

Relieve pain or improve function? Tenodesis should be selected on the basis of demand

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Abstract

Objective

To compare the effectiveness of arthroscopic intertubercular groove tenodesis (IT) and suprapectoral tenodesis (ST) combined with rotator cuff repair (RCR) in the treatment of small sized supraspinatus tendon tear complicated with long head of biceps tendon (LHBT) lesions

Methods

This cohort study reviewed patients who underwent arthroscopic RCR combined with IT and ST for small sized supraspinatus tendon tear complicated with LHBT lesions with minimum 24 months follow-up. Visual Analog Scale (VAS), American Shoulder and Elbow Surgeons (ASES), Constant-Mueley score (CMS), University of California at Los Angeles (UCLA), Simple Shoulder Test (SST), the range of active motion and the incidence of complications were compared preoperative and postoperative follow-up time. Tendons were sectioned into zone 1 (intra-articular), zone 2 (THL - covered zone) and zone 3 (the upper edge of the suprapectoral). The sections were stained with HE and subjected to immunohistochemistry to compare the pathology in different regions of LHBT.

Results

Total of 139 patients were included in the final analysis. MRI showed that the rotator cuff healed well in all patients and was free of complications. The scores was significantly improved in both groups ($P < 0.001$). At 6 months postoperative, VAS was significantly lower in ST group compared to IT group ($P = 0.039$). In IT group, UCLA was significantly higher at 3 months postoperative than preoperative ($P = 0.01$). In ST group, SST was significantly higher at 12 months postoperative than 6 months postoperative ($P = 0.027$). The range of active motion was significantly improved in both groups ($P \leq 0.001$). In ST group, the range of active abduction motion was significantly improved at 12 months postoperative than 6 months postoperative ($P = 0.008$). 10 tendons were analyzed. The Bonar scores and the variables of zone 1 and 2 of the LHBT were significantly higher than that of zone 3 ($P < 0.05$). The immunohistochemically positive cells in zone 1 and 2 of LHBT were significantly more than those in zone 3 ($P < 0.05$).

Conclusion

IT and ST combined with RCR in the treatment of small sized RCT combined with LHBT lesions can both significantly improve the clinical outcomes postoperative. In the early postoperative period, IT shows potential functional improvement advantages, but for patients whose

Introduction

Long head of biceps tendon (LHBT) lesions are a common cause of shoulder dysfunction and anterior pain¹ that are often associated with adjacent structures injuries, such as rotator cuff tear (RCT)². Previous studies have ascertained a high correlation between LHBT lesions and RCT³. Studies by Singaraju et al.⁴ showed that the correlation between supraspinatus tendon tear and LHBT lesions reached 78.5%. Rotator cuff repair (RCR) combined with tenodesis is the most commonly used technique for the treatment of RCT combined with LHBT lesions⁵. Despite the favorable clinical results yielded by various tenodesis, the gold standard for surgical treatment is not yet determined.

Tenodesis can be performed using various surgical techniques, and tendon fixation locations are often selected according to doctors' surgical preferences, patient age and functional requirement⁵. The common fixed positions include the proximal zone of the intertubercular groove and the upper edge of the suprapectoral. Intertubercular groove tenodesis (IT) has the advantages of simpler technique, shorter surgical time, fewer incisions, etc. However, the postoperative pain relief may be incomplete due to residual pathological tendon tissue⁶. However, academics supporting the suprapectoral tenodesis (ST) believe that the slide of the LHBT in the sheath formed by the transverse humeral ligament is the main cause of pain. Therefore, the resection of this zone of the pathological tendon tissue is crucial for surgery. However, ST surgery is complex, and entail risks of humeral fracture and neurovascular injury^{7,8}. Some studies suggest that there is no significant difference in functional outcome between IT and ST^{9,10}.

However, there are risks of bias associated with complex concomitant damage¹¹, open or arthroscopic surgery¹². To more comprehensively evaluate the postoperative efficacy and complications of the two kinds of tenodesis in the treatment of LHBT lesions and reduce the impact of RCT on the efficacy evaluation results, this study only included patients with small rotator cuff injuries combined with LHBT injuries.

Recent studies in the literature have reported that the pathological changes of LHBT are correlated with the patient's pain severity and functional scores¹³. Understanding the histologic regional differences of LHBT may help identify which patients are at risk for persistent pain relative to which tenodesis technique is chosen. To date there is a paucity of literature examining histologic differences found in the LHBT. Recent studies in the literature have reported that the pathological changes of LHBT are correlated with the patient's pain severity and functional scores¹³. Understanding the histologic regional differences of LHBT may help identify which patients are at risk for persistent pain relative to which tenodesis technique is chosen. To date there is a paucity of literature examining histologic differences found in the LHBT^{14,15} and, to our knowledge, none have quantified the regional differences between the intra-articular, the transverse humeral ligament (THL) - covered zone, and the upper edge of the suprapectoral.

The purpose of this study was to evaluate the efficacy of RCR combined with arthroscopic IT or ST in patient with small sized supraspinatus tendon tear combined with LHBT lesions, and to quantify the regional histologic differences seen at the zone 1 (intra-articular), zone 2 (THL - covered zone) and zone 3 (the upper edge of the suprapectoral) regions of the LHBT. The hypothesis of this study was that both RCR combined with IT and ST can significantly improve the pain and function of patients. The pathological changes in the THL - covered zone of LHBT are more significant. ST has a significant advantage in relieving pain in the early postoperative period, which is related to the complete removal of the pathological tissue of LHBT.

