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Surgical repair of a biceps tendon rupture: A systematic review

Josh Nelson
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Surgical Repair of a Biceps Tendon Rupture: A Systematic Review

Josh Nelson, BS, ATC

Thesis submitted to the
College of Physical Activity and Sport Sciences
at West Virginia University
in partial fulfillment of the requirements
for the degree of

Master of Science
in
Athletic Training

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Key words: Bicep tendon rupture, Surgical repair techniques, Long head of the biceps tendon

ABSTRACT

Surgical Repair of a Biceps Tendon Rupture: A Systematic Review

Josh Nelson ATC

Objective: To evaluate the methodological quality of Bicep tendon rupture surgical repair studies found in the current literature. *Data Sources:* Pubmed (1950-2009), CINAHL(1985-2009), SPORTdiscus(1987-2009), MEDLINE, Google Scholar, SCIENCE DIRECT(1980-2009) from December 2009 to January 2009 were searched using the terms *Distal biceps tendon, Proximal Biceps tendon, Long head of the biceps tendon* individually. Second the term *biceps tendon rupture* was combined with each of the following words: *anatomy, surgical treatment, conservative treatment, imaging, conservative treatment, biomechanics, etiology, and epidemiology*. Third, Citations were cross-referenced from studies to include literature not found in the original search. *Study Selection:* Studies were selected based on the following inclusion criteria: 1) The studies were written in or translated to English; 2) The term bicep tendon rupture must be present in the title; 3) The abstract must include the name of the surgical repair technique used; and 4) Bicep tendon pain or dysfunction must be the chief complaint. Exclusion criteria consisted of any study that included a surgical repair to a rotator cuff muscle. *Data Extraction:* All the studies that met the inclusion criteria were collected and evaluated using the Coleman Method scale. First each study was read completely without the use of the Coleman Method scoring checklist. Next, each article was read a second time using the Coleman Method scoring checklist by both evaluators. Based on the check list the studies were awarded points on whether the scored information was included. Finally when all of the studies were scored the two evaluators come together and compared their scores for each study and discrepancies were discussed until an agreement was reached. *Data Synthesis:* The ten studies that were collected varied in subject population, type of surgical procedure performed was either a tenotomy or tenodesis, and whether the study conducted was a prospective or retrospective design and level of methodological quality. The subject population of the studies varied from 12 to 307. The Methodological quality of the studies according to the Coleman Method score ranged from 12 to 76, with the average mean score of 63.9. *Conclusion:* There is a lack of high quality methodological studies in the current literature, although some quality studies do exist. However, the number of quality studies is small making it difficult to draw strong conclusions as to which surgical technique provides the best outcome for the patient.

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INTRODUCTION

Ruptures of the biceps brachii can occur at four possible locations; the long head of the biceps (LHB), short head, distal attachment and the muscle belly. While all four locations can suffer damage and tissue failure, rupture of the long head of the biceps tendon accounts for 95% of bicep tendon ruptures, the distal bicep tendon makes up 3 % and the short head and muscle belly account for the remaining 2 % of bicep brachii ruptures.^{1,2,3} A rupture is typically seen in men who are over the age of forty and is typically seen in the dominant arm of individuals, with the most common site of rupture being the bone-tendon junction.^{3,4} A rupture can be caused by two mechanisms, traumatic overload and chronic overuse.^{5,6,7,8,9} Traumatic rupture is typically caused by an eccentric contraction while over loading the biceps brachii.^{2,10,11} A rupture that has chronic overuse pathology is typically the result of degenerative changes in the tendon of the biceps brachii that occurred over a long period of time, and is usually associated with inflammation or osteophyte formation.¹²

While rupture does occur during sporting activities it is still a very rare injury to sustain while playing sports. Only two percent of all biceps tendon ruptures occur as a result of sports.^{13,14} The sports with the highest rate of bicep tendon rupture are the sports that involve overhead arm motion, baseball, swimming, track and field or sports that require powerful contraction of the biceps brachii like powerlifting.³ These sports place the greatest amount of tension and stress on the tendons of the biceps brachii.

Another factor that corresponds with the rupture of a biceps tendon is the presence of a tear in the labrum. The most common type of labral tear seen with a biceps tendon rupture is a type II SLAP tear which in some studies accounted for 41% of all SLAP tears in overhead athletes.¹⁵ A type II SLAP tear is a tear to the labrum with also a detachment of the LHB from

the attachment on the supraglenoid tubercle. These injuries, while usually associated with other types of glenohumeral joint injuries such as instability or a rotator cuff tear, can occur independently and will require a surgical intervention in order to correct the problem. With the average population the reanchoring of the LHB tendon has shown to provide good functional results with up to 97% of the people returning to their previous level of activity with minimal complications.¹⁶ The athletic population has shown less success with surgical correction of the defect to LHB and labrum with only 75% of the patients returning to previous levels of competition.^{16,17,18}

Chronic tendonopathy is also an indication for surgical intervention of the LHB tendon. Chronic tendonopathy is often a source of pain and dysfunction in the Glenohumeral joint.^{19,20} Tenodesis or tenotomy has been a treatment option for chronic tendonopathy for the past fifty years. In a study Kempf²¹ using elderly patients who underwent tenotomy for biceps tendonopathy had significant improvements in the levels of pain and physical activity when compared to the group who choose a conservative treatment.²¹ Gill²¹ also had success using thirty patients who had a release of the biceps tendon for treatment of biceps tendonopathy, in which 90% were able to return to their previous level of activity.²¹

When a rupture does occur there are several surgical options for repair depending on the location of the tear. The first option is a tenodesis which is a reattachment of the ruptured tendon.^{16,18,19} The site at which the LHB tendon is reattached is the bicipital groove. Tenodesis of the LHB tendon offers good functional outcome with only a few functional limitations. Even with reattachment it is possible for strength deficits when compared to the non-injured arm usually with elbow flexion and supination.^{17,18,21} The other treatment option is a tenotomy in which the damaged portion of the tendon is cut away but the tendon is not reattached to the

humerus.^{17,22,23} As a result the patient could have a slight decrease in strength with elbow flexion and a higher rate of muscle fatigue with repeated supination. In the case of the LHB, this is recommended for patients of older age as the strength deficits are minimal and usually will have no impact for the average person. Reattachment is the treatment of choice for younger patients or patients who would be unable to perform daily tasks as a result of the limitations.^{24, 25, 26,27}

Outcomes in the literature about the reattachment versus non-reattachment of the LHB is variable. In a study performed by Deutch cited by Frost¹⁷ noted an overall strength deficit of approximately 25% if the LHB was not reinserted onto the bicipital groove. The study also stated that patients did not see the strength deficit as a problem in their daily lives but it should also be noted that none of the subjects was under the age of forty or functioning in high level athletics. Becker, which was cited by Frost,¹⁷ also reported bicipital groove reattachment yielded excellent outcomes in 75-100% of patients with non-humeral attachment yielding excellent results in 65-100% of patients, with the most significant complaint being the loss of flexion strength and a decrease in supination endurance.¹⁷ The surgeon usually determines which type of procedure to use based on the age of the person and the level of function. If the person is younger or will be limited functionally by decreased strength and endurance the bicipital groove reinsertion is done, while others who may not be hindered by the strength deficits will undergo conservative treatment or non-anatomical repair.¹⁷ Another factor that is taken under consideration when deciding whether or not to reattach a ruptured tendon is the physical appearance that results from an unrepaired biceps tendon rupture, which is called cosmesis.¹⁷

There have been a plethora of studies conducted comparing different surgical techniques for correcting a rupture of the biceps tendon; however these studies are based on poor

methodological quality that lead to unreliable and speculative results and conclusions. That is why it is important to not only critically evaluate the results of the studies but also to evaluate the methodological quality of the studies themselves in order to verify that only the highest quality studies are influencing patient treatment. Therefore, the purpose of this study is to evaluate studies that have been conducted to assess the functional outcomes of different surgical repairs of biceps brachii tendon ruptures. To accomplish this each study will be evaluated using the Coleman Method of scoring.

METHODS

The design of this study was a systematic review. All studies were obtained through searches on specific databases using keywords, combinations of keywords, or cross-referencing. Studies that met the inclusion criteria were evaluated using the Coleman Method for methodological quality.

Instrument

Systematic reviews of randomized controlled trials (RCT) are considered by many to be the gold standard in determining the effectiveness of health care treatments.²⁸ The goal of a systematic review is to eliminate or weight the results of studies of low validity and quality that show effectiveness of treatment.

Reliability of the assessments of the RCT has been an area that in the past has received little consideration. In 1998 review 21 scales for assessing the quality of RCT were described but only 12 had any evidence of reliability. Sixty scales were examined by Verhagen,²⁸ and the reliability for the majority of the scales was reported as unknown.²⁸ Another concern with the scales being used for research purpose is the scales do not use an individual rating, but rather a consensus rating from two assessors.^{28, 29} Due to the lack of ability of most scales to evaluate the

reliability of studies, researchers who wanted to do a systematic review were faced with the difficult question of which scale to use.

The Coleman Method was developed as a tool to provide researchers the ability to evaluate surgical procedures in a systematic review, before which there was no method that determined high levels of reliability with the specific use of evaluating surgical procedures.^{30, 32} The current evaluating tools are specific to the evaluation of other types of treatment most commonly physical therapy and rehabilitation techniques. These types of tools will produce scores that do not accurately reflect the surgical study. Due to the fact that the Colman Method is a relatively new evaluation tool, there have not been studies performed to show the reliability of the Colman Method. Other tools have been designed to evaluate rehabilitation protocols, but the Coleman tool was designed specifically by the surgeon and investigator for use during a systematic review.^{30, 31, 33, 34}

The use of the Coleman Method is to evaluate the methodological reliability of various surgical protocols for an anatomic injury. The process involves the use of two examiners reviewing the literature to determine if a study meets the inclusion criteria. After the study has been evaluated and qualifies for inclusion into the review, it is then reviewed again and given a score based on the Coleman Methodology Score.^{17, 30, 31}

The Coleman Method (Table C1) is a 10-item two part scale consisting of part A and part B to evaluate the methodological quality of a surgical study. Each specific item of the checklist contributes to the total score which is out of a possible 100.^{17, 30} A score of 100 indicates high methodological quality and that the outcome of the study is due to the surgical technique and not because of chance, biases and confounding factors.^{17, 30} In order for the study to be correctly scored each category must be clearly stated in the study and evident to the

evaluator (Table C2).^{30,31} In section A the first measure is the size of the sample used during the study. The scale rates a study having more than 60 participants with a score of ten, which is the highest score possible. Studies that have 41-60 participants receive a score of seven, with studies that have less than 20 participants are awarded no points. Sample size has a great impact on the number of errors that could occur in a study; the more test subjects the less chance of having errors affect outcomes.^{30,31} The second point of scoring is for the mean follow-up of the study. This is to note whether the investigators evaluated subjects following their surgery and the amount of time that has elapsed from the surgery until re-evaluation.^{30,31} The third point to be scored is the number of different surgical procedures included in each reported outcome. The fewer the surgical procedures used the more valid the outcome measure will be. However, each procedure will need individual outcomes measurement upon completion.^{30,31} If a study compares two different surgical techniques the study must include the outcome measures from both techniques. The fourth point of evaluation is the type of study that was conducted. The study with the highest methodological design is the randomized clinical trial (RCT) because of the limitation of bias and error in a study of that design.^{30,31} The fifth point of emphasis is the diagnostic certainty of that study. This examines whether the study completed a full pre-operative MRI, or ultrasound. Also, that after the surgery was performed a comparison is made as to whether the diagnosis and correction was specific for the subjects particular injury.^{30,31} The sixth criterion that is scored is that the description of the surgical procedure is given. This needs to be included so that the evaluators of the study understand the surgical procedure that is being performed.^{30,31} The seventh and final criterion in part A is description of the postoperative rehabilitation. This section is scored on whether the study described the rehabilitation post-surgery and described the process of returning to normal function.^{30,31}

