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Surgical approach of long head of biceps chronic rupture - a systematic review

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Abstract

Background and aims: address the intricate challenges associated with chronic ruptures of the LHBT within the surgical domain and contribute valuable insights into surgical techniques and patient reported outcomes measures.

Methods: A computerized search of the literature in accordance with PRISMA guidelines was conducted in May 2024, comprehending four different databases- Pubmed®, SCOPUS®, Web of Science® and Cochrane Library®-, based on the following search query: (*long head of biceps tendon rupture*) AND ((*tenodesis)* OR (*chronic*)). The Methodological index for Non-randomized Studies (MiNOrS) was used to assess study quality

Results: There were 78 patients included in this systematic review, with mean follow-up ranging from 19.1 months to 3.8 years. Patients were predominantly male (91%), with mean age ranging from 41 to 61 years old. The mean time interval between LHBT rupture and surgery ranged from 9 weeks to 30.1 months and surgical management involved open subpectoral tenodesis in 4 of 5 articles. The primary complaints of all patients were pain, cramping and/or Popeye deformity, whether after failing to improve after a period of conservative treatment, whether by post-surgical rupture of a previously performed LHBT tenodesis or ‘‘iatrogenic’’ rupture following surgical tenotomy. There is evidence of an overall mean improvement ≥ 85% regarding pain (93.4%), deformity (90.1%), strength (85%) and cramping (90.7%), besides significant progress in terms of scores of evaluation. There were no reports of infection, neurovascular injury, adhesive capsulitis or humeral pain/fracture in any study.

Conclusion: When conservative treatment fails, LHBT tenodesis for symptomatic isolated chronic rupture of the LHBT is related to good to excellent clinical and patient reported outcomes measures, with low complication rates.

Key-words: *long head of biceps, chronic rupture, surgical treatment, tenodesis*

Resumo

Introdução e objetivos: abordar os complexos desafios inerentes às ruturas crónicas do tendão da longa porção do bicípite no domínio cirúrgico e contribuir com perspetivas relevantes sobre as técnicas cirúrgicas e resultados relatados pelos doentes.

Métodos: Uma pesquisa computadorizada da literatura de acordo com as diretrizes PRISMA foi realizada em maio de 2024, compreendendo quatro bases de dados diferentes - Pubmed®, SCOPUS®, Web of Science® e Cochrane Library® -, com base na seguinte consulta de pesquisa: (long head of biceps tendon rupture) AND ((tenodesis) OR (chronic)). O índice metodológico para estudos não aleatórios (MINORS) foi utilizado para avaliar a qualidade dos estudos.

Resultados: Foram incluídos 78 doentes nesta revisão sistemática, com um seguimento médio que variou entre 19,1 meses e 3,8 anos. Os pacientes eram predominantemente do sexo masculino (91%), com idade média variando de 41 a 61 anos. O intervalo médio de tempo entre a rutura do tendão da longa porção do bicípite e a cirurgia variou entre 9 semanas e 30,1 meses e o tratamento cirúrgico envolveu tenodese subpeitoral convencional em 4 dos 5 artigos. As queixas referidas por todos os doentes eram dor, cãibras e/ou deformidade Popeye, quer por não terem melhorado após um período de tratamento conservador, quer por rutura pós-cirúrgica de uma tenodese previamente efetuada ou rutura "iatrogénica" pós-tenotomia. Evidencia-se uma melhoria média global ≥ 85% no que diz respeito à dor (93,4%), deformidade (90,1%), força (85%) e cãibras (90,7%), para além de uma evolução significativa ao nível dos scores de avaliação. Não houve relatos de infeção, lesão neurovascular, capsulite adesiva ou fratura/dor umeral em nenhum estudo.

Conclusões: Quando o tratamento conservador falha, a tenodese do LHBT para a rutura crónica isolada sintomática do LHBT está relacionada com bons a excelentes resultados clínicos relatados pelos doentes, com baixa taxa de complicações.

