Tendon-to-Bone Healing after Repairing Full-Thickness Rotator Cuff tear with a Triple-Loaded Single-row Method in Young Patients

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Abstract

Background: Arthroscopic repair has been recommended for young patients with full-thickness rotator cuff tear (RCT), but the healing rates raise concern. The SCOI (Southern California Orthopedic Institute) row has been developed over three decades of experience, which reported an excellent clinical outcome. However, studies that focus purely on a younger patient population remains limited in number. The current study aims to discuss the initial tendon-to-bone healing after repairing full-thickness RCT with SCOI row method in young cohort.

Methods: Patients younger than 55 years who had a full-thickness RCT and underwent an arthroscopic repair with SCOI row method were reviewed. Clinical outcome were assessed at baseline, 3 and 6 months post-operatively. Visual analog scale (VAS), University of California at Angeles (UCLA) scale and Constant-Murley score were completed to assess pain and function. Active range of motion was also examined, including abduction and flexion of the involved shoulder. Preoperative MRI was performed to assess the condition of torn tendon, while postoperative MRIs in 3 and 6 months post-operatively were carried out to assess the tendon-to-bone healing. Repeated measurement ANOVA and chi-square test were used where applicable.

Results: 89 patients (57 males and 32 females) who met the criteria were including in the study, with a mean age of 44.14 ± 8.638 years. Compared with baseline, clinical outcome was significantly improved in 3 and 6 months post operation, supported by improvement in VAS, UCLA score and Constant-Murley score, as well as range of motions. Greater improvement was also noted in 6-month postoperative assessment than 3-month postoperative assessment. Three- and six-month postoperative MRI demonstrated an intact repair in all shoulders, and regeneration of the footprint, which supported the manifestation of tendon-to-bone healing. The mean thickness of regeneration tissue was 7.35±0.76mm when measured in 3-month postoperative MRI, and 7.75±0.79mm in 6-month MRI, which showed statistical difference (P=0.002). The total satisfactory rate reached 93.3%.

Conclusion: Arthroscopic primary rotator cuff repair of fullthickness RCT with SCOI row method in patients aged younger than 55 years provides excellent clinical outcomes and rapid regeneration of footprint.

Introduction

Rotator cuff tear (RCT) is a common disorder associated with pain and dysfunction in the shoulder, of which prevalence increases with age [1]. Full-thickness RCTs are present in approximately 25% of individuals in their 60 s and 50% of individuals in their 80 s [2]. However, studies that focus purely on a younger patient population remains limited in number. Young patients frequently undergo a traumatic tear of the supraspinatus tendon, as the supraspinatus bears the majority of shoulder-stabilizing strain and has unique anatomic constraints that render it more susceptible to injury [3]. For patients younger than 55 years they tend to have a higher demand of joint function [4], because most of them afford the

heavy responsibility of family in China. Tendon-to-bone healing contributes to increased strength, increased function, and higher patient- and physician-derived outcome scores [5].

Many factors have been associated with rotator cuff tendon healing following repair, including increased age, tear size, tendon and bone degenerative changes, and gap formation between the repaired tendon and its bony insertion shortly after surgical repair [6–8]. Although advancements in surgical skills, techniques, technology, and equipment have significantly facilitated the arthroscopic repair of full-thickness RCT, failed repairs were frequently reported [9–12]. Approximately 40% RCT patients suffered from anatomic failure after arthroscopic repair [9, 11, 12, 10]. Obviously, such a successful rat is not acceptable for young patients. Stephen J. Snyder proposed that biologic repair of all living tissues consistently requires 5 key elements: stabilization, inflammation, revascularization, cellular repopulation, and remodeling [13]. Thus, the SCOI (Southern California Orthopedic Institute) row has been developed over three decades of experience, which showed greater than 90% healing rates [14].

The SCOI row method utilizes medially-based single-row anchor with 3 high-strength sutures to fix the cuff securely with minimal tension, and punctures small holes or bone marrow vents in the prepared tuberosity that facilitate the bone marrow to flow and cover the repaired cuff forming a healing blanket. Advocates stressed the evidence of tendon-to-bone healing, supported by the large regeneration of footprint area and that the rotator cuff could be completely restored after repair[13]. Moreover, young population has several biologic and mechanical factors favoring a successful rotator cuff repair [15]. Thus, the SCOI row method might be the optimal treatment option for young patients with full-thickness RCT. The current study aims to discuss the clinical outcome and tendon-to-bone healing in MRI in young patients who suffered from medium to large full-thickness RCT and repaired with SCOI row method