Methods

Patient Selection and Demographics

This study was approved by the Medical Ethics Committee (Approval No. Ke2024-139-1) and in compliance with the Declaration of Helsinki, and all patients were informed of this clinically validated treatment and signed consent forms. From January 2020 to July 2022, patients with small sized RCT combined with LHBT lesions who underwent arthroscopic RCR combined with ST or IT were reviewed. This study defined small sized RCT as supraspinatus tendon tears with the length of the greatest diameter of the tear was less than 1cm based on Deorio and Cofield classification¹⁶. Tenodesis was performed for LHBT inflammation, dislocation/subluxation, and partial tear. The patients were evaluated for RCT, LHBT lesions, and other combined injuries in the shoulder through preoperative physical examination, shoulder MRI (Fig. 1), and endoscopic exploration (Fig. 2).

Included criteria: 1. RCT was diagnosed by MRI and preoperative physical examination as small sized supraspinatus tendon tear and LHBT lesions; 2. Only RCR combined with IT or ST were performed during the surgery, and no other surgeries were performed; 3. The patient consented to surgery and signed the informed consent form. 4. Age, gender and BMI are not limited.

Exclusion criteria: 1. The affected shoulder was associated with other concomitant injuries (glenolabial injury, nerve injury, shoulder instability, open wound, shoulder arthritis, scapular fracture injury) than small sized supraspinatus tendon degeneration tear and LHBT lesions; 2. Patients who have previously received invasive treatment for the ipsilateral shoulder joint; 3. Additional biceps procedure other than IT or ST (superior capsular reconstruction using biceps tendon¹⁷, biceps rerouting¹⁸). 4. Complete rupture of LHBT; 5. Mental illness and other debilitating causes that impact the competence to give informed consent, complete question evaluation and follow-up.

Surgical Treatment

Arthroscopic surgeries were performed by a single senior orthopedic surgeon. General anesthesia was used in all surgeries. All procedures were done arthroscopically, and the patients were positioned in healthy lateral decubitus. The standard and anterior portals were routinely established to explore and identify pathological changes in the LHBT, such as tenovaginitis, partial tear, subluxation, dislocation, or degeneration. Moreover, the LHBT was routinely drawn into the joint by a probe or retriever to examine the extra-articular portion of the tendon within the bicipital groove. Routine lateral and posterolateral portals were used to observe the size of the supraspinatus tendon tear and to clean the subacromial space. The rotator cuff residuals and footprint areas were cleaned and freshened using a shaver and tissue-link. Depending on the size and tension of the supraspinatus tendon tear, one or more anchors

were used to RCR in single or double rows¹⁹. The postoperative results of RCR under the microscope are shown in Fig. 3, and the fixation positions of the LHBT are shown in Fig. 4.

Intertubercular groove tenodesis was performed as follows: Rotator cuff repair completed. In the subacromial space, the intertubercular groove and LHBT were exposed by a shaver or tissuelink. The bone was freshened up at the edge of the articular cartilage and a wire anchor was implanted (Fig. 5A). Using a suture hook loaded with nylon suture material, LHBT was pierced at the level of upper portion of transverse humeral ligament and a suture was passed through the nylon loop to perform a shuttle relay (Fig. 5B and C). A different colored suture limb was then passed under the biceps tendon (Fig. 5D and E). Two sutures of the same color were placed on each side of the LHBT using a suture retriever, and both ends of the same colored suture strand were tied in a sliding or non-sliding fashion to fix the LHBT in situ (Fig. 5F). The LHBT was cut and resected with a shaver just proximal to the suture site and at the superior glenoid tuberosity.

Suprapectoral tenodesis was performed as follows: RCR completed. In view of the standard portals, the shaver was used to explore the LHBT and intertubercular groove in the area above the suprapectoral insertion, the bone was freshened up at the intertubercular groove and a wire anchor was implanted at the upper edge of the suprapectoral. The LHBT was fixed in the same way. Use an arc-shaped scissors to mark at the joint cavity exit of the LHBT and below the THL. The LHBT was cut at proximal to the suture site and in the area above the suprapectoral insertion (Fig. 5G). Measure the length of LHBT, cut the LHBT according to the markings and zone them (zone 1: intra-articular; zone 2—the transverse humeral ligament (THL) - covered zone—zone 2—the upper edge of the suprapectoral). (Fig. 5H)

All patients followed a rehabilitation program implemented by a physician and a rehabilitation nurse²⁰. Regular outpatient evaluation and examination were conducted postoperative and an individual adjustment rehabilitation plan was devised according to the patient's recovery condition. The abduction brace was worn daily during the four weeks postoperative to limit the range of active motion and strengthen the training of the surrounding joints. Active training was performed 4–8 weeks postoperative to strengthen proprioception and limb control. The muscle strength of the rotator cuff was strengthened at postoperative month 2 to establish a good movement pattern. At 3 months postoperative, the ability to resume daily activities should have been restored as much as possible, and special training should be conducted for the resumption of sport activities.