List of Abbreviations

ASES- American Shoulder and Elbow Surgeon

DASH- Disabilities of the Arm Shoulder and Hand (DASH)

LHBT- Long Head of Biceps Tendon

LOE- Level of evidence

MAYO- Mayo Elbow Performance

MINORS- Methodological Index for Non-Randomized Trials

Pain VAS- Pain Visual Analogue Scale

PROMs- Patient Reported Outcome Measures

SANE- Single Assessment Numeric Evaluation

SF-12 PCS- Short Form 12 Physical Component Summary

SPBS- Subjective Proximal Biceps Score

WORC- Western Ontario Rotator Cuff Index

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Introduction

The long head of biceps tendon originates proximally from the supraglenoid tubercule and the superior glenoid labrum and courses the glenohumeral joint distally through the bicipital groove on the humerus. On the bicipital tuberosity, the LHBT inserts more proximally and mostly functions as a forearm supinator[1]; it also serves as a flexor of the elbow, plays a role in flexing and medially rotating the shoulder[2] and works as a stabilizer of the glenohumeral joint[3]. LHBT ruptures are typically categorized as either partial-thickness or full-thickness tears, frequently occurring in the hypovascular zone positioned between 1.2 and 3.0 cm from the tendon's insertion point[4].

Traumatic rupture of the LHBT has been extensively described as a common cause of anterior shoulder pain and instability[5]. LHBT ruptures account for more than 90% of all biceps brachii injuries[6, 7], frequently associated with underlying rotator cuff tendinopathy[3, 8, 9], concomitant superior labral anterior-posterior lesion, tendinitis and tenosynovitis[10]. Risk factors for rupture include recurrent tendinitis, a history of rotator cuff pathology, a contralateral biceps tendon rupture, age and inflammatory arthritis[1]. Most proximal LHBT ruptures occur in patients over the age of 50 years [3, 9, 11], reflecting the cumulative effects of age-related degeneration and repetitive microtrauma on tendon integrity, leading to intrinsic tendon degeneration within the bicipital groove or along the biceps-labral complex[6]. While the exact incidence remains elusive, studies also report a higher prevalence of traumatic LHBT ruptures without the presence of rotator cuff disease among physically active populations, particularly young athletes engaged in overhead sports[12-14].

Clinical diagnosis is typically based on a history of trauma, frequently involving eccentric contraction of the biceps, and the presence of the pathognomonic "Popeye sign" observed during physical examination, a cosmetical abnormality resulting from distal displacement of the long head of the biceps muscle. Recently, the use of high-resolution ultrasound is becoming more common in the diagnostic process due to its high specificity, allowing for a more precise and non-invasive evaluation of the injury[5].

In most cases, LHBT are either asymptomatic or present with mild symptoms. These cases can often be successfully managed conservatively through nonoperative measures, including rest, activity modification, nonsteroidal anti-inflammatory drugs, physical therapy, cryotherapy and corticosteroid injections into the bicipital sheath[1, 4, 7, 15]. However, certain individuals, due to missed diagnosis or first seeking treatment at a later stage, may develop

muscle belly cramping, persistent muscle pain, muscular weakness, loss of supination and elbow strength and a cosmetic unappealing deformity[1, 8, 16, 17]**.** In fact, studies that focused on results following chronic LHBT rupture reported loss of strength at the elbow rather than the shoulder and evidenced that elbow flexion strength could reduce by 16-28% and supination strength could decrease by 12-23% [18, 19].

In cases where symptoms persist despite conservative management, surgical intervention may be warranted. Even though most surgeons do not offer surgery for individuals more than 3 months after rupture, some experts propose that tenodesis could lead to improved patient outcomes by enhancing the shape, strength and length-tension relationship of the damaged LHBT[20]. Although uncommon, recurrence of symptoms due to post-surgical rupture of a previously performed LHBT tenodesis or ‘‘iatrogenic’’ rupture of the LHBT following surgical tenotomy may require revision tenodesis. Past clinical series reported a 45% prevalence of Popeye deformity and 8% cramping arm pain after arthroscopic surgical tenotomy of the LHBT [21]. Ideally, these tears should be identified early and surgically treated so that the muscle-tendon unit can be retensioned and tenodesed. In patients who present with chronic ruptures, the tendon may be retracted, shortened, or altogether absent, hindering the procedure due to the scarring and retraction, which may preclude success[8, 16].

Therefore, the forthcoming study aims to address the intricate challenges associated with chronic ruptures of the LHBT within the surgical domain, once the specific nuances of LHBT reconstruction and tenodesis are less well-documented. Consequently, there exists a critical gap in the literature regarding standardized protocols and outcomes assessment for these procedures. Through comprehensive analysis and discussion, the study endeavors to contribute valuable insights into surgical techniques, improving patient outcomes and bridging the existing gaps in understanding chronic LHBT ruptures.