Methods

Patients

The study was approved by the local institutional review board (2019-GJWK-01). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The inclusion criteria were as follows: (1) Symptomatic full-thickness RCT with evidence in MRI, but showing ineffectiveness in conservative treatment including 6-week physical therapy, non-steroidal anti-inflammatories and activity modification; (2) Tear size between 2 and 5 cm in anterior to posterior dimension measured under arthroscopy; (3) Only supraspinatus tendon was sutured and repaired; (4) Primary repair through SCOI row method that a single-row technique augmented with bone marrow vents; (5) Minimum 6-month follow-up; (6) the operation performed by a same surgeon; (7) Aging less than 55 years.

Exclusion criteria included: (1) Irreparable tears; (2) Tears requiring interval slides and/or margin convergence sutures; (3) Tears requiring anchor fixation of the subscapularis tendon; (4) Concomitant injuries in the involved shoulder, such as Bankart lesion, Hill-Sachs lesion.

Surgical Procedure

All procedures were performed under general anesthesia. The patient was in the lateral decubitus position with the arm in 70 degrees of abduction and 15 degrees of forward flexion. Posterior mid-glenoid portal and anterior mid-glenoid portal were created to enter glenohumeral compartment and probe the pathology of biceps and subscapular tendon. Arthroscopic biceps tenotomy and tenodesis were conducted if biceps tenosynovitis was involved. A mid-lateral subacromial portal was created to enter the subacromial space. Subacromial decompression were performed if signs of coracoacromial ligament undersurface mechanical abrasion were present. Acromioplasty would be performed with subacromial decompression if impingement syndrome was significant. The tear pattern and size was arthroscopically assessed from the lateral portal based on the previous description [16, 17] (Figure.1a).

During repair, the arm was placed in 45 degrees of abduction and neutral rotation. Debridement and trimming the infraspinatus tendon was depended on the surgeon if the tendon was partially torn. The torn supraspinatus tendon was debrided to a stable edge by a motorized shaver, and anatomic footprint soft tissues were debrided to bare bone. One 0r two anchors (Corkscrew® FT Anchor, Arthrex, USA) with three high-strength sutures were used based upon tear size and pattern. Anchors were inserted into the prepared bone with 5 mm lateral to the articular cartilage at a 45-degree angle to the subchondral bone [14] (Figure.2). This specific angle was recommend as it guarantee the strongest fixation of cuff edge and best resistance to anchor pull-out [18]. The anchor was seated with the eyelet facing the cuff tendon. Microfracture awl (microrevo punch, Linvatec, USA) was used to create bone marrow vents with fat globules emerging. 7 ~ 9 vent holes are made in the tuberosity, beginning a few millimeters away from the anchor pilot holes, which were at approximately 1.5 cm deep and aimed down the humeral shaf [14] (Figure.1b). Rotator cuff repair was performed utilizing a standard shuttle technique with the sutures passed as simple stitches in a "fan-like" array [19]. All sutures were tied with locking sliding knots placed over the cuff and followed by three reverse half-hitches on alternating posts [19] (Figure .1c). Once all the knots are tied, the scope concentrated on viewing the final repair and assessing the tension. The emerging Crimson Duvet bone marrow enveloping the footprint would be observed once the fluid inflow was suspended (Figure.1d).

Postoperative rehabilitation

Standard rehabilitation instruction were suggested under a physical therapist. The involved arm were immobilized in a neutral rotation sling for 4–5 weeks. On postoperative day one, active elbow, wrist, and hand exercises as well as shoulder shrugs were allowed. During the first to sixth week post operation, passive supine external rotation, pendulum exercises, abduction and forward flexion exercises were carried out, followed by gradually increase active motion. Strengthening was initiated at 8 weeks.

Generally, patients were allowed to resume full, unrestricted activities at 16–20 weeks. Heavy lifting and returning to sports are delayed until 6 months in the usual case.

Patient Evaluation

Each patient was assessed at baseline, and 3, 6 months post-operatively. An independent investigator was responsible for the evaluation. Visual analog scale (VAS), University of California at Angeles (UCLA) scale and Constant-Murley score were completed to assess pain and function. Active range of motion was also examined preoperatively and at each time of follow-up, including abduction and flexion of the involved shoulder. Preoperative magnetic resonance imaging (MRI) was performed to determine the intact repair of tendon, while postoperative MRIs in 3 and 6 months were carried out to assess the tendon healing after repair. The regeneration tissue thickness in the footprint were measured in the MRI. The tear pattern and size was confirmed during arthroscopic operation [16, 17]. Global assessment of each patient in terms of pain, function and satisfaction was finished at the end of follow-up

Statistical analysis

All statistical analyses were performed using SPSS for Windows (version 23.0). Continuous data were presented as the mean ± standard deviation (SD). Repeated measurement ANOVA and chi-square test were used where applicable. $P < 0.05$ was considered statistically significant.