Clinical Evaluation

This study retrospectively analyzed the general data, preoperative scores and range of active motion, and preoperative data (including the number of anchors used, the length of the LHBT removed, and the time of surgery). All patients were re-examined at the 3rd, 6th, 12th, 24th months after the surgery, as well as at the last follow-up. The Visual Analog Scale (VAS)²¹, the University of California at Los Angeles (UCLA)²², American Shoulder and Elbow Surgeons (ASES)²³, and Constant-Mueley score (CMS)²⁴, Simple Shoulder Test (SST), range of active motion (flexion, abduction) and complications were recorded by a shoulder specialist physiotherapist. The rotator cuff and LHBT were reviewed by MRI, and the degree of retear and healing after RCR was evaluated according to the Sugaya classification²⁵.

Histopathology

The removed portion of the biceps tendon was placed in neutral-buffered 10% formalin solution for approximately 24 hours. After formalin fixation, specimens were histologically processed and 5 mm sections were obtained. Both the removed portion of the biceps tendon sections and surrounding tenosynovium sections adjacent to the tendon were stained with H&E and evaluated histologically using the Bonar score²⁶ for tendon pathology. In addition, immunohistochemistry staining for substance P (SP) and calcitonin gene-related peptide (CGRP), as markers of pathologic changes of the LHBT²⁷; matrix metalloproteinases 13(MMP 13), a marker for tendon degeneration were performed (Fig. 6).

A macro was written in the ImageJ 1.50 image processing software to conduct effective and consistent image analysis. Images of the whole slide (see Fig. 6) were generated in the .tif format for the immunohistochemistry staining and were stored in a single directory in the RGB format. All these images were saved at the same resolution and magnification to ensure consistent analysis among different samples. The software opened each image file for analysis and applied a constant threshold to create masks for the extent of immunohistochemical positive staining and the whole section area. The reported results represent the ratio of immunohistochemically

positive cells to the total number of cells within the whole section area. Additionally, the mask was saved in a graphic file for users to visually inspect.

Statistical Analysis

SPSS28.0 software was used for statistical analysis. Measurement data are expressed as Mean $\pm$ SD. One-way analysis of variance or the Kruskal-Wallis rank-sum test was performed for continuous data. If there were significant differences, a post hoc analysis was performed using the Game-Howell method for unequal variance and the Tukey method for equal variance to find statistically distinct groups. For categorical data, the chi-square or Fisher exact test was performed to compare each pair of groups. Using analysis of variance to determine differences among zones with respect to the Bonar score. When significant differences among zones were obtained, the Tukey test procedure was selected as post hoc analysis to determine which zones were different. Statistical significance was set at $P < 0.05$.

Results

Patient Demographics

A total of 139 patients were eligible for this study, including 75 patients with intertubercular groove tenodesis (Group IT), 64 patients with suprapectoral tenodesis (Group ST). There were no significant differences in age ($P = 0.688$), gender ($P = 0.078$), dominant side involvement ($P = 0.751$), course of disease ($P = 0.229$), diabetes ($P = 0.98$) or smoking history ($P = 0.342$) between the two groups.

Intraoperative data

Both sets of patients successfully underwent the surgery with no nerve, vascular injury and other serious complications occurring during the surgery. There were no significant differences in surgery time ($P = 0.87$) and number of anchors ($P = 0.59$) used between the two groups. The length of LHBT excised between the two groups was significantly different ($P < 0.001$).

Rotator cuff healing and Complications

At the last follow-up of MRI examination postoperative, the LHBT was well fixed, the supraspinatus tendon of all patients healed well (Figure 7) and 94.2% of the patients were of Sugaya type I-II, and 5.8% were of Sugaya type III. None of them presented a Popeye deformity, cramping pain, fracture, and neurovascular injury.

Score

The scores were significantly improved in both groups ($P < 0.001$), the scores were significantly improved at 6 months postoperative compared with 3 months postoperative (VAS: IT group: $P < 0.001$, ST group: $P = 0.039$; UCLA: IT/ST group: $P < 0.001$; ASES: IT group: $P = 0.001$, ST group: $P < 0.001$; CMS: IT/ST group: $P < 0.001$; SST: IT/ST group: $P < 0.001$). At 6 months postoperative, the VAS score was significantly lower in ST group compared to IT group ($P = 0.039$). In IT group, the UCLA score was significantly higher at 3 months postoperative than preoperative ($P = 0.01$); In ST group, the ASES score was significantly higher at 12 months postoperative than 6 months postoperative ($P = 0.027$). Patient clinical scores data are listed in Table 1.

Table 1
Comparisons of clinical scores between IT group and ST group.

