomy or tenodesis was performed if there was evidence of biceps tear or tendinopathy. The arthroscopy was then placed into the subacromial space. The degenerated rotator cuff edge was debrided with a soft tissue shaver. The tear size, extent of retraction, mobility, and reparability of the rotator cuff were identified. If the cuff stump could not be repaired to the original footprint after release of all adhesions superficial and deep to the cuff (Fig. 1A), autologous ITB-GT interposition would be performed.

Autologous ITB-GT Interposition

The tears of the subscapularis and/or infraspinatus tendon were repaired first, leaving only superior facet defects to be bridged. Then, two healix anchors (DePuy, Raynham, USA) were placed along the articular margin of the humeral head and the sutures were passed through the cuff stump in a horizontal mattress configuration (Fig. 1B). The size of the residual defect was measured, including the anterior–

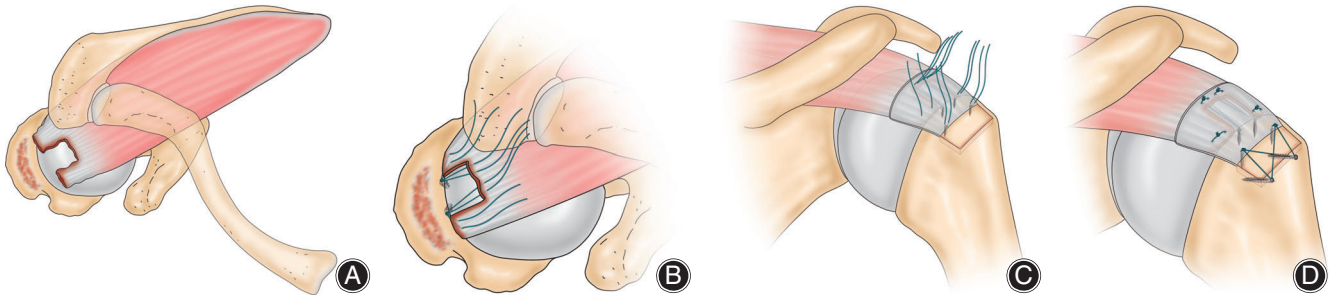

Fig 1 Autologous ITB-GT interposition. (A) A cuff stump that could not be repaired to the original footprint after the release of all adhesions. (B) Two anchors were placed along the articular margin, and the sutures were passed through the cuff stump in a horizontal mattress configuration. (C) The ITB-GT was then guided into the shoulder joint and secured to the cuff stump. (D) The Gerdy's tubercle was secured by a double-row technique. ITB-GT, iliotibial band with Gerdy's tubercle.

posterior and medial-lateral dimensions. The ITB-GT in the ipsilateral knee joint was harvested. The length of iliotibial band was equivalent to double the medial-lateral dimension of the residual defect to allow the band to be later folded in half. The size of Gerdy's tubercle was approximately 1.5 cm medial to lateral × 1 cm anterior to posterior × 0.8 cm superior to inferior. Outside the joint, the sutures already passed through the cuff stump were then passed through the folded-band also in a horizontal mattress configuration. The graft was guided into the shoulder joint and secured to the cuff stump (Fig. 1C). A size-matched bleeding bone bed in the cuff footprint area on the tuberosity was created onto which the Gerdy's tubercle was press-fitted and secured using a double-row technique (Fig. 1D).

Postoperative Rehabilitation

A senior physiatrist administered all the postoperative rehabilitation. After surgery, patients wore an abduction pillow, which allowed 30° to 45° abduction and slight internal rotation, for 12 weeks. Patients were allowed to remove the sling to shower, dress, and perform rehabilitation. Initial rehabilitation included gentle pendulums, as well as elbow, wrist, and hand motion exercises, which were performed three times daily. Passive range of motion was allowed on the second day after surgery, and active range of motion was allowed at 4 weeks after surgery. Muscle strengthening was started once the patient had obtained full painless active elevation. Light work and return to a routine lifestyle were allowed at 6 months. Full return to recreational activity with heavy demands on the shoulder was allowed at 12 months.

Outcome Measures

Patients were assessed preoperatively and at ≥2-year final follow-up. All assessment data were collected by an independent surgeon who was blinded to this study.

Active Range of Motion (ROM)

The forward elevation and external rotation beside body were measured with a goniometer with patients in a supine position. Internal rotation was the highest vertebral level achievable in the midline posteriorly as the patient reached up behind with a "hitch-hiking" thumb. For statistical analysis, internal rotation up to the level of the sacrum was designated as 0 point, and 1 point was added for each level above this.