Results

Patients demographics

89 patients who met the criteria were including in the study, including 57 males (64.0%) and 32 females (36.0%). The mean age was 44.14 ± 8.638 years, ranging from 23 to 55 years. The longest disease duration was 17 weeks while the shortest was 6 week, and the mean value was 10.59 ± 3.407 weeks. 50 patients (56.1%) had tobacco use history while 39 patients denied tobacco use. The average in-hospital length was 2.24 ± 1.704 days.

Of the patients, 96.6% (86 of 89) claimed a traumatic etiology. Specifically, 60.5% (52 of 86) were sustained while patients were lifting heavy objects; 11.6% (10 of 86) suffered from a traffic accident; 12.8% (11 of 86) were related to athletic events; 15.1% (13 of 86) were due to fall. Based on the evidence of MRI and arthroscopy, 67 patients (75.3%) were found supraspinatus tendon torn alone, and 22 patients (24.7%) had concomitant injury of infraspinatus tendon. As for the tear size, 37 patients were of medium size (2 to 3 cm), 52 were of large size (3 to 5 cm) [17]. There were 50 crescent-shaped tears of supraspinatus tendon and 39 U-shaped tears.[16]

Concomitant procedures during arthroscopic operation

The additional surgical procedures was determined based on preoperative clinical examination and intraoperative diagnostic examination finding. 58.4% (52 of 89) patients needed subacromial decompression, of which 37 patients received acromioplasty when an anterior spur was present or

additional space was required for visualization or instrumentation in the subacromial space. Biceps tenotomy and tenodesis were performed on 10 patients (11.2%) with anterior shoulder pain, pain with palpation over the bicipital groove, and MRI and arthroscopic evidence. 20 patients (22.5%) received debridement of partial-thickness tear of infraspinatus according to the torn thickness.

Complications

There were no infections, neurovascular injuries, revision procedures for shoulder stiffness, or other complications requiring repeat surgical intervention.

Clinical Outcomes

Compared with baseline, clinical outcome was significantly improved in 3-months assessment, supported by improvement in VAS (mean − 5.621, 95%CI -6.102 to -5.139, P < 0.001), UCLA score (mean 19.483, 95%CI 18.113 to 20.853, P < 0.001) and Constant-Murley score (mean 38.276, 95%CI, 32.877 to 43.674, P < 0.001)). Patients also claimed significant improvement in VAS (mean − 6.552, 95%CI -7.024 to -6.079, P < 0.001), UCLA score (mean 20.759, 95%CI 19.478 to 22.039) and Constant-Murley score (mean 43.552, 95%CI 37.989 to 49.115, P < 0.001) in 6-month follow-up when compared to baseline. Active range of motions including abduction (mean 82.931, 95%CI 69.146 to 96.716, P < 0.001) and forward flexion (mean 77.241, 95%CI 65.801 to 88.682, P < 0.001) in 3-month post operation were much better than that at baseline (both P < 0.001). Similar result was found in comparison between baseline and 6-month follow-up, with mean difference of 90.172 (95%CI 76.036 to 104.309, P < 0.001) in abduction and 84.897 (95%CI 74.352 to 95.442, P < 0.001) in forward flexion.

VAS (mean − 0.931, 95%CI -1.337 to -0.525, P < 0.001), UCLA score (mean 1.276, 95%CI 0.317 to 2.234, P = 0.011) and Constant-Murley score (mean 5.276, 95%CI 2.439 to 8.113, P = 0.011) were also improved in 6-month follow-up than in 3-month follow-up. Significant difference between 3-month and 6-month postoperative assessment was also observed in active range of motion in terms of abduction (mean 7.241, 95%CI 1.151 to 13.332, P = 0.022) and forward flexion (mean 7.655, 95%CI 1.911 to 13.399, P = 0.011). The results were shown in Table.1.

Postoperative MRI demonstrated an intact repair in all shoulders [13]. Furthermore, postoperative MRI in both 3-month and 6-month follow-up found regeneration in the footprint, which showed a good trend of tendon-to-bone healing (Figure.3). The mean thickness of regeneration tissue was 7.35 ± 0.76 mm when measured in 3-month postoperative MRI, and 7.75 ± 0.79 mm in 6-month MRI, which showed statistical difference (P = 0.002).