	Preoperative	At 3 months follow-up	At 6 months follow-up	At 12 months follow-up	At 24 months follow-up	P Value	Post hoc analysis				
							Preoperative-At 3 months follow-up	At a follow-up of 3 to 6 months	At a follow-up of 6 to 12 months	At a follow-up of 12 to 24 months	
VAS											
IT group	5.10 ± 2.63	3.8 ± 2.04	2 ± 1.59	0.94 ± 1.02	0.53 ± 0.23	<0.001	0.216	<0.001	0.892	0.410	
ST group	5.40 ± 2.68	3.7 ± 2.27	1 ± 1.03	0.63 ± 0.96	0.46 ± 0.76	<0.001	0.065	0.039	0.123	0.172	
P Value	0.744	0.744	0.039	0.433	0.64						
UCLA											
IT group	17.3 ± 5.51	21.5 ± 4.83	32.06 ± 4.55	32.47 ± 2.98	34.76 ± 2.47	<0.001	0.01	<0.001	0.946	0.922	
ST group	16.8 ± 5.72	21.65 ± 6.24	30.74 ± 3.96	32.16 ± 2.61	33.05 ± 8.82	<0.001	0.06	<0.001	0.354	0.890	
P Value	0.78	0.933	0.115	0.594	0.352						
ASES											
IT group	40.6 ± 31.95	63.2 ± 19.8	88.94 ± 11.22	91.65 ± 8.89	94.54 ± 9.01	<0.001	0.263	0.001	0.290	0.289	
ST group	52.5 ± 20.88	66.3 ± 14.68	85.11 ± 13.0	92.16 ± 8.17	96.07 ± 8.43	<0.001	0.11	<0.001	0.049	0.391	
P Value	0.463	0.577	0.309	0.778	0.531						
CMS											
IT group	52.55 ± 19.83	53.0 ± 13.81	79.77 ± 12.13	82.12 ± 8.04	84.5 ± 9.0	<0.001	0.928	<0.001	0.734	0.832	
ST group	45.1 ± 15.63	51.4 ± 15.77	75.53 ± 10.15	80.42 ± 7.40	83.09 ± 2.15	<0.001	0.165	<0.001	0.191	0.762	
P Value	0.195	0.735	0.094	0.415	0.411						
SST											
IT group	5.0 ± 3.75	4.75 ± 2.31	9.94 ± 2.49	10.65 ± 0.93	10.96 ± 0.54	<0.001	1	<0.001	0.413	0.933	
ST group	3.45 ± 3.07	4.8 ± 3.0	9.26 ± 2.42	10.64 ± 1.00	10.90 ± 0.78	<0.001	0.14	<0.001	0.627	0.0.642	
P Value	0.16	0.953	0.168	0.802	0.244						

Data are presented as mean ± standard deviation unless otherwise indicated. IT: intertubercular groove tenodesis; ST: suprapectoral tenodesis. VAS: Visual Analog Scale, ASES: American Shoulder and Elbow Surgeons, CMS: Constant-Mueley score, UCLA: University of California at Los Angeles, SST: Simple Shoulder Test.

Range of active motion

The range of active motion was significantly improved in both groups ($P \leq 0.001$), the range of active motions were significantly improved at 6 months postoperative compared with 3 months postoperative (forward flexion: IT group: $P = 0.001$, ST group: $P < 0.001$;

Abduction: IT/ST group: $P < 0.001$). In ST group, the range of active abduction motion was significantly greater at 12 months postoperative than 6 months postoperative ($P = 0.008$). The patient range of active motion data are listed in Table 2.

Table 2
Comparisons of range of active motion between IT group and ST group.

	Preoperative	At 3 months follow-up	At 6 months follow-up	At 12 months follow-up	At 24 months follow-up	P Value	Post hoc analysis			
							Preoperative-At 3 months follow-up	At a follow-up of 3 to 6 months	At a follow-up of 6 to 12 months	At a follow-up of 12 to 24 months
Active flexion										
IT group	113.5 ± 41.46	124.00 ± 37.19	168.82 ± 18.25	177.06 ± 8.49	177.14 ± 8.25	<0.001	0.465	0.001	0.218	0.797
ST group	111.75 ± 40.56	115.00 ± 37.91	162.63 ± 23.06	173.68 ± 12.57	175.42 ± 14.9	<0.001	0.836	<0.001	0.322	0.679
P Value	0.84	0.453	0.355	0.594	0.641					
Active abduction										
IT group	102.37 ± 42.31	122.5 ± 36.69	165.30 ± 26.19	175.88 ± 9.39	178.20 ± 6.40	<0.001	0.087	<0.001	0.109	0.653
ST group	110.5 ± 41.26	112 ± 37.78	158.42 ± 34.04	175.26 ± 11.24	176.32 ± 6.53	<0.001	0.901	<0.001	0.008	0.789
P Value	0.357	0.378	0.403	1.0	0.881					
Data are presented as mean ± standard deviation unless otherwise indicated. IT: intertubercular groove tenodesis; ST: supraopectoral tenodesis.										

Histopathology

10 tendons were analyzed. The Bonar scores of zone 1 and 2 of the tendons were significantly higher than that of zone 3 ($P < 0.05$). Among the variables of the Bonar score, the tenocytes score, ground substance score, collagen score, vascularity score of zone 1 and 2 were significantly higher than that of zone 3 ($P < 0.05$). Results are shown in Table 3. The pairwise comparisons of different tendon zones showed that the immunohistochemically positive cells in zone 1 and 2 was significantly more than those in zone 3 ($p < 0.05$). The complete list of comparisons can be found in Table 4.

Table 3
Comparisons of Bonar score between IT group and ST group.

Zone 1	Bonar Score	Tenocytes	Ground substance	Collagen	Vascularity
	9.3 ± 0.9	2.1 ± 0.3	2.3 ± 0.1	2.2 ± 0.3	2.2 ± 0.2
Zone 2	10.3 ± 1.0	2.2 ± 0.5	2.6 ± 0.6	2.3 ± 0.4	2.4 ± 0.5
Zone 3	2.8 ± 1.3	1.3 ± 0.1	1.0 ± 0.5	0.6 ± 0.3	0
Data are presented as mean ± standard deviation unless otherwise indicated.					

Table 4
Comparison of quantified tendon pathology

	Zone 1	Zone 2	Zone 3	P Value	Post hoc analysis		
					1 vs 2	2 vs 3	1 vs 3
SP	0.06	0.07	0.03	$p < 0.001$	0.83	$p < 0.001$	$p < 0.001$
CGRP	0.10	0.09	0.01	$p < 0.001$	0.93	$p < 0.001$	$p < 0.001$
MMP13	0.13	0.08	0.02	$p < 0.001$	0.76	$p < 0.001$	$p < 0.001$
Data are presented as mean unless otherwise indicated.							