Methods

Research Framework and Literature Search

The design and reporting of this systematic review are in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. A computerized search of the literature was conducted in May 2024, comprehending four different databases- Pubmed®, SCOPUS®, Web of Science® and Cochrane Library®-, based on the following search query: (*long head of biceps tendon rupture*) AND ((*tenodesis)* OR (*chronic*)).

Study Eligibility

For a comprehensive review, controlled trial, cohort, case-control and case series studies concerning the LHBT rupture published since January 2010 were considered for eligibility. Studies investigating the clinical outcomes following revision biceps tenodesis after surgical LHBT tenotomy or previously failed LHBT tenodesis were also included in this review. Studies limited to the acute aspect of the rupture, rotator cuff pathology and tenodesis performed by any cause rather than LHBT rupture were excluded. Review articles, abstracts, posters, letters to the editor and all articles in languages other than English were also excluded.

Searching Strategy and Data Extraction

First and foremost, the results obtained from the survey were compared and the duplicated articles were excluded by the reviewer GN. Thereafter, two reviewers (GN and RC) independently screened articles identified in the literature search based on title and abstract. Subsequently, the inclusion and exclusion criteria were employed to ascertain the articles suitable for inclusion in the final review. Full-text reviews were conducted on all potentially eligible articles prior to the final decision regarding their inclusion in the study.

Data collection adhered to the guidelines outlined in the Cochrane Handbook for Systematic Review, employing a tailored data extraction form aligned with the recommended procedures. This form was designed to capture pertinent details regarding a) study characteristics: authors, journal, year of publication and study design; b) demographic and clinical characteristics: sample size, male/female ratio, age of population, definition of chronicity comorbidity profiles, c) technical characteristics: surgical indication, methodology, surgical procedures, intraoperative observations d) outcomes: length of follow-up, main study results, most significant conclusions; e) study limitations. A singular reviewer was responsible for data

extraction, with validation performed by a second reviewer. Instances of discordance during the selection process were resolved through deliberation between the two reviewers, with the final decision resting with RC.

The full process is outlined in the flowchart displayed in the appendix of this review (Figure 1).

Risk of Bias and Quality Appraisal

The quality of the selected papers for review and their risk of bias was accessed independently by two researchers (GN, RC) using the Methodological Index for Non-Randomized Studies (MINORS)[22]. This scale is a validated instrument consisting of 12 items designed to assess the methodological quality of nonrandomized surgical studies. The last 4 items are specific to comparative studies. Each item was scored as 0 if not reported, 1 when reported but inadequate, and 2 when reported and adequate. Maximum score is 16 for non-comparative studies and 24 for comparative studies. The level of evidence was also recorded. Two authors (GN and RC) independently assessed the methodological quality of all included articles, and all disagreements were discussed until consensus was reached.

Results

Study selection

A total of 432 articles were identified through the literature search. After removing duplicates, 285 articles underwent eligibility screening based on their titles and abstracts. 28 articles were retained for full-text review, of which 23 were excluded for failure to satisfy the inclusion criteria and 5 were included for quantitative and narrative analysis (see Figure 1). There was a single retrospective comparative study (LOE: III) and 4 case-series studies (LOE: IV). There were no studies of level I or II evidence. The average MINORS scores were 11 (range: 10-12) for noncomparative studies and 18 for the lone comparative study.

Population and Surgical Characteristics

There were 78 patients included in this systematic review, with mean follow-up ranging from 19.1 months to 3.8 years. Patients were predominantly male (91%), with mean age ranging from 41 to 61 years old. The primary complaints of all patients were pain, cramping and/or Popeye deformity, whether after failing to improve after a period of conservative treatment, whether by post-surgical rupture of a previously performed LHBT tenodesis or ‘‘iatrogenic’’ rupture following surgical tenotomy. Moreover, in all studies, patients were assessed thoroughly for any concomitant shoulder pathology using ultrasound or MRI. Four studies excluded cases with underlying shoulder pathology, instability or those who underwent any additional repairs at the time of surgery, whereas Euler et al.[9] included patients with concomitant rotator cuff repair.

The mean time interval between LHBT rupture and surgery ranged from 9 weeks to 30.1 months and surgical management involved open subpectoral tenodesis in 4 of 5 articles, whereas McMahon et al.[2] reported on open suprapectoral tenodesis. Fixation technique was made by interference screws in 50 patients (64.1%) and by suture anchors in 28 patients (35.9%). In this regard, both Anthony et al.[23] and McMahon et al.[2] performed in bone interference screw technique at all patients, whereas Waugh et al.[10] performed on bone suture anchor technique on 100% of cases. Ng et al.[8] and Euler et al.[9] performed both techniques, with a proportion of interference screw/suture anchors (%) of approximately 45/55% and 85/15%, respectively.