Visual Analogue Scale (VAS)

The Visual Analogue Scale (VAS) was a 10-cm line with anchor statements on the left (score of 0) and on the right (score of 10). Score of 0 was consider as no pain, 1–3 mild pain, 4–6 moderate pain, and 7–10 severe pain. The patient was asked to mark their current pain level on the line.

American Shoulder and Elbow Surgeons (ASES) Score[18]

The ASES score consisted of a score summation using a 100-point system (50 points for daily function and 50 points for pain). The pain score was calculated by subtracting the VAS from 10 and multiplying it by five. For the functional portion, each of 10 separate questions was scored on an ordinal scale from 0–3 for a maximal raw functional score of 30 points. The raw score was multiplied by 5/3 to make the maximal functional score out of 50 possible points. The pain and functional portions were then summed to obtain the final ASES score.

Constant–Murley Score[19]

Constant–Murley score was based on a 100-point scale, which included four portions: pain (0–15, 0 maximal pain and 15 no pain); activities of daily living (4 × (0–5) = 0–20, 0 worst and 5 best for each item); mobility (4 × (0–10) = 0–40, active, pain-free range of elevation: + 2 points per 30°, where 0 worst and 10 best for each item; position of hand: 0 worst to 10 best) and strength (0–25, 1 point per 0.5 kg, maximum 25 points). A total score of 0 was worst and 100 was best function.

Patient Satisfaction Rate
At final follow-up, the patients were additionally asked about their satisfaction regarding the clinical outcomes (i.e., very satisfied, satisfied, neutral, or not satisfied). The proportion of very satisfied and satisfied patients was defined as patient satisfaction rate.

MRI Assessment
At final follow-up, MRI was performed in all patients to assess the tendon integrity and acromiohumeral interval (AHI). The tendon integrity was classified as fully intact, partially intact, or not intact according to Boileau's classification[20]. Fully intact indicated that there were no visible defects in the native cuff, cuff–graft interface, or graft–humerus interface. Partially intact indicated that a partial-thickness defect was detected in the native cuff, cuff–graft interface, or graft–humerus interface. Not intact indicated that there was a full-thickness defect at some point in the construct. The AHI was assessed on coronal oblique MRI by the shortest distance between the inferior surface of the acromion and the upper subchondral surface of the humeral head.

Statistical Methods
All statistical analyses were performed using SPSS software (IBM-SPSS statistics 23.0; New York, USA). Continuous variables were presented as the mean and standard deviation. Continuous variable distributions were tested for normality with the Shapiro–Wilk test. Based on this result, either a two-tailed *t*-test or a nonparametric equivalent was used for comparison. The significance level was set at 0.05.

Results

Intraoperative Results
The concomitant procedures included 13 infraspinatus repairs, 7 subscapularis repairs, 15 biceps tenotomies, and one biceps tenodesis. The mean duration of surgery was 1.82 ± 0.67 h (range, 1.40–2.62 h) (Table 1).

Functional Outcomes

Active Range of motion
The mean duration of follow-up was 25.3 ± 3.5 months (range, 24–28 months). At final follow-up, all the 16 patients exhibited significantly improved forward elevation, external rotation, and internal rotation (75.00° ± 13.16° to 159.37° ± 8.51°, t = 26.71, P = 0.001; 17.81° ± 11.54° to 35.31° ± 8.26°, t = 6.57, P = 0.001; 2 to 11, t = 13.10, P = 0.001, Table 2).

Visual Analogue Scale (VAS) Score
The VAS score significantly decreased from preoperative 6.50 ± 1.41 points to 1.06 ± 0.93 points at the final follow-up, indicating that the pain was significantly reduced postoperatively (t = 11.68, P = 0.001, Table 2).

American Shoulder and Elbow Surgeons (ASES) Score
The ASES score improved significantly from preoperative 38.50 ± 8.68 points to 81.75 ± 6.80 points at final follow-up (t = 15.42, P = 0.001, Table 2).

Constant–Murley Score
The Constant–Murley score improved significantly from preoperative 32.50 ± 8.53 points to 77.12 ± 6.72 points at final follow-up (t = 17.28, P = 0.001, Table 2).

Patient Satisfaction Rate
Among the 16 patients, 14 patients were very satisfied or satisfied with their clinical outcomes. Therefore, the overall satisfaction rate was 87.5% (14/16).