Discussion

The most important findings of this study are as follows: (1) Arthroscopic small sized supraspinatus tendon repair combined with IT or ST showed good clinical outcomes. (2) At 6 months postoperative, the VAS score was significantly lower in ST group compare with IT group. Based on a comparison of scores and range of active motion between the two types of tenodesis, IT showed an advantage in functional improvement. (3) There were significant differences in the length of LHBT excision between the two groups. There were also clear regional histologic differences in different zones of the LHBT. The histopathological scores of zones 1 and 2 of LHBT were significantly higher than that of zone 3.

The fixation position of LHBT during tenodesis is contested. According to some studies, the results showed no significant differences in VAS, ASES, CMS, and SST between IT group and ST group^{28,29}, which aligned with the findings of this study. However, Yi et al.³⁰ evaluated 71 patients with RCT and LHBT lesions that were repaired through IT or ST. They yielded better VAS scores 3 months postoperative in patients with ST. Guerra et al.³¹ found similar results in a retrospective study involving 1,923 patients. Therefore, patients may be better suited for ST given its pain relief characteristics. In previous studies, it was observed that the improvement advantage of ASES with IT compared with ST at the final follow-up of 2 years³¹. This study also concluded that at most follow-up time points, the scores and range of active motion in IT group were better than ST group. Moreover, the UCLA in the IT group was significantly improved at 3 months postoperative compared to preoperative values, while the SST and the range of active abductive motion in ST group were still significantly improved at 12 months compared to 6 months postoperative, suggesting that IT showed an advantage of early or better functional improvement. For patients with high requirements for restoring function and range of active motion, IT could be the better option. The functional scores and range of active motion of the two groups of patients showed improvement at 24 months postoperative compared to 12 months postoperative, but the difference did not reach statistical significance. The change in the rate of improvement suggests that the rapid improvement period is from 3 to 6 months postoperative, and the biomechanical remodeling period of LHBT has basically been completed; from 6 to 12 months postoperative, LHBT has been able to gradually accept the daily activity load, thereby promoting the functional scores and range of motion to reach a relatively balanced state; while some indicators that still improved at 12–24 months postoperative may be due to the further optimization of neuromuscular control and the enhanced adaptability of patients to the shoulder compensation mechanism. It is worth noting that the functional scores and range of active motion of the IT group were always better than those of the ST group during the follow-up process, but at 24 months postoperative, the ASES score of the ST group was better than that of the IT group, indicating that at the final follow-up time point of this study, there was no statistical difference or potential advantage in the functional scores and range of active motion between the two surgical techniques, suggesting that the clinical value of the two surgical methods may be more reflected in the early improvement of functional scores and range of active motion, and it emphasizes that the surgical plan should be selected based on the early needs of the patients.

Compared with IT, ST allows for the removal of more LHBT tissue. Pain mainly comes from mechanical and chemical stimuli^{32,33}. During the ST, the complete lesion area of the LHBT can be removed, more inflammatory tissues around the LHBT can be cleared and more growth factors can be produced^{3,34}. Moreover, the downward movement of the fixed position can better control the tension and length of the LHBT and reduce the stimulation between LHBT and surrounding structures (such as subscapular and Pulley structure)^{35,36}. Therefore, the complete resection of the pathological tissue of the LHBT is the key to alleviate pain³⁷. However, ST has a larger surgical scope in front of the shoulder joint, can entail vascular injury, new neurogenesis, and scar tissue formation in the anterior space of the shoulder joint, resulting in increased discomfort during activities. Therefore, patients underestimate the functional improvement^{38,39}. These findings suggest that postoperative pain does not impede the rehabilitation exercises for improving shoulder

joint range of active motion, whereas an excessively extensive surgical procedure may adversely affect the patient's postoperative rehabilitation progress.

Gilmer et al. compared the LHBT pathology of patients requiring tenodesis through arthroscopic and open surgery, and found that arthroscopic examination could only reveal 32% of the tendon, which might lead to an underestimation of the pathology⁴⁰. Taylor et al. showed in a cadaveric study that among 277 patients with LHBT inflammation, 47% of the patients presented with extra-articular lesions of the LHBT that remained hidden from view during standard diagnostic arthroscopy⁴¹. In the standard arthroscopic examination, LHBT lesions, especially the extra-articular lesions, were extremely difficult to detect. SP and CGRP were largely present throughout the entire tissue section, with the highest accumulation in the axon bundles and blood vessels. Both proteins immunoreactivity increases in the nerve endings of inflamed tissues; suggesting a role for these modulators in both pain and inflammation, thus, they were selected as markers of pathologic changes of the LHBT^{27, 42}. Previous studies have reported that the LHBT at the molecular level shows significantly increased levels of MMPs in patients with RCT⁴³, which as marker are known to correlate with tendon degeneration. Similarly, Taylor et al. divided LHBT into three different anatomical regions: extending from the articular margin to the margin of the subscapularis tendon, zone 2 within the bicipital area extending from the margin of the subscapularis tendon to the proximal margin of the pectoralis major, and zone 3 extending from the subpectoral region to the musculotendinous junction⁴¹. Using these reference zones, we sectioned specimens into 3 zones and evaluated each segment independently. Similar to their findings, our study showed that there were a amount of pathological changes in the zone 1 and 2. The scores in the zone 1 and 2 were significantly higher than zone 3. This suggests that the proximal tendon of LHBT may have a higher level of inflammation. This finding supports that when dealing with LHBT lesions, at least the intra-articular and THL-covered parts of LHBT should be removed to completely eliminate the diseased tissue of LHBT and alleviate postoperative pain. That is, the optimal fixation position might be the upper edge of suprapectoral.