Characteristics of individual studies are detailed in Table I.

Postoperative clinical and functional outcomes

Patients were evaluated preoperatively and postoperatively with a comprehensive history or questionnaire regarding cosmetic concerns, pain level and extent of cramping. Eight measures of patient reported outcomes were reported including Subjective Proximal Biceps Score (SPBS), American Shoulder and Elbow Surgeon (ASES), pain Visual Analogue Scale (VAS), Short Form 12 Physical Component Summary (SF-12 PCS), Disabilities of the Arm and Shoulder and Hand (DASH), Mayo Elbow Performance, Single Assessment Numeric Evaluation (SANE) and Western Ontario Rotator Cuff Index (WORC).

Although the 6 studies shared the main goal of evaluating the clinical and patient reported outcomes after tenodesis of long head of biceps tendon following chronic rupture, some studies had secondary goals related to this topic.

On one hand, both Ng et al. [8] and Waugh et al. [10] focused on analyzing the patient reported outcomes who have undergone biceps tenodesis, upon failure of the conservative management of isolated symptomatic chronic LHBT rupture.

On the other hand, Anthony et al.[23], Euler et al.[9] and McMahon et al.[2] focused on three different features- iatrogenic rupture, revision tenodesis and timing of surgery, respectively. Anthony et al.[23] described the surgical outcomes of a subpectoral biceps tenodesis after failed surgical tenotomy or auto-rupture of the tendon in a population of active patients; Euler et al.[9] conducted a retrospective comparative study in order to assess the clinical results of open subpectoral LHBT tenodesis in patients with chronic LHBT ruptures and to compare the results between primary and revision cases; McMahon et al.[2] lead a study reporting the surgical technique and objective clinical outcomes in a series of patients with LHBT tenodesis done more than 3 months after rupture.

Main Findings

Post-operatively patient reported outcome measures have significantly increased compared to pre-operatively on all studies. There is also evidence of an overall mean improvement ≥ 85% regarding pain (93.4%), deformity (90.1%), strength (85%) and cramping (90.7%), besides significant progress in terms of scores of evaluation.

Both Ng et al.[8] and Waugh et al. [10] demonstrated that symptomatic chronic LHBT ruptures improve with an open subpectoral tenodesis. In the first study[8], 90.9 % (10/11) of the cases reported improvement in strength, cosmesis and pain, whereas only one patient reported no progress; he was the oldest patient (65 years) in the series and had the longest interval between injury and surgery (96 months). Similarly, in the second study[10], 100% of patients reported significant progress in pain, function and cosmetic appearance, which is in line with the pre and postoperatively scores of evaluation: ASES score increased by 59.6 (33 pre-op to 92.6 post-op) and the mean pre-op pain VAS was 6.3/10 compared to 0.2 post-op. All patients described difficulty in work and required analgesia pre-operatively compared to none post-operatively.

In Anthony et al.[23], 100% of the patients (10/10) had resolution of their cosmetic deformity and 90% (9/10) reported improvement in cramping and fatigue symptoms, demonstrating that open subpectoral tenodesis, after failed surgical tenotomy or auto-rupture of the LHBT, in young active patients, provides predictable clinical resolution. Moreover, nearly all patients were able to return to their desired activity levels (90%) and achieved primarily good to excellent surgical outcomes on the basis of SANE and WORC scores- a mean improvement of 37.8% (61.1 pre-op to 84.2 post-op) and 61.7% (53.2 pre-op to 86 post-op), respectively.

Euler et al.[9] showed that open subpectoral tenodesis was a safe and effective method for the treatment of chronic LHBT ruptures and for the revision of failed post-surgical LHBT ruptures. Taking both primary and revision cases into account, 96% of the patients reported improvement in pain (1/25), 79.2% in deformity (19/24), 72% in strength (18/25) and 82.4% in cramping (14/17). Considering the failure cases, 87.5% occurred on the primary group, with higher prevalence related to deformity and strength. Median post-operative SPBSs (8) demonstrated statistically improvement when compared to the median pre-operative baseline (1)- 23/25 patients (92%) showed improvements in the overall SPBS with a mean change of -6 points. Additionally, twenty patients (74%) completed the shoulder survey containing postoperative and SF-12 PCS scores. ASES score significantly improved from 52.0 pre-op to 90.7 post-op and the SF-12 PCS score improved from 39.9 to 52.5.