MRI Outcomes
At final follow-up, MRI showed the tendon integrity was fully intact in 14 patients, partially intact in two patients, and not intact in zero patients (Fig. 2). Moreover, the AHI improved significantly from 3.63 ± 1.25 mm preoperatively to 8.37 ± 1.02 mm postoperatively (t = 11.78, P = 0.001) (Fig. 2).

Complications
During the follow-up, one patient had slight pain in the harvest site, but no drug intervention was required. No patient in the group developed infection, neurovascular injury, severe stiffness, or significant glenohumeral osteoarthritis.

Discussion

The main findings of this study were that autologous ITB-GT interposition resulted in favorable functional and MRI outcomes in patients with IRCTs at a mean follow-up of 25.3 months. The functional outcomes had significant improvement as measured by active ROM, VAS score, ASES score, and Constant–Murley score with an overall satisfaction rate of 87.5%. The tendon integrity being fully intact was observed in 14/16 of the patients, and the AHI improved significantly as shown by the MRI scan.

The Concept of Irreparable Rotator Cuff Tears (IRCTs)
The term "irreparable" is often incorrectly used and interchanged with the term "massive." Although most IRCTs are massive tears, massive tears are not necessarily irreparable. IRCTs, as the name suggests, are any rotator cuff tears which cannot be repaired primarily to the original footprint on the greater tuberosity, or in which cuff repair is successful but will almost certainly be associated with structural failure[2].

Kim *et al.* found several clinical and radiographic signs that might suggest irreparability including: (i) chronic pseudoparalysis; (ii) large mediolateral tear size; (iii) a narrowed (<6 mm) or absent acromiohumeral interval; (iv) positive tangent sign; and (v) high grade of fatty infiltration of the supraspinatus[21].

TABLE 2 Comparison of the preoperative and final follow-up functional outcomes

Variables	Preoperative	At final follow-up	*P* Value
Forward elevation,°	75.00 ± 13.16	159.37 ± 8.51	0.001
External rotation,°	17.81 ± 11.54	35.31 ± 8.26	0.001
Internal rotation[a]	2	11	0.001
VAS score[b]	6.50 ± 1.41	1.06 ± 0.93	0.001
ASES score[c]	38.50 ± 8.68	81.75 ± 6.80	0.001
Constant-Murley score	32.50 ± 8.53	77.12 ± 6.72	0.001

The data are shown as mean ± standard deviation; [a]Internal rotation up to the level of the sacrum was designated as 0 point, and 1 point was added for each level above this; [b]Visual Analogue Scale; [c]American Shoulder and Elbow Surgeons score.