At the end of follow-up, all patients claimed pain relief after repair, of which 96.6% received significant pain relief. Most of the patients had improvement in joint function as well. The total satisfactory rate reached 93.3%, and 28.1% of the patients felt very satisfied. The details were described in Table.2.

Discussion

The most important finding of this study is that tendon-to-bone healing after repair of rotator cuff was obsevred in the MRI for young patients, with regeneration in the footprine in the initial 3 and 6 months postoperatively. The new tissue in the footprint would be the fundation to provide strong fixation of the repaired tendon. The reported accuracy of MRI to detect a healing rotator cuff repair ranges from 86–100% [20, 21]. In the current study, the level of regeneration of the footprint was assessed with MRI. The mean thickness of regeneration tissue was 7.35 ± 0.76 mm when measured in 3-month postoperative MRI, and 7.75 ± 0.79 mm in 6-month MRI, which showed statistical difference (P = 0.002). Accordingly, excellent clinical outcomes were reported in the present study.

Elhassan et al. [20] proposed that the surgical technique, the timing of surgery, tension on the repair, the biomechanical construct, fixation, patches, biologic augments, and the postoperative rehabilitation strategy, affect rotator cuff repair healing. Although comparable clinical efficacy between double-row and single-row repair techniques, reports indicated that the double-row technique typically provided improved postoperative tendon integrity and lower risk of re-tear [22–25]. Double-row technique has been highlighted for its superior biomechanical properties, such as a larger footprint area, improved initial strength and stiffness, and decreased gap formation and strain [26, 27]. Milano et al. found that double-row repair was significantly more resistant to cyclic displacement than single-row repair in both tension-free and tension repair, which account for a lower risk of tear recurrence [28]. Sugaya et al. published a comparable outcome that 90% impaired rotator cuff were intactly repaired in the group of dual-row fixation, while merely 74% in the group of single-row fixation [29]. Kim et al. suggested that the repair integrity of RCT treated with arthroscopic single-mattress, double-pulley, and double-mattress suture bridge techniques was 80%, 87.5%, 88% respectively [30].

Nevertheless, Nelson et al. argued that repair strength might be directly related to the total number of sutures passed through the tendon being repaired rather than the number or configuration of suture anchors [31]. Another study performed by Mazzocca et al. also proved that the single-row repair technique was similar to the double-row techniques in loads to failure, cyclic displacement, and gap formation, and they attribute this to a larger number of suture passes through the tendon [27].

Different from conventional single-row, SCOI row method used a single row of screw-in suture anchors triple-loaded with high strength sutures passed as simple stitches in a "fan-like" array [32]. Coons et al. suggested that three simple sutures provide superior suture-tendon security than combinations of one mattress and two simple stitches subjected to cyclic loading [33]. Our result also supported this view. The current study showed that all impaired rotator cuff tendon were intactly repaired. Meanwhile, a medially based repair with anchors placed near the articular margin of the greater tuberosity has multiple benefits, which is capable to minimize repaired tendon tension, better screw purchase beneath the subchondral bone, and avoid lateral shift of the muscle-tendon junction [34]. An in-vivo experiment reported by Dierckman et al. suggested that repairing a shortened tendon to the lateral versus medial foot-print increases 5.4-fold of repair tension[35]. Animal models revealed that the decreased modulus of elasticity with increasing tendon tear chronicity might also partial contribute to minimize the tendon tention [36, 37]. Kim et al. proposed that low-tension repairs promoted the complete healing [38]. On the other hand,

the low tension repair reduced the early pain of the involved shoulder after operation, which also helped to decrease analgesic use and length of in hospital. Our paients rarely complained intolerable pain at the first few days after operation, which largely augmented the patients' satisfaction. 96.6% of the patients claimed much pain relief at the end of follow-up.

A recent published randomized trial by Kotaro Yamakado compared the clinical outcomes and cuff integrity using suture bridge or medially based single-row rotator cuff repair. They found that no significant differences were present in the clinical outcomes and cuff integrity between the 2 treatment groups at final follow-up, but incomplete healing was more frequent in the single-row group [34]. However, the regeneration of footprint was rarely described in the previous studies [14, 32, 13], which was observed after repair through SCOI row method. Notably, regeneration of footprint were observed in the initating 3-month MRI, and more growth of the footprint was noted in the 6-month MRI.