McMahon et al.[2] established that LHBT open suprapectoral tenodesis is possible more than 3 months after rupture. 90% of the patients reported full recovery from daily work and sports activities, without biceps pain or spasm, whereas 10% reported Popeye deformity. The average pre-operative DASH score was 37.2 and at follow-up there was a significant

improvement of 11.2 with a score change of 26, just like the pre-operative Mayo performance was 57.5 and at follow-up the average score significantly increased to 86.

There were no reports of infection, neurovascular injury, adhesive capsulitis or humeral fracture in any study, following prior studies that found low incidence of complications after open LHBT tenodesis[24].

Summary of PROMs are illustrated on Tables II and III.

Discussion

The primary finding of this review is that performing biceps tenodesis is a secure option in symptomatic LHBT chronic ruptures as it is associated with excellent PROMs and high patient satisfaction at mid-term follow-up, with low complication rates. Even though chronic ruptures of the LHBT are usually asymptomatic and treated non-operatively, patients reported long-term bicipital pain, cramping, weakness and deformity to be the key factors for seeking surgical intervention.

Many proximal biceps tenodesis techniques, both arthroscopic and open have been described, although previous studies have failed to demonstrate a significant difference in their outcomes[25]. On account of injury´s chronicity and based on previous reports, LHBT´s scarring and retractation was the main intraoperative finding that hindered the surgeon´s decision whether or not to perform the surgery, once it could preclude its success. Within this context, an arthroscopic approach is a technically challenging surgery and probably the main reason why all included studies opted for open tenodesis.

The choice of a fixation technique is dependent upon position, mobility and quality of the LHBT as well as surgeon preference. When surgery is performed early enough after injury and a good quality tendon that can be reattached more proximally in the humeral metaphysis is found, intraosseous fixation with an interference screw is recommended. However, in cases with poor tendon quality, severe scarring or retraction[16] of the LHBT, an extraosseous fixation with the use of suture anchors at the humeral diaphysis may be more appropriate to keep an appropriate length-tension relationship. In addition, prior cadaveric studies have shown better biomechanical properties and load to failure of interference screw fixation rather than other fixation techniques[26-28]. Anterior humeral pain is a well-documented complication resulting from LHBT tenodesis, particularly if suture anchor´s technique is performed[29]; Mazzocca et al. [30] found anterior humeral pain in 9 of 41 patients (22%), whereas Gregory et al. [31] suggested that pain around the site of tenodesis may persist in more than half of the cases.

Ng et al.[8] performed a retrospective study of 11 patients (mean age, 41 years) undergoing open subpectoral tenodesis at least 3 months after rupture (mean interval, 25 months), subsequently reporting their patient´s subjective self-assessments of strength and pain improvement of 74% and 78%, respectively. However, a statistical difference related to cosmesis should be noted: only 3 of the 11 patients reported normal cosmetic appearance post-

operatively, corresponding to 3 of the 5 patients whom the interference screw technique was applied.

Anthony et al. [23] included 11 symptomatic patients (mean age, 43 years) that received open subpectoral tenodesis at a mean interval of 8 months between injury and surgery, for isolated auto-ruptures (5 of 11) or following a tenotomy (6 of 11), using interference screw technique on all patients. Postoperatively, nearly all patients achieved primarily good to excellent surgical outcomes based on SANE and WORC scores, with resolution of cosmetic deformity in all patients and cramping in 90% of patients. Moreover, comparing both studies, it is important to emphasize two points regarding surgical fixation- timing and outcome. Ng et al.[8] reported difficulty in obtaining enough tendon length for interference screw fixation in 6 of 10 cases and all of them failed to revert the Popeye sign, whereas Anthony et al. [23] was able to perform it in all cases, probably due to shorter interval to surgery, leading to a 100% rate of resolution.

Similarly, McMahon et al.[2] also conducted a retrospective study of 11 patients (mean age, 56.9 years) who performed open suprapectoral tenodesis with interference screws, more than 3 months after rupture (mean interval, 30.1 months). In order to be able to perform a suprapectoral tenodesis, the elbow was 60 degrees flexed, contrarily to the other studies in which it was 30 degrees flexed. According to previous studies, subpectoral tenodesis appear to favor lower re-operation rates comparing to suprapectoral tenodesis, with patients experiencing less pain given that LHBT is released from the bicipital groove[32]. Nevertheless, both DASH and Mayo scores had an approximate improvement of 25%, and 90% of the patients reported no biceps pain or spasm, besides significant postoperatively strength increase of 17.4% in internal rotation at 0 degree of arm abduction. Additionally, a normal cosmetic appearance was achieved in 80% of cases compared to 28% reported in Ng et al.[8], which may reflect a higher success rate using interference screws rather than suture anchors.