In part B, items 8 through 10 are divided into separate sections with individual scoring for each item. There is a main topic for total points under each header and subtopics also with individual scoring. In this section, each subtopic receives the total points if the given topic is included in the study and zero if not stated or included. The three main headers are outcome criteria, procedure for assessing outcome, and description of the subject selection process. This section focused on the scoring outcome from the research conducted by the investigators.^{30, 31}

The first section of part B focuses on outcome criteria, and specifically looks at are the outcome measures clearly defined, timing of the outcome is clearly stated, outcome criteria used had good reliability and good sensitivity. If the outcomes were not described or were vague the study would receive a zero for that portion. The next section focused on the procedure for assessing outcomes. The first aspect that was scored was that the subjects were not chosen from the surgeons own files. Next, the investigator was independent from the surgeon and there was a written assessment for determining the outcomes. Finally completion of the assessment by the subjects, and outcomes are recorded by the assessor. The final section of part B, assess the subject selection process. Points are awarded if the recruitment of subjects were clearly defined, and 80% of the recruitment was reported in the final outcome.

The Coleman Method was the selected tool of choice because of the ability to assess surgical based studies. Other investigative tools are not equipped to evaluate studies where the ethics of medicine make it impossible for a RCT, or for the subjects and investigators to be blinded.

Data Sources

Several data base search engines were used in the collection of studies for this systematic review. Pub Med(1950-2009), CINAHL(1985-2009), SPORTDiscus(1987-2009), MEDLINE, Google Scholar and SCIENCE DIRECT(1980-2009) were searched using the individual terms *rupture of the biceps tendon, rupture long head of the biceps tendon, slap lesion and tendinopathy* were searched individually. Second, the term rupture of the biceps tendon were combined with *anatomy, surgical treatment, conservative treatment, imaging, biomechanics, etiology, and epidemiology*. This procedure was followed for each individual database search engine listed above. First, all searches were limited to peer review journals and second written in English or translated to English. Third citations were cross referenced to capture more studies that were not included in the original search. Finally after identifying all the studies from the search engine, the inclusion and exclusion criteria were applied to determine which studies were to be evaluated using the Coleman Method.

Study Selection

Studies were selected based on the following inclusion criteria (Table C3): 1) The studies are written in or translated to English; 2) The term bicep tendon rupture must be present in the title; 3) The abstract must include the name of the surgical repair technique used; and 4) Bicep tendon pain or dysfunction must be the chief complaint. The exclusion criteria included any study in addition to the biceps tendon repair or a surgical repair of a torn rotator cuff muscle.

Data Extraction

The training of the two reviewers involved reading through the Coleman Method scoring method three times in order to understand the grading criteria and the point values for parts A and B. Next the two reviewers, evaluated three studies were evaluated using the Coleman

Method from a systematic review. The two reviewers then read the three studies, evaluated the studies using the Coleman Method and then compared their scores with the scores from the systematic review. After completing the Coleman Method scoring of the studies, a comparison of the scores was made using the systematic review scores. This served as the orientation and training of the investigators to the Coleman Method.

All the studies that met the inclusion criteria were collected and evaluated by the reviewers. First, the studies were read separately without the use of the Coleman Method tool. Then the studies were read a second time using the Coleman Method checklist. Based on the Coleman Method checklist the studies were awarded points according to the information included. Finally, after all studies were evaluated the primary and secondary reviewers compared scores from the Coleman Method and assessed the discrepancies. When the discrepancies occurred, the two examiners discussed the scores and resolved the study in question.

DATA SYNTHESIS

The data synthesis included two parts: biceps tenodesis and biceps tenotomy, both of which are used to surgically treat a LHB tendon rupture.

Study Quality

The ten studies ^{18,21,24,26,35,36,37,38,39,40} that met inclusion criteria varied in subject population, mechanism of injury, chief complaint, outcomes measures, surgical technique used to correct the defect and methodological quality. The subject population in the studies varied from patients being referred to an orthopedic physician by a general medical doctor to having already been treated for a glenohumeral joint pathology involving the LHB. The subject population in the studies ranged from 12 ³⁵ to 307 ³⁴ with a mean of 63.9. The number of

subjects/patient for the included studies can be viewed in Table D1. The studies had similar inclusion and exclusion criteria for patient selection, consisting of surgical tenodesis or tenotomy correction of a glenohumeral joint pathology involving the LHB. The pathology behind the surgical intervention however varied from study to study. Some studies used patients with SLAP tear,²⁶ while others had biceps tendonitis^{21,24} or a rupture of the long head of the biceps.^{18,32,33,34,35,36,37} Exclusion criteria was limited in the studies as the goal was to evaluate the result of the surgical technique used and not the mechanism or pathology of injury. However, the one exclusion criteria common to most studies was failure of the patient to meet the appropriate number of follow up appointments after the surgery, which resulted in that patient being removed from the study.

The main outcomes measure in all ten studies^{18,21,24,26,35,36,37,38,39,40} was to evaluate the functional outcomes of the different surgical techniques to correct LHB tendon pathology. Specifically, Kelly and Drakos²¹ evaluated the effectiveness of a biceps tenotomy by assessing strength differences, patient satisfaction, fatigue discomfort, Popeye sign and a functional scoring assessment. Mazzocca et al.³⁹ looked at the functional outcomes of the bone tunnel tenodesis technique using the Rowe score, American Shoulder and Elbow Surgeons score, Constant Murley score and the Single Assessment Numeric Evaluation score as well as patient reported pain scales and patient reported satisfaction scores. No matter which type of surgical technique was used, the subjects pain levels and functional movement of the glenohumeral joint determined the success of the surgical treatment.

The design used in the various studies concentrated on one specific surgical technique or in some cases two surgical techniques. The surgical technique(s) would be evaluated using functional assessments along with patient reported satisfaction and pain. Boileau and Boque³⁷

compared the functional outcomes of two surgical groups. One group underwent a simple tenotomy, while the other group underwent fixation screw tenodesis. The two groups were evaluated using a Constant score consisting of pain, activity, mobility and strength. Mobility of the shoulder in all three planes of motion was assessed as well as symptoms related to the biceps such as muscle belly retraction, muscular cramps and pain over the LHB tendon. The results of the two groups were then compared showing only one statistically significant difference between the two groups related to retraction of the biceps in which the tenotomy group reported a higher occurrence. Walch ³⁶ using 307 shoulders with rotator cuff pathology performed a simple tenotomy of the long head of the biceps tendon. The Constant score which includes pain, activity, mobility and strength was used as the outcome measure both pre and post operatively. In all cases there was statistically significant improvement for all categories of the Constant score. Checchia ³⁵ evaluated the functional outcomes of bicep tenodesis for damage of the LHB following a rotator cuff tear. Differences in range of motion between the pre and post operative glenohumeral joint as well as using the UCLA score were used to determine surgical outcome. For the majority of the patients, range of motion improved when compared to the pre and post operative measurement. Results for the UCLA score were that 93.4% of patients scored in the satisfactory range. One of the problems with the studies however, is that the majority focused on the outcomes of only one surgical technique. There are very few studies that compared the functional outcomes of two different surgical techniques.

The methodological quality of the studies ranged from 12 ⁴⁰ to 76 ³⁹ with the mean average score being 53.9. A specific analysis of each point measure can be found in Table D2. Of the ten studies included all met the inclusion criteria. All were surgical studies that focused on the correction of LHB tendon pathology. Of the studies selected five had low subject

numbers which affected the ability to score high on the subject selection process for the Coleman Method.^{18, 26, 35, 38, 40} All but two of the studies^{26, 39} were retrospective studies, while the other two were prospective studies. Only three of the studies^{35, 36, 40} had diagnostic certainty through the use of MRI or CT scan. The remaining studies used diagnostic arthroscopic surgery to identify the defects. All^{18, 21, 24, 26, 36, 38, 40} but three studies^{35, 37, 39} provided an in depth description of the surgical procedure used. A specific analysis of the studies based on the Coleman Method scale can be found in Tables D3 through D12

Effectiveness of Long Head of the Biceps Surgical Techniques

The pathology of injury to the LHB tendon ranged from acute ruptures of the LHB tendon to chronic degeneration in the case of tendinopathy. Injury to the LHB tendon can occur as an isolated injury or can be secondary to a rotator cuff muscle tear or SLAP lesion. The site of injury can vary as much as the cause of the injury. Lesions of the LHB tendon are evident at the origin on the supraglenoid tubercle, the MTJ or the muscle. Unfortunately, there is no standardized surgical protocol for determining which surgical techniques will provide the best outcomes for LHB pathology. This may be due to the case by case nature of LHB pathology and the surgical technique selected. Overall, there have been reports of good results for both the tenodesis procedure and the tenotomy procedure. In the ten studies, four looked at outcomes following tenotomy,^{18, 21, 38, 36} five reported outcomes following tenodesis,^{24, 26, 35, 39, 40} and one compared outcomes from both tenotomy and tenodesis³⁷.

Kragh³⁸ evaluated the use of muscle belly repair in cases of traumatic rupture of the LHB tendon in paratroopers. While the Kragh study does not specifically focus on a rupture of the LHB the functional deficits of the conservative treatment population is similar to the functional deficits of a tenotomy, thus the basis for its inclusion in this study. The study population

consisted of twelve paratroopers who suffered rupture of the LHB after getting their arm tangled in their parachute lines. Nine of the paratroopers underwent surgical repair, while three others chose a non-operative treatment. Post surgical rehabilitation was the same for all the subjects who underwent surgical intervention. Three to five days post surgery the splint and dressing were removed and a compression wrap was placed on the arm along with a dynamic splint for early motion. The brace locked the forearm rotation in neutral and blocked the last 30 ° of motion. Each week extension was increased by 10 °. At eight weeks resistive exercise were introduced and at 12 weeks supervised strength programs were allowed. Functional outcomes were evaluated by measuring strength, assessing appearance and determining patient satisfaction. When the surgical repair group was compared to the non-surgical group there was a statistically significant difference in supination torque, supination torque ratio and appearance. Nine of the patients who underwent repair reported excellent satisfaction whereas all three subjects who underwent non-surgical treatment reported only satisfactory results.