In previous studies, the discussion of IT and ST also included surgery time, blood loss, esthetic effect, etc. Liu et al.²⁸ contended that IT entailed a shorter surgery time and with comparatively less blood loss, while Yi et al.³⁰ came to the opposite conclusion. Raphael et al.⁴⁴ compared 34 patients who underwent ST, and the results showed that patients with LHBT resection had lower esthetic satisfaction. This study found no significant difference in the surgery time and there were no complications such as Popeye deformity in the two types of tenodesis. The inconsistent findings may be related to the proficiency of the surgical techniques involved. Moreover, this study observed improvement in the scores and range of active motion in both tenodesis at various follow-up points, highlighting that period's importance as a transitional period of rehabilitation. In previous studies, the follow-up time with significant differences in clinical results ranged from 2 weeks to 2 years, indicating that rehabilitation exercises in each period should not be ignored, and the specific rehabilitation plan should still be adjusted according to patients' conditions. A follow-up of 5 years postoperative, or even longer follow-up results are still important.

Limitations

This study had several limitations. Firstly, this study was not a prospective randomized controlled study, but strict inclusion and exclusion criteria were established during the study. The patients enrolled were rigorously screened based on medical history, physical examination and endoscopic exploration, and follow-up results of patients at various follow-up times were completely collected to minimize selection bias. Secondly, the sample size of this study is relatively small sized. Despite yielding significant differences in pain, score and range of active motion, the study should be supported by more medical evidence. Third, the postoperative follow-up time in this study was relatively short; however, the follow-up time already included a period of 24 months postoperative, which was the most important rehabilitation transition period during the follow-up period. However, more long-term follow-up results are still needed to more comprehensively evaluate the clinical efficacy of the two types of tenodesis. Finally, the patients included in this study presented the common LHBT lesion combined with small sized RCT in clinical practice, thereby bringing the study closer to clinical practice and giving full play to the clinical protocol guiding role of the study. Meanwhile, the type of RCT was limited to small sized supraspinatus tendon tear, reducing the impact of concomitant injuries on the study results and the potential bias from other subtypes of injuries.

Conclusion

Intertubercular groove and suprapectoral tenodesis combined with rotator cuff repair in the treatment of small sized supraspinatus tendon tear combined with long head of biceps tendon lesions can both significantly improve the clinical outcomes postoperative. Since pain does not significantly affect rehabilitation, intertubercular groove tenodesis shows potential functional improvement

advantages, so it seems to be a better choice, but for patients whose purpose of pain relief, the suprapectoral tenodesis is also a good choice.

Abbreviations

- ITIntertubercular groove tenodesis
- STSuprapectoral tenodesis
- RCRRotator cuff repair
- LHBTLong head of biceps tendon
- VASVisual Analog Scale
- ASESAmerican Shoulder and Elbow Surgeons
- CMSConstant-Mueley score
- UCLAUniversity of California at Los Angeles
- SSTS Simple Shoulder Test

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Ethics Committee (Approval No.Ke2024-139-1).

Consent for publication

All patients were informed of this clinically validated treatment and signed consent forms.

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

Funding

Not applicable

Authors' contributions

TJD: research design and implementation; YG: research, data analysis and thesis writing; SXB, TJG, HZW: data collection and thesis review; ZZ, YT, DZZ: Collect data and organize personnel evaluation.

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Clinical trial number

Not applicable

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Figures



Figure 1

Preoperative MRI revealed small sized supraspinatus tendon tear (white arrow) and inflammation of the LHBT (white arrow)