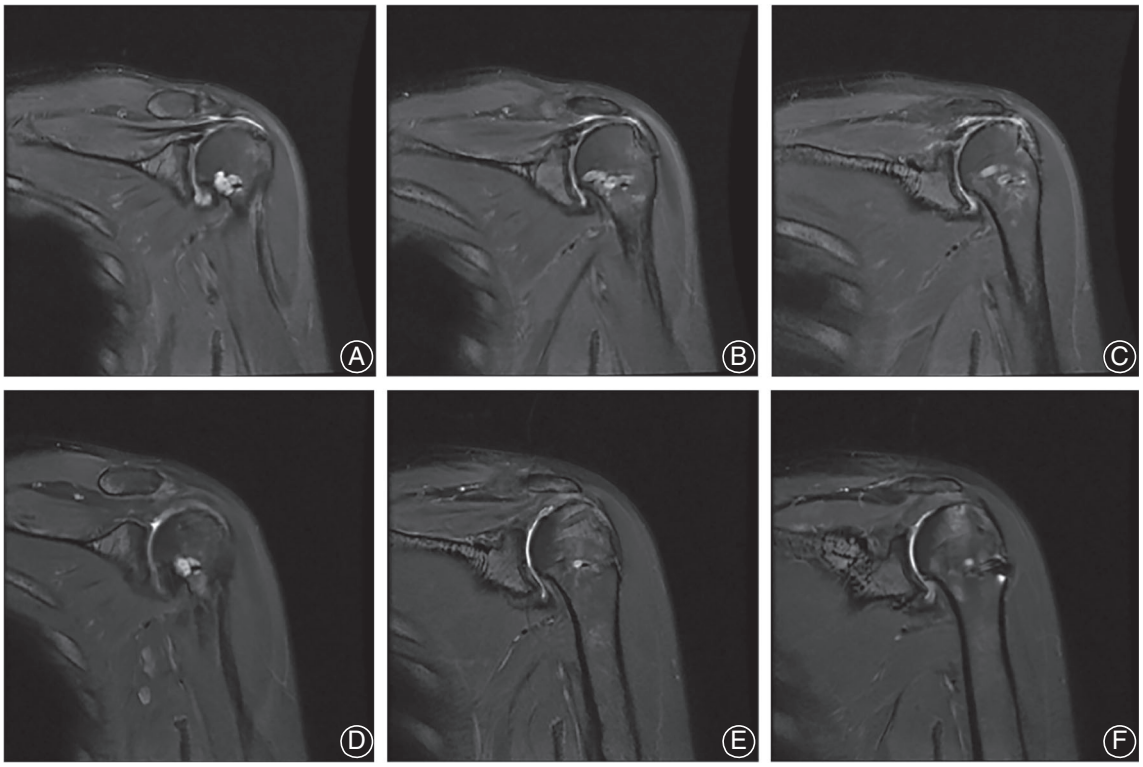

Fig 2 This patient underwent autologous ITB-GT interposition for IRCT (left shoulder). (A-C) The preoperative MRI showed a massive rotator cuff tear with a significantly narrowed AHI. (D-F) At final follow-up, the tendon integrity was fully intact and the AHI significantly improved to 9 mm.

Surgical Procedures for Irreparable Rotator Cuff Tears (IRCTs)

Several methods have been described for the management of IRCTs including isolated arthroscopic debridement, partial rotator cuff repair, tendon transfer, superior capsule reconstruction, and reverse shoulder arthroplasty[3–8]. Liem *et al.* reported on a cohort of 31 patients who underwent isolated arthroscopic debridement for IRCTs[3]. At 47-months follow-up, the VAS, ASES, and Constant score improved significantly. However, abduction strength was significantly lower on the operated side *vs* the contralateral side, and radiologic analysis showed the progression of osteoarthritis in 10 cases (32.3%). Chen *et al.* reported on a cohort of 37 patients who underwent partial repair for IRCTs[4]. At 29.6-months follow-up, the VAS and ASES improved significantly. However, the rate of repair failure showed by MRI scan was up to 41.6%. Gerber *et al.* evaluated the clinical outcomes after latissimus dorsi transfer for IRCTs in 46 patients[5]. Gerber *et al.* found the active ROM, abduction strength, and the subjective scores got significant improvement at a follow-up of 147 months. Nevertheless, Namdari *et al.* reported that this procedure did not restore the normal shoulder kinematics

and required a long period of rehabilitation[6]. Reverse shoulder arthroplasty is effective in treating IRCTs, but not an optimal treatment choice for younger, active cases[7, 8].

Recently, there has been an increasing interest in graft interposition for the management of IRCTs, where the graft is used to bridge the gap between cuff stump and the original footprint[9, 10]. Despite various graft materials having been tried, foreign material reaction and poor healing potential between the graft and the tuberosity are common complications[12–15]. Soler *et al.* reported on a cohort of four patients who underwent graft interposition with porcine dermal collagen for IRCTs[14]. At 6 months after surgery, all patients reported a worsening of clinical picture due to resorption of the graft caused by an inflammatory response. Ciampi *et al.* reported a re-tear rate of 51% at 12 months after graft interposition with collagen material for IRCTs[12]. In another report, Ranebo *et al.* reported on a cohort of 10 patients who underwent synthetic interposition graft made of Dacron[15]. In seven of 10 patients (70%) with available ultrasonography, the graft was interpreted as not intact.

Advantages of Autologous ITB-GT Interposition

The advantages of using autologous ITB-GT for interposition include the following: (i) as this is autologous material, there is no risk of foreign material reaction; (ii) as this graft is attached with Gerdy's tubercle, strong rotator cuff reconstruction can be expected to result from bone-to-bone healing; (iii) as most of the surgical steps are performed outside the joint, the working space is larger; and (iv) the cost is lower compared with that of using allograft, xenograft, and synthetic graft.

This study has several limitations. First, this study was retrospective in nature with all the inherent limitations of a retrospective study. Second, this study included a limited number of patients due to the relatively low incidence of IRCTs. Third, this study did not compare the index procedure with any control group.

Overall, autologous ITB-GT interposition was a useful treatment option for patients with IRCTs. This surgical procedure led to significant improvements in active ROM, subjective functional outcomes, and excellent tendon integrity at a minimum 2-year follow-up.

Authorship declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors. All authors are in agreement with the manuscript.

Competing interests

The authors declare that they have no competing interests.

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