Tenotomy: Kelly ²¹ evaluated functional outcomes following arthroscopic Tenotomy of the LHB. Using a retrospective study design involving fifty four subjects diagnosed with biceps tendinitis. At a minimum of two years the American Shoulder and Elbow Surgeons (ASES), UCLA and L'Insalata shoulder questionnaires were administered to rate surgical outcomes as well as contralateral strength and range of motion measurements. The average American Shoulder and Elbow Surgeons, UCLA and L'Insalata shoulder questionnaires scores were 75.6, 27.6, 77.6, respectively. Seventy percent of the subjects reported having a tendon retraction (Popeye sign) and 68% of the patients reported good or better satisfaction with the outcomes. Gill ¹⁸ reported functional outcomes of thirty two patients following a LHB tendon release for bicipital tenosynovitis, dislocation, or partial rupture. This study was retrospective in design.

The average clinical follow up was nineteen months. At the time of follow up, twenty nine patients, (96.7%) did not require additional medication for pain control. Twenty seven of the thirty two patients (90%) were able to return to a previous level of activity. Twenty nine of the thirty two patients (96.7%) returned to their previous occupation. The mean ASES score was 81.8 at the 19 month follow up.

The last study to evaluate the outcomes following tenotomy of the LHB was conducted by Walch.³⁶ This study involved 307 shoulders with rotator cuff tears that failed conservative treatment. Arthroscopic tenotomy of the LHB tendon was performed with no attempt to correct the rotator cuff. The Constant scoring method was used to evaluate surgical outcomes and was given to the subjects before the surgical procedure and again at the follow up appointment. The average follow up was 57 months post-op, with a range of 24-168 months. At follow up the Constant score was as follows: 51.1% as excellent, 20.5% as good, 14.7% as fair, and 13.7% as poor. Of all the shoulders operated on 50% showed some deformity in the biceps muscle. Subjectively 59% percent of the patients reported the outcome as excellent, 26% rated it as good, 10% rated their result as fair and 3.9% rated their outcome as poor.

The Coleman scores varied for the tenotomy studies. The average Coleman Method score for this section was 47.75 with a range of 38-63. The highest score was the Walch³⁶ study with a Coleman score of 63, while the lowest score in this section was the Kelly²¹ study with a Coleman score of 38. Most of the articles in this section did not receive points due to inadequate description of the surgical technique, rehabilitation protocol used and for diagnostic certainty. Despite the inclusion of this information, not enough information was provided to score points by the Coleman standards. A detailed scoring of these studies can be found in Tables D2 through D12.

Tenodesis: Boileau ²⁶ performed a prospective study using 10 subjects with a repair of the LHB tendon following a SLAP tear and 15 subjects who underwent interference screw fixation tenodesis. The outcomes assessment was completed at 35 months post surgery by an independent observer. Subjective satisfaction was assessed using a four point scale ranging from very satisfied to dissatisfied. The return to previous level of activity was also assessed. Pain was assessed using a visual analog scale and functional outcome was determined through the use of the Constant score. Elbow flexion and forearm supination strengths were also evaluated using a dynamometer. The Constant scores were similar between the two groups except for the activity sub score which was statistically higher in the tenodesis group. The subjective measures were different between the two treatment groups. The repair group had 60% dissatisfaction rate compared to 93% of the tenodesis group who rated their outcome as very satisfying. Also 87% of the subjects from the tenodesis group were able to return to a previous level of sport activity compared to only 20% of the repair group.

Becker ²⁴ completed a retrospective study focusing on tenodesis of the LHB for chronic bicipital tendinitis. The subject population started with 90 subjects but 63 subjects failed to complete the appropriate follow-up leaving a total of 27 subjects. The repair for thirteen subjects was a suture anchor tenodesis and keyhole tenodesis for fourteen subjects. The final follow-up occurred on average seven years post-op. At that time none of the subjects had any noticeable muscle atrophy with only one experiencing point tenderness over the bicipital groove.

Mazzocca ³⁹ performed sub pectoral biceps tenodesis with an interference screw on 50 patients diagnosed with biceps tendinosis. The diagnosis was determined using consistent history, physical exam and special tests. The decision to surgically treat was made based on the clinical presentation, provocative pain tests and the individual response to an injection that

implicated the biceps tendon as a source of pain. All patients failed attempts at conservative treatment. The outcome assessment used the Rowe score, ASES score, Constant Murley score and the Single Assessment Numeric Evaluation and was performed at a minimum of one year. Subjective measures included a 0-10 verbal pain scale, along with girth measurements of the biceps. The mean score of the Rowe scale was 81 out of 100, the mean score for ASES was 9 out of 12, the mean for Constant Murley was 87 out of 100 and finally the average score for the Single Assessment Numeric Evaluation was 84 out of 100.

Checchia³⁵ completed 15 suture fixation tenodesis on patients who had LHB lesions following rotator cuff tears. Assessment of the outcomes was based on the UCLA score system and was completed on average at 32 months post-op. Of the 15 patients in the study 11 achieved excellent results, 3 had good results, 1 had a fair result. The average range of motion at the glenohumeral joint was 125° before surgery and 160° post surgery. External rotation increased from 41° to 59° from pre to post op. Berlemann⁴⁰ used keyhole tenodesis on 20 shoulders in order to correct LHB pathology that ranged from chronic impingement syndrome to a complete rupture of the LHB tendon. All the patients in the study were evaluated in the authors shoulder clinic. A history was taken, a visual analog pain scale from 1-10 was administered and range of motion and glenohumeral joint function were graded from 0-3 where 0 was normal and 3 was very difficult. In the short term, 7% of subjects reported an excellent outcome, with 67% reporting a good outcome, 14% a fair outcome with two failures. In the long term however, 40% of the patients reported excellent outcomes. Pain using the visual analog scale ranged between 7 to 9 with an average of 7.7 pre-op which decreased short term post-op to a range of 0 to 7 and an average of 3.8. In the long term the pain was reduced to an average of 2.9 on a ten point scale and a range of 0 to 8.

Both the highest and lowest rated studies using the Coleman Method were in this section. The highest rated study was the Mazzocca³⁹ study which scored a 76 on the Coleman Method. The lowest scoring study by Berlemann⁴⁰ scored a 12 on the Coleman Method. The average Coleman method score for this section was 46 with a range of 12 to 76. The low average scores can be attributed to the lack of diagnostic certainty, poor description of the surgical technique and poor description of the rehabilitation protocol. As with the tenotomy section most of the information was included in the majority of the studies but not with sufficient detail to earn a rating. A detailed scoring of these studies can be found in Tables D3 through D12.

Tenotomy and Tenodesis: There was only one study that directly compared the outcomes of tenotomy and tenodesis and that was the Boileau³⁷ study. Boileau³⁷ conducted a retrospective study of seventy two shoulders with massive irreparable rotator cuff tears that underwent either arthroscopic tenodesis or arthroscopic tenotomy of the LHB. The tenotomy procedure was a simple release of the LHB allowing the tendon to retract back into the bicipital groove. The tenodesis technique used was the interference screw technique. The functional assessment used the Constant score and range of motion testing. The Constant score consisted of four sub sections; pain(0-15), activity level (0-20), active range of motion (0-40) and strength (0-25). The strength score was assessed using a spring balance measure. This assessment was given pre and post-operatively. The follow up assessment was given at an average of 35 months post-op. At the follow up exam the functional assessment using the Constant score was given, along with questions concerning patient discomfort and cosmetic deformity. When comparing the pre and post-operative Constant score of the two different surgical treatments cosmetic deformity was statistically different. Sixty-two percent of the tenotomy group reported muscle belly retraction and the presence of a Popeye sign, whereas only 3% of the tenodesis group reported muscle belly

retraction. All of the functional assessment measures between the two groups showed no statistical difference.

The Boileau ³⁷ study scored a 58 on the Coleman Method which was the second highest score in the review. A high score was achieved due to the size of the study, duration of follow up, diagnostic certainty, description of the procedure, description and adherence to the rehabilitation, outcomes, and assessing outcomes as well as subject selection. Points were lost for evaluating two surgical techniques in the same study and for the retrospective design. A detailed scoring of this study can be found in the Table D11.

DISCUSSION

The purpose of this study was to examine the methodological quality of LHB tendon rupture surgical repairs found in the literature. There were three experimental hypotheses in the study of the literature. First, that there would be little to no difference between the surgical techniques for repair of the LHB tendon. Second, there would be enough information present in each study to be scored using the Coleman Method. Third, the location of the tear in the tendon and the comorbidity of a labral tear and tendinopathy will have an effect on the surgical technique used. Based on the information gathered throughout the literature there was sufficient information to confirm the first and second hypothesis. The third hypothesis however can not be confirmed based on the current literature.

The methodological scores of the study were in the low to mid range of the Coleman Method grading scale with scores ranging from 12 to 76 out of a possible score of 100. The mean score of the ten studies was 59.3 out of 100. There was one study that scored high on the Coleman method and that was the study by Mazzocca and Cote ³⁹ which scored 76 out of 100. The majority of the other studies clustered around the mean with the exception of a few outliers.

All ten of the studies used similar outcome measures to determine if the surgery was a success, which included pain scales, range of motion and strength testing, satisfaction of the surgery and function following the surgery.^{18,21,24,26,35,36,37,38,39,40} Three studies based their outcome criteria according to the Constant score.^{26, 36, 39} Two studies used the American Shoulder and Elbow Surgeons shoulder evaluation.^{18,21} One study used the UCLA score to determine functional outcomes following surgery.³⁵ Three studies used simple pain scales and return of the patient to functional activity.^{24, 26, 38} Most studies also evaluated the long term results of the surgical repair using a follow up time of at least thirty months.^{21, 26, 35, 36, 37} At the time of follow up, the majority of the studies reported that patients had returned to their previous level of activity and most patients were happy with the result of their surgery.

Evaluation of Positive Outcomes

Through the examination of the studies on LHB tendon surgical repair techniques there were several positive outcomes as well as the final results of the surgical studies themselves. The studies were divided into three categories the first category being the studies that evaluated the effectiveness of tenodesis.^{24, 26, 35, 39, 40} The second group of studies focused on the outcomes following a tenotomy of the LHB tendon.^{18, 21, 36, 38} Finally the third category of studies compared both tenotomy and tenodesis, which had only one study.³⁷ The single study that compared both tenotomy and tenodesis allowed for a direct comparison of the two different surgical techniques and determination of effectiveness.

Surgical repair of the LHB tendon following a lesion has been shown to be an effective form of treatment. The tenotomy of the LHB was shown by Walch³⁶ to provide satisfactory results in regard to pain and function of the subjects as 88% of the subject population rated the surgery as fair according to the Constant score, with ninety six percent of the patients in that

study self reported their surgical outcome as fair or better. The other study that investigated the outcomes of tenotomy reported similar functional outcome assessment scores as well as patient reported satisfaction.^{18,21, 38} The only negative feedback reported by the patients who underwent the tenotomy was the cosmesis of the biceps brachii muscle with up to 50% of the subject population reporting deformity.³⁸ In the study done by Kelly²¹ there was also no significant deficits of strength or muscle fatigue when compared to the contralateral side.