SSP: supraspinatus. HH: head of humerus. LHBT: long head of biceps tendon

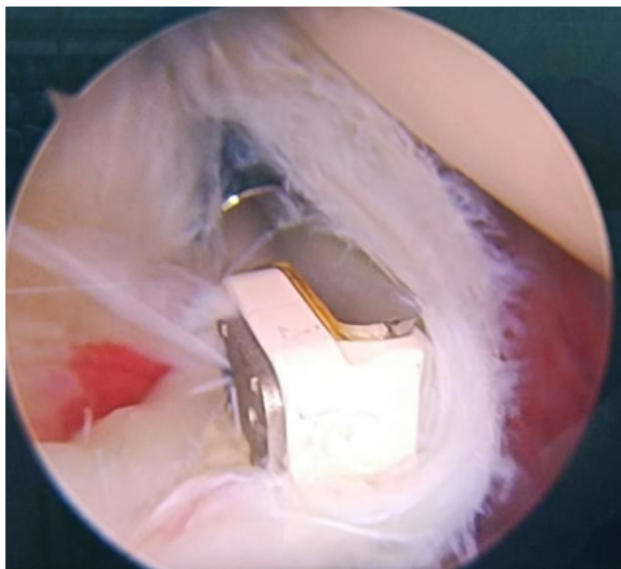


Figure 2

Microscopic examination of LHBT lesions

LHBT: long head of biceps tendon

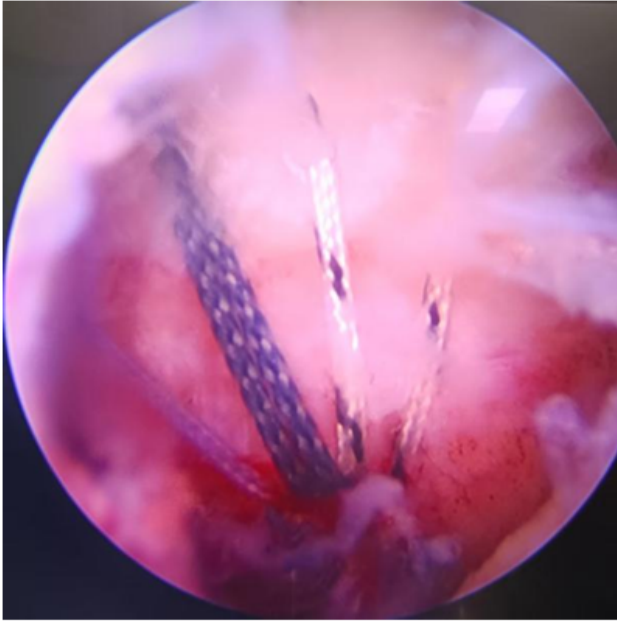


Figure 3

Postoperative arthroscopic RCR

RCR: rotator cuff repair

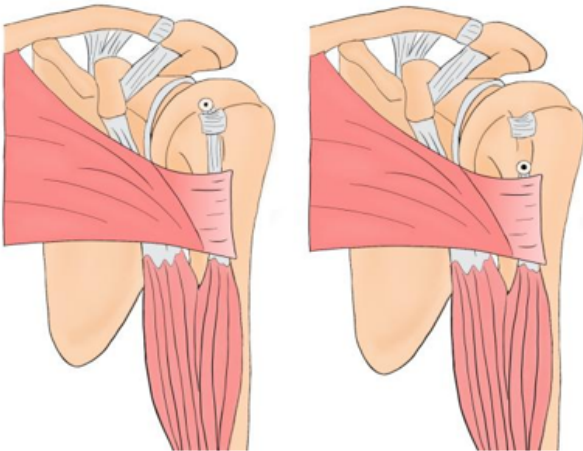


Figure 4

Fixation position of the LHBT

LHBT: long head of biceps tendon

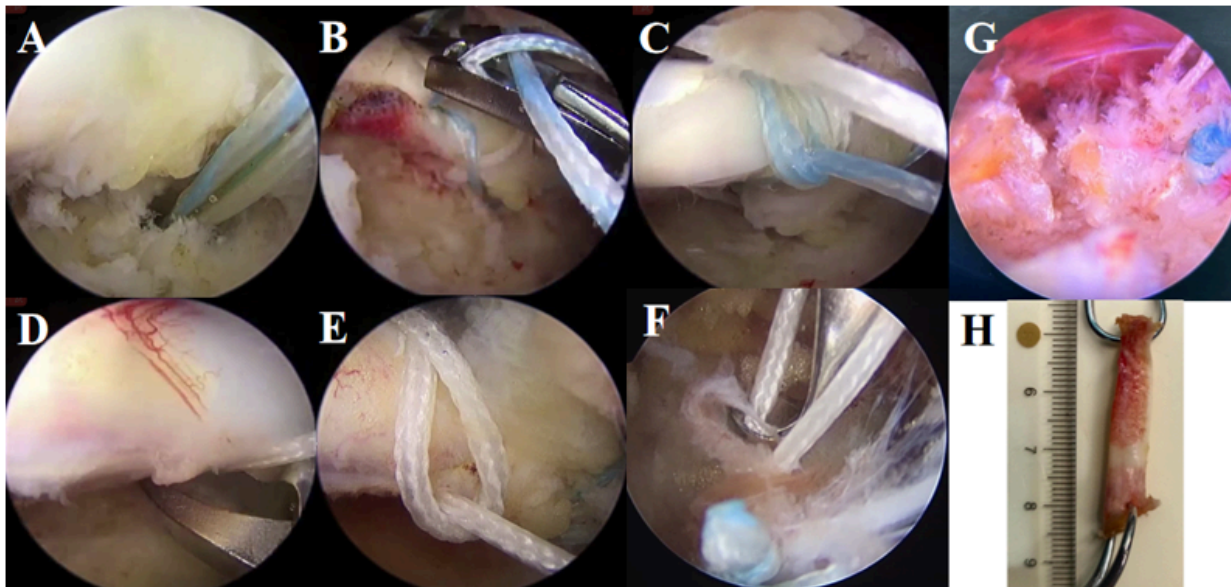


Figure 5

Arthroscopic suprapectoral tenodesis progress. (A) Freshen up the bone and implant a wire anchor. (B and C) A suture is threaded through the LHBT to make a lasso-type loop; (D and E) A suture goes under the LHBT to make a lasso-type loop; (F) Both ends of the same color suture strand were tied in a non-sliding fashion to fix the LHBT in situ. (G) Cut off and remove the LHBT. (H) Measured the length of LHBT extracted in vitro.