Euler et al.[9] conducted a retrospective study of 27 patients (mean age, 61 years) who have been submitted to surgical treatment for symptomatic chronic rupture of the LHBT and hypothesized that patients who underwent primary tenodesis (74%) would demonstrate greater symptomatic improvement when compared to those who underwent revision tenodesis (26%). Median postoperative SPBSs demonstrated a statistically significant improvement when compared to the median preoperative baseline, but no significant difference was found between primary and revision groups. Furthermore, there were significant improvements postoperatively in both ASES and SF-12 PCS scores, also with no statistically significant differences between primary and revision group. However, there are two significant details that must be highlighted:

firstly, this was the only study in which concomitant pathologies, including pathology of the rotator cuff, were simultaneously addressed at the time of surgery, preventing the determination of how much the repair of the chronic biceps ruptures resulted in clinical improvements; secondly, SPBS has not been formally validated and future studies are needed to confirm it as an outcomes measure.

Waugh et al. [10] performed an open subpectoral tenodesis with suture-anchors in 18 patients (mean age, 49 years) to assess its utility in active older patients with chronic traumatic LHBT rupture, at a mean interval of 9 weeks between injury and surgery. All patients reported improved cosmetic appearance and had less pain postoperatively, as evidenced by their ASES and VAS scores, with no correlation between the time to surgery and the outcome.

Recently, Mirzayan et al. [11] described a first report regarding reconstruction and tenodesis of the LHBT utilizing *gracillis* allograft, similarly to those performed for distal biceps tendon ruptures. Although further clinical research is needed, this article describes a novel surgical technique which avoids donor-site morbidity and allows the integration of the graft into the native muscle belly, with good functional and clinical outcomes.

Study limitations include the small cohort, which limits generalizability; however, that reflects the fact that most patients with isolated LHBT ruptures are well-managed conservatively, so few reports in the literature of this condition are available. Also, there is no standardized cut-off defining LHBT rupture “chronicity”. Additionally, there is potential performance bias since the procedures were performed by a single surgeon. In studies in which patients were personally interviewed to gather information for scores, potential for recall bias, interview bias, detection bias and problems with patient comprehension of the questions being asked out. 91% of the patients were males, which may reflect selection bias due to higher physical demands or psychosocial factors associated with having a "Popeye sign." Subsequent studies including larger patient cohorts and utilizing a randomized control trial framework would be useful in determining if this treatment method could be utilized in a wider selection of patients to improve the outcomes when compared to the current standard of care, which is predominantly non-operative.

Conclusion

When conservative treatment fails, LHBT tenodesis for symptomatic isolated chronic rupture of the LHBT is related to good to excellent clinical and patient reported outcomes, with low complication rates. Due to sparse literature in this specific topic, future randomized controlled trials are needed to reach stronger conclusions.