High levels of functional outcome assessment and subject reported satisfaction were reported in the studies focusing on tenodesis of the LHB tendon. Ninety-three percent of patients were satisfied with the outcomes of the surgical repair and were able to return to a previous level of activity.³⁵ With the tenodesis repair there was a very low incidence of suture dehiscence.³⁵ Patients who underwent the tenodesis surgical procedure also had excellent outcome measures. In one study the functional outcomes were measured by four different outcome measure scales and all of the patients scored above 80% percent in all four outcome scales.³⁶ The long term results of biceps tenodesis were also reported to be excellent by Berlemann⁴⁰ who reported having good to excellent with patients who followed up an average of seven years following the surgical intervention.

Limitations of Study

Although both the tenotomy and tenodesis reported positive outcomes there are still limitation of this study that must be addressed. One of the biggest limitations is the number of studies that evaluated the outcomes following a LHB tendon repair. With so few studies available it makes it difficult for any conclusions to be drawn about which technique provides the most functional outcome. Furthermore, the surgical techniques were not described in detail making it difficult to definitively state that one procedure was better then the other. In addition

with only one study directly comparing tenodesis to tenotomy it makes it difficult to compare the two surgical procedures as each study had different variables and outcome measures. This makes study to study comparison of the two procedures very difficult. As a result any conclusion made by comparing one study population to another cannot be made with a high level of objectivity.

Another limitation of this study was the inclusion of studies only written in or translated to English. Inclusion of studies written in other languages would have increased the number of studies included in the review. Lack of detail in the studies was also a limitation of this systematic review. Multiple studies could not be evaluated when it came to rehabilitation protocols simply because the information provided was not specific enough to score according to the Coleman Method.^{18, 21, 24, 35, 38, 40} The majority of studies also scored zero points when it came to diagnostic certainty because post operative histopathology on the subjects was not included.^{18, 21, 24, 26, 37, 38, 39, 40}

The varying outcome measure tools used by each study also makes direct comparison of each study difficult. With studies using a wide range of outcome assessment tools, such as the Constant score, UCLA score, Rowe score and the American Shoulder and Elbow Surgeons score. Each evaluation tool has its individual assessment protocol and one assessment instrument does not correlate to the other assessment instruments. The Constant, UCLA, Rowe and American Shoulder and Elbow Surgeons score all take into account pain, range of motion, strength and patient function level. The American Shoulder and Elbow Surgeons score however has been shown to be the most reliable with an intra-examiner reliability of .94.³⁵ The range of the other tests fall slightly below the score of the American Shoulder and Elbow Surgeons.³⁵

Finally, study design contributed to the low scores of the studies. All of the studies with the exception of Mazzocca³⁹ and Boileau²⁶ were retrospective in design and received zero points for that section. Mazzocca³⁹ and Boileau²⁶ were prospective studies which allowed them to receive some points. However, no study was able to achieve a perfect score for study design as no study was a randomized control trial.

Clinical Relevance

The use of the systematic review to evaluate the methodological quality of the LHB tendon surgical techniques shows that there is a lack of studies available that meet the inclusion criteria of this review. Future studies should look to directly compare the outcomes of two surgical techniques. This type of information can help future researchers eliminate deficits and provide more definite conclusions regarding what surgical technique provides the best opportunity for a full functional recovery and patient satisfaction.

The methodological scoring of the studies in this review had a wide range from 12 to 76 with a mean of 59.3. Areas that need the most improvement are in diagnostic certainty, description of postoperative rehabilitation and study design. This will allow for more thorough research studies to be conducted that will validate to the conclusions drawn from the study and will ultimately lead to standard treatment protocols for LHB tendon ruptures.

CONCLUSION

While there are some high quality methodological studies in the literature, based on the Coleman Method the majority of the studies are of low quality. As a result of the low number of quality studies it is difficult to draw strong conclusions as to which surgical technique provides the best outcome for the patient. If the information provided by the low quality studies are taken into consideration then it would appear that there is no functional difference between a tenotomy

and tenodesis as both surgeries are reported to have good post surgery results by the subject population. Until there are sufficient high quality studies conducted comparing tenodesis and tenotomy directly, there can be little to formulate a standard treatment protocol with high quality functional outcomes.

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APPENDICES

APPENDIX A

THE PROBLEM

Research Question

A bicep tendon rupture is an uncommon injury in athletics as it only affects 1.2 individuals per 100,000.^{1, 36, 37} This injury is more common in middle aged athletes between the ages of 30-50 years old more than in any other population group.^{1, 10, 38, 41, 36,} With more people remaining active throughout their life span, this type of injury tends to become more evident among the recreational athletes. This is largely attributed to the changes in the musculoskeletal and neuromuscular systems. These include changes in bone formation, poor vascular supply in the tendons and the loss of elasticity in the tendons.^{1, 40} It is the degeneration that takes place over the course of a life time that is one of the most frequent precursors to a biceps tendon rupture.⁴⁰ In recent years, the increase in biceps tendon ruptures has been associated with specialization in sports. Furthermore, participating in sports year round, causes an increase in tissue break down, especially in athletes that start at a younger age. As a result, clinicians will start to see greater rates of degeneration in the tendons of overhand athletes such as baseball players and swimmers.^{10, 38, 41} This increase in degeneration acts to weaken the tendon which can lead to ruptures in a much younger population then has ever been seen before.

The most common rupture site is the long head of the proximal biceps tendon; accounting for almost ninety six percent of tendon ruptures, followed by the distal biceps tendon with only three percent of ruptures.^{10, 38, 41,} The most common mechanism for rupture is flexion of the elbow with supination of the forearm as the arm undergoes an unanticipated eccentric load.^{42, 43} When the long head of the biceps ruptures the most functional limitation is at the GHJ. Since the

long head of the biceps tendon has been shown to depress, compress, stabilize and limit the external rotation of the humeral head, it would be apparent why the GHJ presents with more functional limitations.^{23,45}

When a rupture of the biceps tendon does occur, a clinical and diagnostic evaluation are performed. However, not all results are conclusive for a biceps tendon injury. Due to the musculature of the GHJ and the location of the long head of the biceps tendon may be a confounding variable for the effectiveness in imaging the long head of the biceps.^{8,48} Magnetic Resonance Imaging is capable of detecting not only complete ruptures of the biceps tendon but is also capable of detecting partial tears that ultrasound may not detect.^{48,49} However, the gold standard for determining if there has been a bicep tendon rupture like many other injuries is through the use of arthroscopy.^{48,49}

When a rupture does occur, rehabilitation or surgical intervention are considered. The rehabilitation process allows the person to return to competition sooner than the surgical repair, but the downside is that the person will often never regain full strength. The most common technique used to repair a rupture of the long head of the biceps is the keyhole technique.⁵⁰ These techniques include the two incision suture fixation, a single incision suture fixation, and finally the soft tissue button. All of these techniques involve fixation of the ruptured tendon either directly to the bone or to a soft tissue button.^{49, 50}

The effectiveness of the surgical repair has been well documented through multiple clinical studies. Mainly, the studies describe the type of repair, the postoperative outcomes and progress of that individual. Usually progression was described in terms of range of motion, strength and any surgical complication.⁴⁴ These studies, although useful, often lacked some of the basic principles of an experimental study. These principles include randomization, blinding

of the procedures to the data collectors, and control groups. Without these basic concepts of an experimental hypothesis, how can the data collected be trusted as valid and reliable? This is why it is necessary to evaluate the quality of these studies to ensure the conclusions drawn from them are applicable to the clinical setting. What is printed in the literature often will have a direct impact on how that patient is rehabilitated and what follow up procedures are used post-surgically. Therefore the following research question is being proposed: are there any studies that evaluate various surgical techniques that will be rated high using a methodological quality assessment tool?

Experimental Hypothesis

1. There will be little to no difference in outcomes between different surgical techniques.
2. The location of the tear in the biceps tendon and comorbidity of a labral tear and tendinopathy will have an effect on the surgical technique used
3. There will be enough information in each study to be scored on the Coleman Method.

Assumptions

1. All studies will meet the inclusion criteria. The inclusion criteria will include but not limited to:
 - a. In the English language or an English translation
 - b. Specific to LHB tendon
2. No studies will meet exclusion criteria
3. Both primary and secondary reviewers using the Colman Method will be reliable in scoring
4. Coding for each study using the Colman Method will be reliable
5. Surgical studies may not be conducted with randomization due to ethical considerations.
6. There will be a clear understanding of the surgical protocol for the rupture of LHB.

Delimitations

1. All studies that were used were in the English language or English translation, thus eliminating other studies of importance.

Operational Definitions

1. Bone Tunnel Technique- A fixation technique used to secure the long head of the biceps tendon when intracortical fixation is needed. ^{13, 14}
2. Coleman Method- A method of analyzing the quality of surgical studies. ¹⁷,
3. Distal Biceps tendon Rupture- A failure of the connective tissue that secures the biceps brachii to the bicipital tuberosity. ^{3, 5, 8,}
4. Intrinsic abnormalities- Changes to the physical make up and appearance of the biceps tendon. ^{52,}
5. Keyhole Tenodesis- The Proximal LHB tendon is formed into a knot and in a keyhole shaped hole in the bicipital groove of the proximal humerus. ^{42,}
6. Kinematics- Study of joint motion
7. Kinetics- Mechanism by which a physical change is affected
8. Long Head of the Biceps tendon- Is the lateral most portion of the biceps brachii and originates from the supraglenoid tubercle and glenohumeral labrum. ¹
9. Proximal Biceps tendon Rupture- Is a failure of the connective tissue that secures the long head of the biceps to its origin at the supraglenoid tubercle. ^{3, 13, 14}
10. Slap Lesion- Superior Labrum Anterior Posterior tear in the glenoid labrum.
11. Tendon Dislocation- Tendon that is no longer operating with in its normal location. ⁵²
12. Tenotomy- A removal of the torn tendon. ¹⁷
13. Tenodesis- A repair and anchoring of the tendon ¹⁷

Limitations

1. There may be differences between the first and second reviewer
2. The inexperience of the reviewers to properly score the study
3. If there are disagreements about a study's score, the higher score will be used to show the study in the best light possible
4. Only studies published in the English language or in an English translation will be included.
5. Due to ethical reasons some studies will not have randomized clinical trials

Significance of the Study

As the population continues to remain active throughout their life, there will be an increase in the number of biceps tendon ruptures based on degenerative changes in the tendon. Some of the most common overuse problems such as tendinosis and tendinopathy are contributing factors to the weakening of the biceps tendon which will ultimately lead to tendon failure. This study will help to inform athletic trainers and physical therapists on what is involved with the repair of a ruptured biceps tendon and of the long term outcomes of each surgery. By better understanding the surgery, the PT or ATC will be better prepared to design a rehabilitation program that will address these complications, resulting in a more effective rehabilitation, and ultimately to a faster recovery of that athlete.