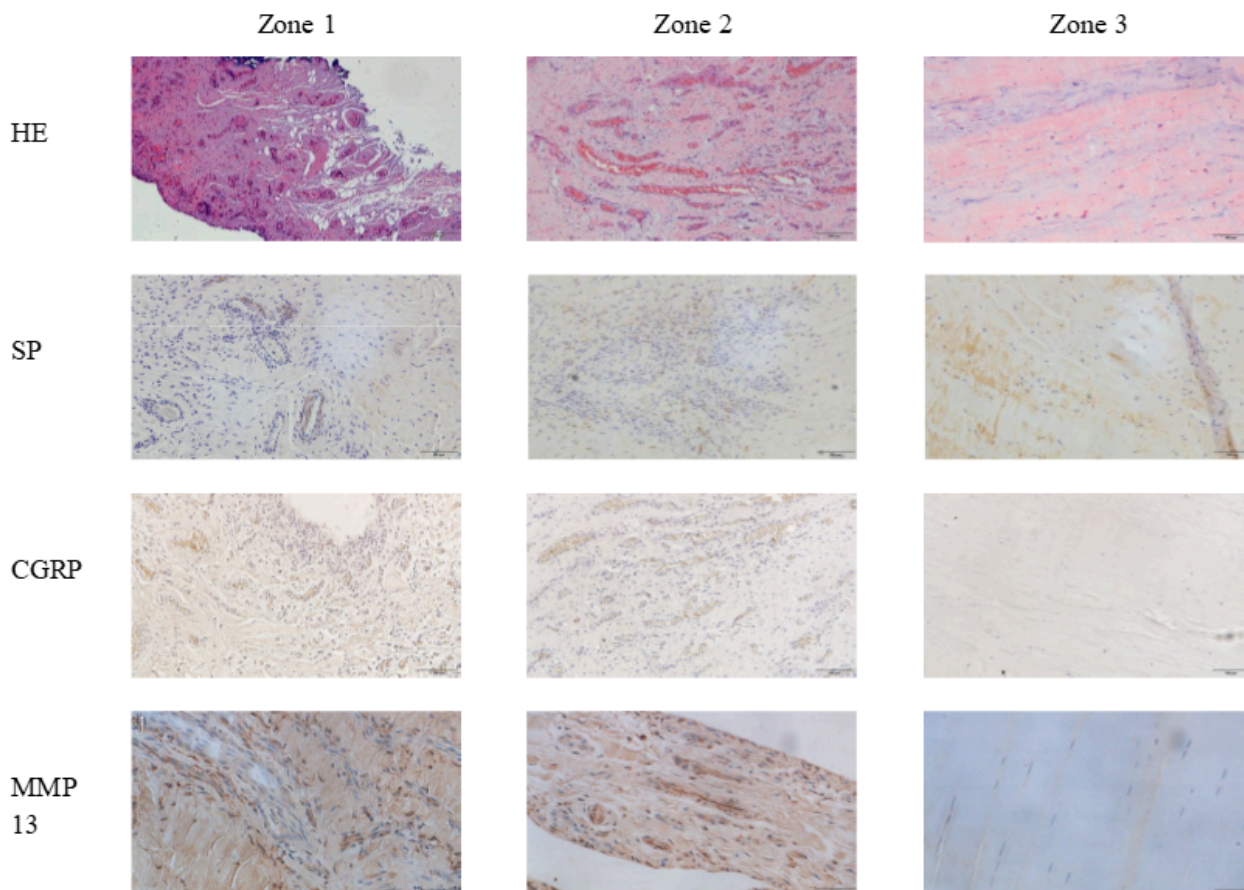


Figure 6

The LHBT sections prepared in HE stain and immunohistochemistry, revealing the pathology in different zones. Scale bar at bottom right. 500µm

SP: substance P. CGRP: calcitonin gene-related peptide. MMP 13: matrix metalloproteinases

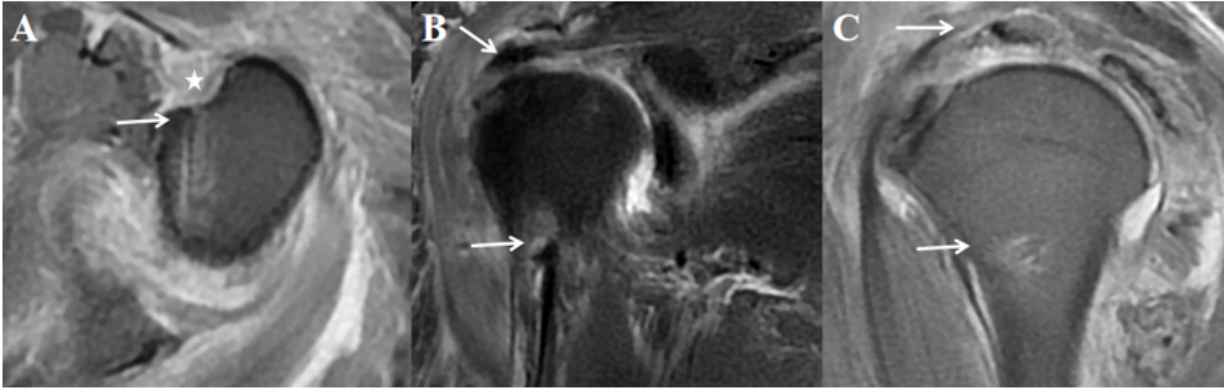


Figure 7

The healing of the LHBT and rotator cuff was assessed by MRI images. (A) Proximal stump of LHBT in axial cut image is identified by finding the first slice with empty groove (asterisk) or anchor position (arrow) ascending from distal to proximal; (B and C) Coronal and sagittal cut image to observe LHBT fixation and supraspinatus tendon healing (arrow)