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Appendix

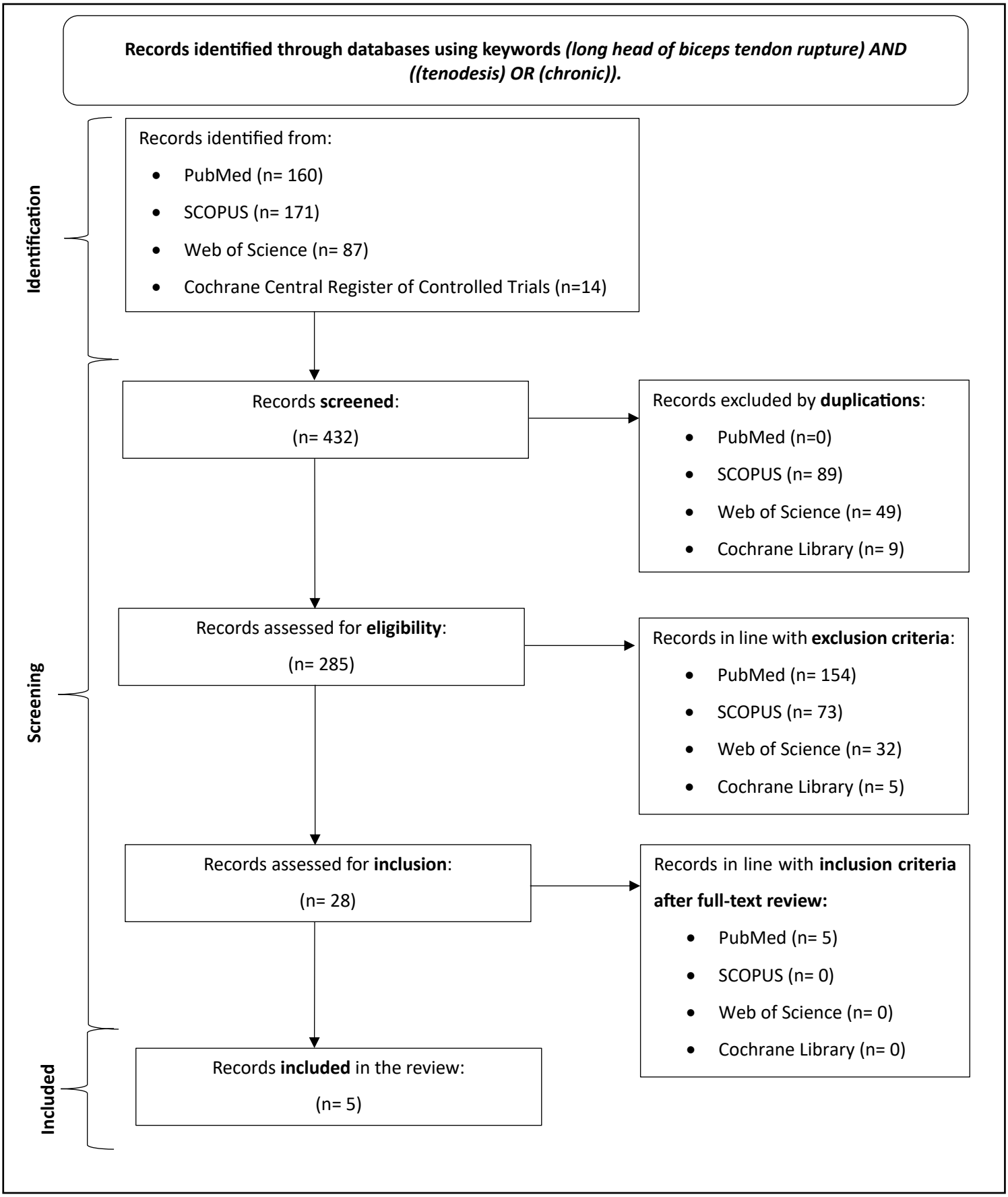

Figure 1. Preferred reporting items for Systematic reviews and Meta-analyses (PRISMA) flowchart

Table I. Characteristics of Included Studies, Population and Surgery

Study	Study Design	LOE	Number (M|F)	Mean Age (R)	Symptoms and Physical Examination	Mean time interval injury-surgery (R)	Procedure	Surgical Fixation (n)	Mean follow up (R)	MINORs Index
Ng CY, Funk L., Int J Shoulder Surg 2012[8]	Retrospective case series	IV	n = 11 (10|1)	41 years (23y-65y)	Biceps cramping, weakness, pain, deformity	25 months (6mo-96mo)	Open Subpectoral Tenodesis	Interference Screw (5) Suture Anchors (6)	29 months (6mo-60 mo)	12/16
Anthony et al., J Shoulder Elbow Surg 2015[23]	Prospective case series	IV	n = 11 (11|0)	43.3 years (33.9y-56.3y)	Biceps cramping, weakness, pain, deformity	8 months (0.5mo-22mo)	Open Subpectoral Tenodesis	Interference Screw (11)	2.6 years (1.6y-4.2 y)	11/16
Euler et al., Arch Orthop Traum Surg 2016[9]	Retrospective comparative study	III	n = 27 (22|5)	61 years (40y-76y)	Biceps cramping, weakness, pain, deformity	9 months (6w-7.5y)	Open Subpectoral Tenodesis	Interference Screw (23) Suture Anchors (4)	3.8 years (2.3y-6.1y)	18/24
McMahon PJ, Speziali A., World J Orthop 2016[2]	Retrospective case series	IV	n = 11 (10|1)	56.9 years (42y-73y)	Biceps pain, weakness, deformity, persistent spasm	30.1 months (3.5mo-240mo)	Open Suprapectoral Tenodesis	Interference Screw (11)	19.1 months (9mo-35mo)	10/16
Waugh et al., Cureus 2022[10]	Retrospective case series	IV	n = 18 (18|0)	49 years (26y-65y)	Biceps pain, deformity	9 weeks (2w-24w)	Open Subpectoral Tenodesis	Suture Anchors (18)	26 months (12mo-36 mo)	11/16