This review will help to highlight the studies that have been published in peer reviewed journals that have sound methodological quality. There are a plethora of studies that are presented, published and as a result, are read by countless professionals. It is through publications or presentations, either in journals or lectures that clinicians are introduced to ideas. However, some of the ideas and conclusions found in these studies are based on experimental studies that have weak methodological designs and therefore are suspect to biased data. By

evaluating the quality of the study as well as the conclusions drawn from that study, clinicians will be able focus on the information that is of the highest quality. The information gathered in the systematic review will be passed along through publications in a peer reviewed journals and presentations at both local and national conferences.

APPENDIX B

LITERATURE REVIEW

Introduction

The Biceps brachii consists of four major components; the long head, short head, distal attachment and the muscle body. All three tendons are susceptible to rupture but the one to reach tissue deformation and failure is the long head of the biceps tendon (LHB). This accounts for approximately ninety five percent of all biceps tendon ruptures.^{1, 3, 10, 44} Rupture of the long head of the biceps occurs during eccentric contraction of the biceps tendon while the muscle is being overloaded and typically occurs in men between the ages of 40 and 60.^{2, 3, 10, 11} It can occur in the younger population after a traumatic injury to the GHJ and is more common in contact sports such as football, rugby, lacrosse, weight lifting and snow boarding.^{2, 3} Rupture of the long head of the biceps tendon is usually associated with some form of degenerative changes evident in the biceps tendon or the surrounding tissue such as rotator cuff damage, tenosynovitis and chronic subacromial impingement prior to rupture.^{4, 6, 7} The rupture usually occurs at the boney attachment or tendo-labral junction.^{3, 4, 6}

With a rupture of the long head of the biceps tendon there are two treatment options. The injury can be treated conservatively with rehabilitation of the affected biceps muscle or with surgery. The age of the individual and functional requirements will determine which course of treatment is suited for that individual. The conservative treatment is more likely to be used in a person who is older and does not require the use of supination.^{3, 7} In most cases, people who undergo the non-surgical treatment will lose approximately twenty percent of supination strength, but will regain most of the ability to perform tasks of daily living.^{3, 7} For those who are at a high level of function, such as elite athletes, loss of supination strength can have a negative

impact on performance and surgical treatment is most appropriate.³ However there have been cases of elite athletes who have ruptured the LHB tendon without repair and were able to play at a very competitive level, one such example is John Elway. Once surgery is determined, there are two popular surgeries used to correct a rupture of the long head of the biceps tendon. The first is a tenodesis in which the LHB tendon is anchored back to the bicipital groove, and a tenotomy in which the tendon is released.^{13, 14}

The focus of this literature review is to provide information regarding biceps brachii anatomy, biomechanics of the glenohumeral joint (GHJ) and elbow in which the muscle functions, etiology and epidemiology of the rupture of the biceps tendon, and finally the diagnosis and treatment of the injury.

Anatomy

Tendons are structures in the body that connect muscle to bone and have three major functions; provide movement to the body, stabilize the joint, and store and release energy.^{53, 60} The tendon consists of several units with the smallest of these units being the fibril. This micro structure is anywhere from 10-500nm in diameter and is primarily made up of collagen fibers.^{54,}⁵⁵ When a group of fibrils are bound by an endotenon, a thin membrane layer containing blood vessels, nerves and lymphatic structures form the fiber. Bundles of fibers form fascicles that are covered by a connective tissue called epitenon which functions like the endotenons.^{54, 55, 56} In some cases there is a third connective tissue layer called paratenon or synovial sheath that acts to reduce friction in areas that are in direct contact with other structures.^{54, 56}

A tendon is a complex tissue containing several elements that performs multiple functions. Tendons are made up of collagen, glycoprotein, water and cells. Type I collagen makes up 65 percent of the total dry mass of a tendon and 95 percent of the collagen present in

the tendon itself.^{54, 56} The remaining five percent of collagen is made up of type III and V collagens.^{54, 56}

The point at which the tendon of a muscle connects to the bone is called the osteotendinous junction. This junction occurs when the fibers from the tendon blend with the periosteum.⁵⁷ This junction is the point at which the tendon is anchored to the bone in which the tendon must be able to resist the tension forces that are placed on it by the muscle during active movement. The site at which tendon and muscle tissues converge is called the muscle-tendon junction and is a site of weakness in the muscle and a common site for injury.^{53, 56} The function of the MTJ is to transmit loads from the contractile tissue to the bone and act on the bone in the same way.^{55, 56} The structure is able to transmit loads because of the unique junction formed between the muscle tissue and the collagen of the tendon. At the MTJ there is folding and overlapping of the sarcomeres of the muscle and the collagen fibers of the tendon. This blending of the two different tissues makes a very secure junction and is highly resistant to failure, while still allowing for elongation and contraction of the muscle fibers to provide optimal range of motion.

The biceps tendon has three distinct tendon attachments that allows the biceps to interact with the elbow and the glenohumeral joint. The long head and the short head are located on the superior aspect of the biceps brachii muscle, while the distal biceps aponeurosis is the attachment for the distal portion of the muscle. The long head of the biceps originates from two different structures in the glenohumeral joint, the supraglenoid tubercle and the labrum. The main point of origin however, is the supraglenoid tubercle which accounts for about 60 percent of the attachment.^{3, 58, 59} The location on the supraglenoid tubercle is where the LHB tendon attachment is located and where the superior, middle and inferior glenohumeral ligaments

converge.^{52, 59} The attachment of the LHB to the supraglenoid tubercle is the weakest area of the LHB tendon. This is due to the interfacing of the tendon fibers and the bone that makes up the attachment site. As with any junction of two different types of materials, there is going to be inherent weakness. The long head of the biceps also attaches to the glenoid labrum on the posterior portion and helps to stabilize that structure.^{59, 60} This gradual joining of the long head of the biceps and the posterior glenoid labrum is called bicipitalarbral complex.^{2, 59, 60} The tendon runs from a superior posterior position in the glenohumeral joint distally toward the muscle belly and passes over the anterior superior portion of the humeral head to enter the intertubercular sulcus.^{3, 52, 59, 60} The intertubercular sulcus also known as the bicipital groove has an average length of 8.1cm, depth of 4.0mm, and width of 10.1mm. It is at the intertubercular sulcus that the long head of the biceps tendon emerges from the glenohumeral capsule covered by a synovial sheath that also originates from the glenohumeral capsule.⁵²

The long head of the biceps tendon is stabilized at this site by several structures. It is stabilized anteriorly by the coracohumeral ligament, transverse ligament, superior Glenohumeral ligament, and by the tendons of the supraspinatus and subscapularis muscle. All of these structures act to thicken the glenohumeral joint capsule at this point by increasing the stabilization of the long head of the biceps tendon.^{52, 59} The primary stabilizer has been shown to be the medial portion of the coracohumeral ligament as the transverse ligament is too weak to prevent the medial dislocation of the tendon.^{42, 52} The tendon exits the intertubercular sulcus at the level of the humeral neck and runs inferiorly until it merges with the short head of the biceps at the muscle belly located at the mid-shaft of the humerus.^{3, 52, 53} The average length of the LHB tendon is around 102mm with a thickness that ranges from 8.4mm to 5.1mm.⁶⁵ The second proximal attachment of the biceps brachii is that of the short head muscle tendon. The

short head (SH) of the biceps brachii originates from the coracoid process and is less like a tendon and more like an aponeurosis. Both the LHB and SH of the Biceps brachii are innervated by the musculocutaneous nerve.

The Biceps Brachii attaches distally to the bicipital tuberosity via the distal biceps tendon as well as having some attachment to the ulna by lacertus fibers that is more commonly known as the bicipital aponeurosis.¹ The distal tendon attaches to both the anterior and posterior aspects of the bicipital tuberosity. The tendon is relatively thin proximally to the attachment but widens as it reaches the bicipital tuberosity.⁶⁶ The average length of the distal biceps tendon is from 22mm to 27mm and has an average width of 7mm. The average area covered by the distal tendon upon insertion is 108mm².⁶⁶

Biomechanics

The section on biomechanics will be divided into two sections: Kinematics and Kinetics. Kinematics refers to the range of motion in a joint while kinetics refers to the force applied to a joint by the surrounding muscle and the line of pull on which muscles act.

Kinematics: The glenohumeral joint is one of the most mobile joints in the human body. It is possible for the glenohumeral joint to execute flexion, extension, hyperextension, abduction and adduction, horizontal abduction and adduction, as well as the medial and lateral rotation, all of which are made possible by the ability of the glenohumeral joint to spin, glide, and roll.^{66,67} One of the muscles responsible for stabilizing the glenohumeral joint during this motion is the biceps brachii. The biceps brachii functions mechanically at both the glenohumeral joint and elbow joint. The Biceps brachii acts as a prime mover in glenohumeral joint flexion but also acts to stabilize the humeral head in the glenoid fossa. The LHB when loaded will decrease the amount of anterior posterior translation of the humeral head and compress as well as limit the

amount of internal and external rotation.^{45,46,47} This limitation is important as extreme external rotation of the humeral head has been shown to load the biceps causing damage to the biceps-labrum complex.⁶⁷ The biceps brachii also crosses the elbow joint and has some mechanical control over that joint.

Kinetics: the LHB tendon travels at a thirty to forty degree angle from the origin on the supraglenoid tubercle to the bicipital groove.^{46,47} The distal biceps tendon attaches to the bicipital tuberosity at an average angle arc of 59° with the midpoint of insertion being an average of 50 degrees.⁶⁸ The largest forces on the biceps tendon being tension, and rotational shear.⁶⁸

Epidemiology

Rupture of the LHB tendon in sport activity is a very rare occurrence with only two percent of bicep tendon ruptures occurring as a result of sport. Rupture of the biceps brachii tendons including the LHB and the distal attachments are more common in middle age men. This is because most of the ruptures are associated with asymptomatic periods of degenerative change in the muscle tendon.^{10,28} A bicep tendon rupture also is more common in the dominant arm of individuals based on use.^{10,44} In sport there are two mechanism that result in a rupture of the biceps tendon, overuse and traumatic overload. Overuse involves excessive overhead activity such as swimming, baseball, and volleyball with tears in the LHB due to repeated microtrauma.^{54,69,70} With sports being the cause of only two percent of all bicep tendon ruptures information regarding rate of occurrence in a single sport is scant.¹⁸ This repeated micro trauma causes a slow degeneration in the tendon which leads to tissue failure. The LHB is particularly vulnerable during the release and deceleration phase of an overhand motion, due to the amount of force that is being transmitted through the LHB tendon.^{69,71} Traumatic overload usually affects weight lifters and body builders who engage in power type activities. Both the LHB and

the distal biceps tendon are vulnerable during these types of high energy lifts. Tissue failure is often caused during an eccentric contraction of the biceps brachii during an unmanageable outside force.^{10, 40} It is far more common for a person to rupture the LHB than either the short head or the distal tendon. LHB accounts for 96% off all bicep tendon ruptures, while the distal tendon makes up only three percent with the short head accounting for less then one percent.⁷² The difference in rupture rates can be attributed to the area of attachment of the two tendons. The cross sectional area of the LHB tendon at the point of attachment at the supraglenoid tubercle is 18mm^2 while the area of attachment for the distal biceps tendon is a 108mm^2 .⁶⁶ With the distal tendon having a larger area, the stress in the tendon is spread out over a larger area decreasing the tension per square millimeter, while the relatively small size of the LHB tendon attachment means an increased tension per square millimeter.