In addition to mechanical augments, biologic cellular augments have been proposed to improve healing in patients who undergo rotator cuff repair. "Bone marrow vents" and "Crimson duvet" from the proximal humeral metaphysis primarily account for the regeneration in the footprint of rotator cuff despite having been completely debrided of all soft tissues at the time of the repair [13]. This "super clot Crimson duvet" is known to contain a rich cache of mesenchymal stem cells (MSCs), platelets with their growth factors and vascular elements, and vascular access channels, all of which will contribute to cuff healing [13, 20]. Nakagawa et al. found that drilling into the footprint improved the quality of repair tissue and biomechanical strength at the tendon-to-bone insertion after rotator cuff repair in an animal model [39]. Milano et al. announced that healing rates were improved from 12.5% in controls to 60% with footprint "microfracture" for large cuff tears [40]. Compared with elder patients, tendon quailty and vascular supply are much better in young patients, which was beneficial to tendon healing after repair [41]. These advantages contribute to the rapid regeneration of footprint after repair of rotator cuff. Thus, SCOI row method was considered as the optimal option for young patients with rotator cuff tear who needs surgical repair.

Limitation in this study was most notably the retrospective nature of the study. The small sample size of the current study does not allow for robust statistical power. We acknowledge the short-term follow-up that 6-month post operation might overrate the intact repair rate after repair with SCOI row method. The risk of re-tear might be increased when patients return to the preinjury level of activity and employment. Thus, a study with longer follow-up was warranted to discuss the regeneration of the footprint and intact repair rate.

Conclusion

Arthroscopic primary repair of fullthickness RCT with SCOI row method in patients younger than 55 years provides excellent postoperative pain scores, functional outcomes and satisfaction. The ability to return to work is an important concern in this young patient population, and most of the patients in our study was able to return to their prior level of function. A repaid regeneration of the footprint was observed in

the early period postoperatively, which supported the manifestation of tendon-to-bone healing. Taken it together, SCOI row technique might be the optimal option for young patients with full-thickness medium and large RCT.

Abbreviations

RCT: rotator cuff tear

SCOI: Southern California Orthopedic Institute

VAS: visual analog scale

UCLA: University of California at Angeles

MRI: magnetic resonance imaging

Declarations

Ethics approval and consent to participate

The study has gotten approval from Medical Ethics Committee of the Fifth Affiliated Hospital of Southern Medical University. Consent to participate is not applicable for this retrospective study.

Consent for publication

This section is not applicable for our study.

Availability of data and materials

The datasets used 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

HBH, YH and CLP contributed to the conception and design of the study. YH was a major contributor for drafting the manuscript. HBH and CLP were the main surgeons in the current study, HBH, TW, MCW and

CYY contributed to the acquisition of the data. YH, YM, MCW and CYY contributed to the analysis and interpretation of the data. TW contributed to the critical revision for important intellectual content. YH, HFZ, YM. MCW, JFOY and MW make important revisions. All authors approved the final version to be submitted. TW and CLP contributed responsible for the overall content as guarantors. All authors read and approved the final manuscript

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Tables

Table.1 Clinical outcome comparison

	Baseline	3-month follow-up	6-month follow-up	P1	P2	P3
VAS	6.83 ± 1.167	1.21 ± 0.861	0.28 ± 0.455	< 0.001	< 0.001	< 0.001
UCLA score	12.72 ± 3.250	32.21 ± 1.859	33.48 ± 1.745	< 0.001	< 0.001	0.011
Constant-Murley score	46.24 ± 11.978	84.52 ± 6.098	89.79 ± 5.978	< 0.001	< 0.001	0.001
Range of active abduction	74.48 ± 32.742	157.41 ± 14.918	164.66 ± 14.936	< 0.001	< 0.001	0.022
Range of active forward flexion	82.24 ± 31.327	159.48 ± 13.386	167.14 ± 12.750	< 0.001	< 0.001	0.011
P1: comparison between baseline and 3-month follow-up; P2: comparison between baseline and 6-month follow-up; P3: comparison between 3-month and 6-month follow-up						

Table.2 Global assessment at the end of follow-up

	6-month follow-up (N = 89)	
	Values	Percentage
Pain relief		
Worse and/or unchanged	0	0%
Minimally changed	3	10.3%
Much changed	15	51.7%
Very much changed	11	38.0%
Joint function		
Worse	0	0%
Unchanged	3	10.3%
Improved	26	89.7%
Satisfaction		
Dissatisfied	1	3.4%
Neutral	3	10.3%
Satisfied	10	34.5%
Very satisfied	15	51.2%