F- Female; **LOE-** Level of evidence; **M-** Male; **MINORS-** Methodological Index for Non-Randomized Trials; **mo-** months; **n-** number; **NR-** Not reported; **n:** number; **w-** weeks; **y-** years

Table II. Patient Reported Outcome Measures- Score Results

STUDY	SCORES		PRE-OPERATIVE		POST-OPERATIVE		IMPROVEMENT	
Anthony et al., J Shoulder Elbow Surg 2015[23]	**Significant P Value:** < 0.05		**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**P Value**
	SANE		61.1	8.8	84.2	7.1	37.8	0.001
	WORC		53.2	9.2	86	8.2	61.7	0.001
McMahon PJ, Speziali A., World J Orthop 2016[2]	**Significant P Value:** < 0.05		**Mean**	**Range**	**Mean**	**Range**	**Mean**	**P Value**
	DASH		37.2	29.2-55	11.2	0-35	26	0.001
	MAYO		57.5	45-70	86	85-100	28.5	0.001
Waugh et al., Cureus 2022[10]	**Significant P Value:** < 0.05		**Mean**	**Range**	**Mean**	**Range**	**Mean**	**P Value**
	ASES		33	10-60	92.6	85-100	59.6	NR
	Pain VAS		6.3	0-10	0.2	0-10	6.1	NR
Euler et al., Arch Orthop Traum Surg 2016[9]	**Significant P Value:** < 0.05		**Mean**	**Interquartile Range**	**Mean**	**Interquartile Range**	**Mean**	**P Value**
	SPBS	**Primary Group**	7.5	7-9	0.5	0-3	NR	NR
		Revision Group	9	9-10	2	0-9	NR	NR
		General Group	8	7-9	1	1-3	6	< 0.001
	ASES		52.0	NR	90.7	NR	38.7	0.006
	SF-12 PCS		39.9	NR	52.5	NR	12.6	< 0.001

ASES- American Shoulder and Elbow Surgeon; **DASH-** Disabilities of the Arm Shoulder and Hand (DASH); **NR-** Not Reported; **MAYO-** Mayo Elbow Performance; **Pain VAS-** Pain Visual Analogue Scale; **SANE-** Single Assessment Numeric Evaluation; **SF-12 PCS-** Short Form 12 Physical Component Summary; **SPBS-** Subjective Proximal Biceps Score; **WORC-** Western Ontario Rotator Cuff Index

Table III. Patients Reported Outcome Measures- Clinical and Physical Evaluation

STUDY		PAIN			DEFORMITY			STRENGHT			CRAMPING/SPASM		
		PRE-OP (n)	POST-OP (n)	IMP (%)	PRE-OP (n)	POST-OP (n)	IMP (%)	PRE-OP (n)	POST-OP (n)	IMP (%)	PRE-OP (n)	POST-OP (n)	IMP (%)
Ng CY, Funk L., Int J Shoulder Surg 2012[8]		11/11	1/11	**90.9%**	11/11	1/11	**90.0%**	11/11	1/11	**90.0%**	NR	NR	**NR**
Anthony et al., J Shoulder Elbow Surg 2015[23]		10/10	2/10	**80%**	10/10	0/10	**100%**	NR	NR	**NR**	10/10	1/10	**90%**
Euler et al., Arch Orthop Traum Surg 2016[9]	**Primary**	18/18	1/18	**94.4%**	17/17	5/17	**70.6%**	18/18	6/18	**66.7%**	13/13	2/13	**84.6%**
	Revision	7/7	0/7	**100%**	7/7	0/17	**100%**	7/7	1/7	**85.7%**	4/4	1/4	**75%**
	General	25/25	1/25	**96%**	24/24	5/24	**79%**	25/25	7/25	**72%**	17/17	3/17	**82.3%**
McMahon PJ, Speziali A., World J Orthop 2016[2]		11/11	0/11	**100%**	11/11	2/11	**81.8%**	11/11	1/11	**90.9%**	11/11	0/11	**100%**
Waugh et al., Cureus 2022[10]		18/18	0/18	**100%**	18/18	0/18	**100%**	18/18	NR	**NR**	NR	NR	**NR**

PRE-OP- pre-operatively; **POST-OP-** post-operatively; **IMP-** improvement

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