Etiology

In order for the biceps tissue to reach a failure point, the force must exceed the stress-strain curve of that tendon. When a tendon is stretched to four percent it enters a zone in which the collagen fibers will loss their natural alignment but will still have the ability to reform to their normal orientation.⁵⁴ If the tendon is stretched beyond that four percent, then micro tearing of the tendon will occur, and if this micro tearing continues with out the tendon having time to heal, then a rupture will occur.^{43, 53} Should a tendon be stretched beyond eight to ten percent, tissue failures on the macro level and the tendon will fail resulting in a rupture.⁵⁴ In the biceps brachii it is far more common for a tendon to fail due to micro trauma rather then a catastrophic tissue failure. This is evident by looking at the pathology of the different types of bicep tendon ruptures. The LHB which makes up 96 percent of ruptures is more common in older populations who have suffered from degenerative changes to the tendon leading to a weakening of the

tendon.^{10, 43} Athletes who engage in repeated overhand motions cause the LHB tendon to become impinged. There are three main factors that lead to the degeneration of the bicep tendon in the middle age population; inflammation, instability and a traumatic event.^{10, 54} It has also been shown that those who suffer from chronic tendinopathy or impingement due to decreased subacromial space are at a greater risk for a micro trauma to the tendon.⁴³ During micro trauma, PGE₂ and LTB₄ is released at the site of the injury, which causes the tendon to weaken and degenerate.⁵⁴ The long head of the biceps tendon shares a synovial sheath with the capsule of the rotator cuff, therefore inflammation of the rotator cuff can lead to inflammation and degeneration of the LHB tendon.^{46, 47}

It is possible for the LHB tendon to rupture due to a traumatic event, however, there is typically but not always some tendon degeneration associated with the rupture. In this case the ruptures are most common during periods of an extremely powerful supination force or from a powerful deceleration force. These types of forces are typically seen in that of professional baseball pitchers or in those who fall on an outstretched arm.^{46, 47}

Glenohumeral joint instability has also been shown to be a factor that can contribute to the rate or rupture in the LHB tendon.⁶⁹ Because of the position of the LHB in the bicipital groove on the anterior aspect of the humeral head the tendon acts to resist anterior translation of the humeral head. In cases of glenohumeral joint instability in which the ligament structure of the glenohumeral joint has been compromised the LHB takes on an even greater role of stabilization.⁷³ Repeated subluxation of the humeral head will often cause the LHB tendon to sublux or even luxate to the medial compartment of the joint capsule. Dislocation of the LHB can cause traumatic lesions to the tendon or can cause inflammatory changes in the tendon which can weaken the tendon making it more vulnerable to rupture.^{10, 73}

Symptoms

There are two major mechanisms for the rupture of the LHB tendon and each will present with signs and symptoms. In the case of the inflammatory overuse mechanism the pain is gradual in onset. In the initial stages of inflammation the LHB tendon will appear to be dull, swollen, discolored with a loss of function secondary to pain.^{3, 46, 47, 74} As the inflammation progresses the tendon sheath will thicken, become fibrotic and less vascular. At this stage the tendon will feel rough and be surrounded by adhesions. The tendon will also appear to be of normal size but will still be painful and have decreased function.^{46 47} In the later stages of inflammation the tendon will be flattened, thin and appear to be fraying. It is in this stage that the adhesions could have firmly bound the tendon to the bicipital groove and is associated with spontaneous rupture of the LHB tendon.^{46 47} Upon rupture there is a resolution of pain which is often mistaken for a resolution of the tendinopathy.^{46 47}

The clinical presentation of the LHB tendon rupture is common to other injuries that are insidious in nature. The patient will be tender to palpation in the bicipital groove when the arm is rotated 10 degrees internally as the bicipital groove faces anteriorly.^{46 47, 69, 75} Pain that is associated with the biceps tendon can be distinguished from glenohumeral joint pain by rotating the arm externally. This will cause the pain to move laterally.^{46, 47} Cosmesis of the biceps brachii muscle will also be evident, and usually presents as a large bulge in the belly of the muscle and a hole present in the proximal LHB.¹⁷ Assessing range of motion in these cases will yield varying results depending on the person and the severity of the inflammation and rupture.^{46, 47, 70} On average, there will be a total loss of strength in the affected arm of 27%.⁴ Loss of flexion strength specifically will average 29% and loss of supination strength is on average 28 %.⁴ Patients will also have decreased muscle endurance in the affected arm between 20-28 %.⁴

When the LHB does rupture the sudden pain that is felt will resolve almost immediately.⁷⁵ A snap or a pop may be felt with a sensation that something is rolling up in the lateral portion of the arm.^{3,75}

Diagnostic tools

Radiographs: Radiographs are extremely limited in the ability to diagnose soft tissue injury but are often the first step of any diagnostic evaluation of an individual complaining of glenohumeral joint pain. X-rays are useful in that gross osseous trauma, diastrophic calcifications or spurs, or decrease in acromial space predisposing to acromial impingement are evident.⁷⁸ There are three common views that are taken of the glenohumeral joint, the anterior-posterior view with the medial to lateral (30-45°) and the cranial to caudal view with 20° of angulations.^{78,79} Another view that is useful in the evaluation of the a rupture to the LHB is the bicipital groove, this view shows if there are any osseous growths in the bicipital groove that would predispose a person to a tendon rupture. These views give the radiologist the best opportunity to view fractures or osseous detachment of the muscle tendons with a reasonable level of accuracy.^{78,79}

Ultrasound: The use of ultrasound to evaluate LHB tendon tears is growing in popularity due to the fact that it is non-invasive, quick and cost less then other diagnostic tools.⁷⁸ However ultrasound sensitivity for diagnosis of the soft tissue trauma in the glenohumeral joint ranges from 57-91 % with a specificity of 76-100 %.^{78,80} This large range makes it possible for the ultrasound to create false positives and false negative readings for the rotator cuff and surrounding tissue. In order for a positive diagnosis of a tear in the rotator cuff or LHB tendon all the muscle tendons must be visualized and have a positive lesion in one of those tendons. The problem with ultrasound is that intratendinous calcification or technical artifacts can present as a

lesion on the rotator cuff decreasing the sensitivity of the ultrasound as a diagnostic tool.^{78, 80} In some cases the ultrasound is better able to detect partial tears of the LHB tendon whereas MRI will only show an increased signal from the LHB tendon but not image the extent of the tear.⁸⁰

In order to ensure the highest quality of diagnostic ultrasound possible a linear transducer that is capable of greater than 7.5 MHz should be used along with a standard examination procedure. The examination should include visualization of all of the rotator cuff tendons and the LHB tendon in the transverse longitudinal plane.⁷⁸ It is also crucial that the transducer head be held perpendicular to the tendon that is being imaged in order to provide the clearest image possible.⁷⁸ The examination should also be performed on the opposite glenohumeral joint as a baseline comparison to avoid misleading artifacts such as anatomical abnormalities.⁷⁸

Magnetic Resonance Imaging: The use of the MRI has become the gold standard for imaging of soft tissue injury in the glenohumeral joint. There have been reliable findings that MRI can accurately detect rotator cuff tears and ruptures of the LHB. Detecting the continuity of a tendon and any lesions or tears that may be in the tendon are evident with MRI.^{74, 78, 81} The use of a T2 weighted MRI will also detect fluid that is present in the subacromial space that would indicate trauma to the LHB tendon. The sensitivity of MRI to detect tendon tears in the GHJ are 80-97%, with a specificity of 94 %, with a negative predictive value of 90 %.^{48, 49, 78, 82} However on the standard MRI image it is difficult to detect a partial tendon tear from tendon degeneration and impingement tendinopathies.^{48, 49, 78} One of the biggest problems in assessing the LHB tendon is that the patient should be positioned properly.^{48, 49} In order for there to be a diagnosis of a full thickness tear in the LHB tendon there must be a discrete gap in the tendon or an abnormally high signal intensity within the tendon.^{49, 81} For partial thickness tears of the LHB tendon there will be no visual gaps but an abnormally high signal strength that only encompass

the entire tendon but rather a small focal point.⁴⁹ The most common view to show the increased signal intensity for both partial and full thickness tears is the sagittal oblique view, using the coracohumeral ligament as a landmark for the origin of the LHB.⁴⁹

MRI Arthrography: In order to overcome the shortcomings of the standard MRI image a contrast agent can be injected into the joint space to increase the sensitivity of the MRI to detect tendon defects in the glenohumeral joint.^{78,79} There are several solutions that can be used as a contrast agent such as pure saline and ringer lactate, mixture of saline and gadolinium.⁷⁸ The mixture of saline and gadolinium will enhance both T1 and T2 MRI images and is the most common contrast agent used.^{78,79} This use of contrast enhances the ability of the MRI to detect partial tears in the muscle tendons of the rotator cuff and LHB and has been shown to improve the sensitivity of detecting labral tears.^{78,79} By adding the contrast to the MRI the sensitivity reaches 88% and is specificity to 91%.⁷⁹

Treatment

Non-Surgical: Rehabilitation can be a useful tool for partial ruptures of the LHB tendon that are located at the bicep-labral junction. The important thing to remember is that an injury of this type is rarely seen as an isolated incident but rather an injury that has resulted in the instability of the glenohumeral joint.⁸⁵ The goal of physical therapy in this case is to provide the glenohumeral joint with the optimal environment for healing while addressing the instability caused in the glenohumeral joint due to the tendon rupture.⁸⁵ In a recent study done by Perot cited by Huijbrechts,⁸⁵ observed that glenohumeral joint instability caused inferior shoulder subluxations and a greater risk of lesions of the bicep-labral junction.⁸⁵ It has been recommended that patients with mild instability in the glenohumeral joint and damage to the

bicep-labral junction be placed into a three month program of activity modification, NSAIDS, and physical therapy.⁸⁵

The physical therapy program should focus on strengthening the rotator cuff muscles to compensate for the instability caused by a compromised LHB. Due to the loss of the LHB the anterior translation of the humeral head increases causing a mechanical stress to the rotator cuff muscles and supporting ligaments.⁸⁵ To ensure that the glenohumeral joint remains stable following the loss of the biceps tendon a patient must focus on increasing rotator cuff and scapular strength, endurance, and proprioception.⁸⁵ The strengthening of the rotator cuff is more important than strengthening the bicep for two main reasons. First if the bicep-labral junction is the site of the rupture, activation of the LHB could only cause further damage to the labrum resulting in a larger stability deficit at the glenohumeral joint. Secondly, if the LHB tendon has completely ruptured from the supraglenoid attachment, strengthening of the LHB will not add any stability to the glenohumeral joint as the LHB is no longer stabilizing the humeral head.⁸⁵

Surgical intervention

Tenotomy of the long the biceps tendon: Tenotomy is a procedure that is most indicated for people who are above the age of fifty with no functional limitations due to the loss in supination strength and endurance. In some studies, the re-operation rate for a biceps tenotomy is less than one percent of the sample population with visible biceps deformity in half the sample after five years.¹⁶ Walch³⁶ has shown that with the proper rehabilitation of the rotator cuff muscles the loss in glenohumeral joint stability can be minimal. The patient is first placed into the beach chair position. A diagnostic arthroscopy is then performed using a standard posterior viewing portal with a superior working portal. From this vantage point the biceps tendon can be visualized and assessed and the damaged portion of the biceps can be resected. It is also possible

to repair any damage to the labrum after the LHB has been resected. Ninety percent of those who have the tenotomy procedure are able to return to work or return to a previous level of sport activity, the only problem being a lack of supination strength and pain during prolonged activities that require supination and the deformity caused by the rupture of the biceps brachii tendon.^{6,17}

Tenodesis long head of the biceps: The benefits of Tenodesis are that it allows for maintaining full strength in elbow flexion and supination, muscular endurance and cosmetic appearance.^{8, 88, 89} There are several techniques that have been developed for the tenodesis of the LHB. Three are arthroscopic techniques and two open techniques. The arthroscopic techniques include interference screw, suture anchor, and ligament washer, whereas the open techniques are the keyhole and bone tunnel techniques.^{13, 14} All of the tenodesis techniques will provide for the same functional outcomes.

The interference screw technique, (Figure B1) starts with a 25mm hole drilled into the humerus 10mm distal to the proximal end of the bicipital groove, ninety degrees to the long axis of the humerus.^{13, 14} The LHB is placed into the hole that was drilled in the humerus.³⁷ The interference screw is then placed in the hole on top of the LHB and screwed into place.

Figure B1

The suture anchor technique, (Figure B2) uses an anchor screw placed in humerus 10mm distal to the proximal end of the bicipital groove, ninety degrees to the long axis of the humerus.^{13, 14} Two sutures are looped through the suture anchor and looped through

the LHB tendon in a mattress fashion. The sutures are secured to the LHB using four square knots.^{13, 14}

Figure B2

The ligament washer technique, (Figure B3) is similar to the previous two techniques in that there is a 10mm hole that is drilled in the humerus 10mm distal to the proximal end of the bicipital groove, and 90 degrees to the long axis of the humerus.^{13, 14} In this case a 13.5mm washer is used to secure the tendon in place. The washer is placed around the screw head and when the screw is placed in the pre drilled hole and screwed home the spiked washer secures the LHB tendon in the correct position.

Figure B3

In the Keyhole technique, (Figure B4) the LHB is prepped by rolling the proximal end of the LHB into a ball and securing the ball together by non-resorbable sutures. A “keyhole” is then made 10mm distal to the proximal end of the bicipital groove. The proximal portion of the key hole measures 10mm in diameter, while the distal portion of the key hole measures only 5mm in diameter.^{13, 14} The ball that was made on the proximal end of the LHB is then pushed into the proximal portion of the key that measures 10mm in diameter and is pushed distally to the

slot that is only 5mm in diameter. Any time that tension is applied to the muscle the ball will be forced into the distal end of the “keyhole” securing the LHB. ^{13, 14}

Figure B4

The bone tunnel technique, (Figure B5) is used when intracortical fixation of the LHB was necessary. The LHB is prepared by using a non-resorbable suture whipstitch over the proximal end of the LHB measuring 15mm in length. ^{13, 14} Then an 8mm hole is drilled 10mm distal to the proximal end of the bicipital groove followed by two 2mm holes that are drilled medially, laterally and distally at a distance of 15mm from the original hole. ^{13, 14} The sutures that were placed in the LHB are then placed into the 8mm hole and pulled through the two 2mm holes causing the LHB to be pulled into the 8mm hole. ^{13, 14} The sutures are then passed through the LHB and tied securing the tendon into place.

Figure B5

Both tenotomy and tenodesis of the LHB tendon will result in different functional outcomes. The tenotomy procedure is not recommended for heavy lifters such as physical

laborers or contact sports because of the high level of muscle fatigue that is associated with the removal of the LHB. For older people, who are less physically active removal of the LHB tendon is a very reliable procedure. Gill¹⁸ evaluated thirty patients who had an arthroscopic release of the LHB and noted that no additional pain medication was required at follow up for 97% of the patients. Ninety percent were able to return to the same level of activity with no complications.^{18,20} Carrol and Hamilton⁹³ used patients who were 60 years of age or older and there was no significant difference in strength between the treated arm and the untreated arm as well as having zero complaints of muscle fatigue during elbow flexion.^{17, 18, 20, 93}

Tenodesis of the LHB tendon is the more favorable procedure for those who are younger and for those who live a more active life style where the loss of the strength and muscle endurance would negatively affect function.^{17, 23} However reattachment of the LHB to the bicipital groove will not help stabilize the glenohumeral joint.

Other than the difference in strength and muscle endurance of the biceps brachii muscle there is little difference in the functional outcomes of patients.¹⁷ The failure rates of the two surgeries are very similar with tenodesis ranging from 5% to 48%.^{24, 26} The failure rate of tenotomy ranges from 13% to 35%.^{18, 21} Both procedures also result in good to excellent outcomes ranging from 40-90%.^{17, 18, 21, 32, 37} The only visible difference between the procedures is that with tenotomy there will be a visible deformation of the biceps brachii muscle.^{17,}

Postoperative

Following surgery the patients who underwent the tenodesis were placed in a immobilization sling for four weeks. As soon as the post-operative pain subsided the patients would start sub maximal isometric deltoid strengthening to assist in glenohumeral joint stabilization.²⁶ Elbow, wrist and finger mobilization as well as pendulum exercises are started on

day one post-operatively. These exercises should be performed for five minutes per day five times a day.²⁶ Week three the patient start passive and active assisted range of motion exercises. At six weeks post-op the patient would begin to strengthen the rotator cuff muscle and start scapular stabilization exercises. At three months post-op functional and sport specific exercises would be started and at four to six months the patient would be allowed to return to full physical activity with no restrictions.²⁶

Summary

Ruptures of the tendons of the Biceps brachii is a rare occurrence in the young and healthy population because of the association with tendon degeneration that is usually only seen in those of middle age.^{2, 3, 28} However, with the increasing amount of sport specialization in younger and younger athletes the rates of chronic inflammation and impingement will cause tendon degeneration in a younger population and could cause an increase in the number of biceps tendon pathology and rupture in the younger age groups. The LHB has been shown to stabilize the glenohumeral joint as it provides a stop to extreme anterior translation of the humeral head.^{52, 59} The rupture of LHB tendon can be caused by acute trauma to the glenohumeral joint and the LHB tendon or by physiological changes in the tendon over a long period of time.^{40, 44} This type of injury is most common in sports that require repeated over head motion with the arm or in contact sports.^{43, 54} When a rupture does occur the most obvious sign is the loss of shoulder function and what is called a Popeye sign in which muscle belly curls upon itself forming a bulge in the muscle belly.^{4, 75} In order to diagnose the tear of the biceps tendon the most useful diagnostic tool that can be used is the MRI, as it allows for not only the location of the tear to be visualized but also the extent of the tear and if there is any trauma to the surrounding tissue.⁷⁸ Once the location of the tear is determined there are several surgical techniques that can be used

to repair the defect depending on the several factors including location and extent of the tear, age and function of the patient. All surgical techniques have similar functional outcomes and success rates.^{17, 18, 21, 32}

There have been a plethora of studies conducted on different surgical techniques used to correct the functional deficits that occur following a bicep tendon rupture. Therefore, it is important to evaluate which surgical techniques will give the younger population the greatest chance to regain a high level of function that will allow them to return to full sport activity. Some of these studies are very well designed and offer a valid and reliable results while others present data that is based on limited or faulty study design. It is not only important to read studies about what techniques offer the greatest functional recovery for individuals but it is also important to analyze the studies to ensure the highest quality experimental methodology is being used in order to support the conclusions.

APPENDIX C
ADDITIONAL METHODS

Table C1. Coleman Method.^{30, 31}

Part A- Only one Score is given for each section

1. Study Size
2. Mean Follow up
3. Number of different surgical procedures, included in each reported outcome
4. Type of Study
5. Diagnostic Certainty
6. Description of surgical procedure given
7. Description of postoperative rehabilitation

Part B- Scores may be given for each option in each section if needed.

1. Outcome Criteria
 2. Procedure of assessing outcomes
 3. Description of subject selection process
-

Table C2. Coleman Method Scoring with explanations. ^{30, 31}

Part A

1. Study Size 10-0

Explanation: The Number of subjects evaluated in the study.

>60: 10, 41-60: 7, 20-40: 4, < 20- not stated or unclear: 0

2. Mean Follow up 5-0

Explanation: The number of months after the surgery the subject is reevaluated.

>24: 5, 12-24: 2, < 12- not stated or unclear: 0

3. Number of different surgical procedures, included in each reported outcome.

10-0

Explanation: More than one surgical technique may be assessed but separate outcomes should be reported.

One procedure: 10, More than one but >90% undergo the main procedure: 7, <90% undergo main procedure, or not stated or unclear: 0

4. Type of Study 15-0

Explanation: The method of study used to examine the surgical procedure.

Randomized control trial: 15, Prospective cohort study: 10, Retrospective cohort Study: 0

5. Diagnostic Certainty

5-0

Explanation: The study completed preoperative ultrasound or MRI to confirm the type of injury to the subject. Also the study performed completed postoperative histopathology to confirm diagnosis of subject.

In all: 5, In >80%: 3, In < 80% not stated or unclear: 0

6. Description of surgical procedure given

5-0

Explanation: The surgical procedure is adequately described by the technique and related information given in detail. The surgery is only fairly described by having the technique stated without explanation. The surgery is inadequately described with no details or not stated or unclear.

Adequate: 5, Fair: 3, Inadequate: 0

7. Description of the postoperative rehabilitation

10-0

Explanation: The rehabilitation used after surgery is well described in the study, also what the patients will complete to return to normal function is included. Information on whether the patients are compliant with the rehabilitation in the study is included.

Described >80% patient complying: 10, Described 60-80% patient complying: 5, Protocol not reported or < 60-80% patients not complying: 0

Part B.

1. Outcome criteria	10-0
Outcome measures clearly defined	2
Timing of outcome assessment clearly stated	2
Use of outcome criteria reported has good reliability	3
Use of outcome with good sensitivity	3

Explanation: The outcomes reported in the study are clearly defined. When the outcomes are not described or are vague in the study that particular section of outcomes scores an automatic 0.

2. Procedure for assessing outcomes	15
Subjects recruited	5
Investigator independent of surgeon	4
Written assessment	3
Completion of assessment by subjects	3

Explanation: The subjects are not chosen from the surgeons own files. The investigator of the data is not directly involved with the surgeon. The assessment of the outcomes of the surgery is recorded in the study. The subjects complete an assessment of the study and results of their surgery independent of the investigator.

3. Description of the subjects selection process	15
Selection criteria reported and unbiased	5
Recruitment rate reported: >80% or <80%	5
Eligible subjects not included in the study satisfactorily accounted for or 100% recruitment.	5

Explanation: The overall recruitment of subjects is clearly reported in the study with no type of bias being shown by investigators. All possible subjects in the study are accounted for in the results.

Table C3. Protocol for Determining Studies

-
1. The studies were written in or translated to English
 2. The Term Bicep tendon rupture, Tendonitis or SLAP tear must be present in the title
 3. The Abstract must include the name of the surgical repair technique
 4. Bicep tendon pain or dysfunction must be the chief complaint in the study
 5. The study must be a Randomized Controlled Trial
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APPENDIX D ADDITIONAL RESULTS

Table D1. Biceps Brachii Surgical Repair Studies

<u>Study</u>	<u>Subjects</u>	<u>Technique</u>	<u>Results</u>	<u>Quality Score</u>
Kragh and Basamania ³⁸	12 subjects with acute rupture of the biceps tendon	9 subjects underwent arthroscopic resection. 3 conservative treatment	Patients who underwent conservative treatment reported increased pain and fatigue with repeated supination	48/100
Kelly and Drakos ²¹	54 patients diagnosed with Biceps tendinitis who failed conservative treatment	40 patients with arthroscopic release of the long head of the biceps tendon.	27 of the patients self-rated the results as good, very good or excellent, 6 rated as fair and 7 rated as poor	38/100
Gill and McIrvin ¹⁸	30 patients who underwent arthroscopic release of the long head of the biceps tendon	30 patients underwent intra articular release of the long head of the biceps brachii tendon.	27 patients returned to sport at previous level with minimal or no complaints. 29 patients returned to work to previous occupation. The mean American Shoulder and Elbow Surgeons shoulder score ranged from 35-100.	42/100
Boileau and Parratte ²⁶	25 consecutive patients operated on for isolated type II SLAP lesion	10 SLAP repair using suture anchors. 15 Tenodesis using interference screw fixation.	The Tenodesis group reported higher levels of activity then the SLAP repair group, 19.5 compared to 16., respectively. 13/15 Tenodesis group returned to previous level of activity compared to 2/10 for SLAP group. 14/15 Tenodesis group reported satisfied or very satisfied compared to 4/10 for the SLAP group.	54/100

Becker and Cofield ²⁴	54 shoulders in 51 patients were followed for an average of 13 years following tenodesis of the LHB for treatment of chronic tendinitis. Only 37 patients met the inclusion criteria	13 shoulders suture anchored, 14 keyhole-tenodesis and 10 side to side tenodesis	22 shoulders were pain free at the time of the follow up. 5 reported slight discomfort 10 reported moderate pain levels	46/100
Mazzocca and Cote ³⁹	50 patients met the inclusion criteria	50 patients underwent sub-pectoral bone tunnel technique	41 patients completed follow up examinations. With 78% of the patients reporting no episodes of pain over the anterior humerus. According to the UCLA score after a mean of 32 months 11 patients achieved excellent results, 3 reported good and 1 had fair.	76/100
Checchia and Doneux ³⁵	15 adult patients with rotator cuff tears and biceps tendon lesions	15 patients underwent a suture fixation tenodesis	According to the UCLA score after a mean of 32 months 11 patients achieved excellent results, 3 reported good and 1 had fair.	42/100
Berlemann and Bayley ⁴⁰	20 shoulders on 19 patients who underwent tenodesis of the LHB	20 shoulders underwent Keyhole tenodesis	5 shoulders were excluded due to inadequate follow up. In the short term 1 shoulder reported excellent result. 10 reported good results. 2 graded the results as fair. 2 reported the results as failures. In the long term 8 reported excellent results, 2 good results 2 graded the results as fair 2 reported the results as failures	12/100
Boileau and Baque ³⁷	72 shoulders with rotator cuff tears with isolated biceps tenodesis or tenotomy	1. 39 cases underwent a tenotomy. 2. 33 cases underwent a fixation screw tenodesis	No statistical difference between the two groups with consideration to pain, activity, strength and mobility. The only statistical difference between the two groups is the evidence of a tendon retraction(Popeye sign) in which the tenotomy group reported a higher rate.	58/100

Walch and Edwards ³⁶	307 shoulders that had full thickness tears of the rotator cuff and underwent surgical repair.	Simple LHB tendon release. (n=307)	Using a Constant score 157 shoulders rated as excellent, 63 as good, 45 as fair and 42 as poor	63/100
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Table D2. Comparison of Studies Based on Coleman Method

Study	Study Size	Mean Follow-up	Number procedures	Type of study	Diagnostics	Procedure	Rehab	Outcomes	Assess outcome	Study Selection
Kragh and Edwards	0	5	10	0	0	5	0	8	10	10
Kelly and Drakos	4	5	10	0	0	0	0	8	6	5
Gill and Mcirvin	4	2	10	0	0	0	0	8	3	15
Boileau and Parratte	4	5	0	10	0	5	10	10	10	0
Becker and Cofield	7	5	10	0	0	5	0	0	9	10
Mazzocca and Cote	7	2	10	10	0	5	10	10	12	10
Checchia and Doneux	0	5	10	0	5	5	0	10	7	0
Berlemann and Bayley	0	5	0	0	0	0	0	0	7	0
Boileau and Baque	10	5	0	0	5	5	10	10	3	10
Walch and Edwards	10	5	10	0	5	3	10	2	3	15

Table D3. Coleman Method Checklist for Kragh ³⁸

Part A.									
1.	Study Size	10	7	4	0				
2.	Mean follow-up		5	2	0				
3.	Number of different surgical procedures				10	7	0		
4.	Type of Study		15	10	0				
5.	Diagnostic certainty			5	3	0			
6.	Description of surgical procedure given	5			3	0			
7.	Description of postoperative rehabilitation				10	5	0		
Part B.									
1.	Outcome criteria		10						
	A) Outcome measures clearly defined			2					
	B) Timing of outcome assessment clearly stated				0				
	C) Use of outcome criteria reported has good reliability					3			
	D) Use of outcome with good sensitivity			3					
2.	Procedure for assessing outcomes		15						
	A) Subjects recruited		5						
	B) Investigator independent of surgeon			4					
	C) Written assessment		3						
	D) Completion of assessment by subjects			3					
3.	Description of subject selection process		15						
	A) Selection criteria reported and unbiased		5						
	B) Recruitment rate reported: >80% or <80%				5				
	C) Eligible subjects not included in study accounted for or 100% recruitment					5			
							Total: 48/100		
Key: Bold Indicates Points Scored									

Table D4. Coleman Method Checklist for Kelly ²¹

Part A.

1. Study Size	10	7	4	0
2. Mean follow-up	5	2	0	
3. Number of different surgical procedures		10	7	0
4. Type of Study	15	10	0	
5. Diagnostic certainty		5	3	0
6. Description of surgical procedure given	5	3	0	
7. Description of postoperative rehabilitation		10	5	0

Part B.

1. Outcome criteria	10			
A) Outcome measures clearly defined		2		
B) Timing of outcome assessment clearly stated		2		
C) Use of outcome criteria reported has good reliability		3		
D) Use of outcome with good sensitivity		3		
2. Procedure for assessing outcomes	15			
A) Subjects recruited	5			
B) Investigator independent of surgeon	4			
C) Written assessment	3			
D) Completion of assessment by subjects	3			
3. Description of subject selection process	15			
A) Selection criteria reported and unbiased	5			
B) Recruitment rate reported: >80% or <80%	5			
C) Eligible subjects not included in study accounted for or 100% recruitment	5			

Total: 38/100

Key: Bold Indicates Points Scored

Table D5. Coleman Method Checklist for Gill ¹⁸

Part A.

1. Study Size	10	7	4	0
2. Mean follow-up	5	2	0	
3. Number of different surgical procedures		10	7	0
4. Type of Study	15	10	0	
5. Diagnostic certainty		5	3	0
6. Description of surgical procedure given	5	3	0	
7. Description of postoperative rehabilitation	10	5	0	

Part B.

1. Outcome criteria 10
 - A) Outcome measures clearly defined 2
 - B) Timing of outcome assessment clearly stated 2
 - C) Use of outcome criteria reported has good reliability **3**
 - D) Use of outcome with good sensitivity **3**
2. Procedure for assessing outcomes 15
 - A) Subjects recruited 5
 - B) Investigator independent of surgeon 4
 - C) Written assessment **3**
 - D) Completion of assessment by subjects 3
3. Description of subject selection process 15
 - A) Selection criteria reported and unbiased **5**
 - B) Recruitment rate reported: >80% or <80% **5**
 - C) Eligible subjects not included in study accounted for or 100% recruitment **5**

Total: 42/100**Key: Bold Indicates Points Scored**

Table D6. Coleman Method Checklist for Boileau ²⁶

Part A.

1.	Study Size	10	7	4	0			
2.	Mean follow-up		5	2	0			
3.	Number of different surgical procedures					10	7	0
4.	Type of Study	15	10	0				
5.	Diagnostic certainty			5	3	0		
6.	Description of surgical procedure given	5				3	0	
7.	Description of postoperative rehabilitation					10	5	0

Part B.

1. Outcome criteria 10
 - A) Outcome measures clearly defined 2
 - B) Timing of outcome assessment clearly stated 2
 - C) Use of outcome criteria reported has good reliability 3
 - D) Use of outcome with good sensitivity 3
2. Procedure for assessing outcomes 15
 - A) Subjects recruited 5
 - B) Investigator independent of surgeon 4
 - C) Written assessment 3
 - D) Completion of assessment by subjects 3
3. Description of subject selection process 15
 - A) Selection criteria reported and unbiased 5
 - B) Recruitment rate reported: >80% or <80% 5
 - C) Eligible subjects not included in study accounted for or 100% recruitment 5

Total: 54/100

Key: Bold Indicates Points Scored

Table D7. Coleman Method Checklist for Becker ²⁴

Part A.

1.	Study Size	10	7	4	0
2.	Mean follow-up	5	2	0	
3.	Number of different surgical procedures		10	7	0
4.	Type of Study	15	10	0	
5.	Diagnostic certainty		5	3	0
6.	Description of surgical procedure given	5	3	0	
7.	Description of postoperative rehabilitation		10	5	0

Part B.

1. Outcome criteria 10
 - A) Outcome measures clearly defined 2
 - B) Timing of outcome assessment clearly stated 2
 - C) Use of outcome criteria reported has good reliability 3
 - D) Use of outcome with good sensitivity 3
2. Procedure for assessing outcomes 15
 - A) Subjects recruited **5**
 - B) Investigator independent of surgeon **4**
 - C) Written assessment 3
 - D) Completion of assessment by subjects 3
3. Description of subject selection process 15
 - A) Selection criteria reported and unbiased **5**
 - B) Recruitment rate reported: >80% or <80% 5
 - C) Eligible subjects not included in study accounted for or 100% recruitment **5**

Total: 46/100**Key: Bold Indicates Points Scored**

Table D8. Coleman Method Checklist for Mazzocca³⁹

Part A.									
1.	Study Size	10	7	4	0				
2.	Mean follow-up	5	2	0					
3.	Number of different surgical procedures				10	7	0		
4.	Type of Study	15	10	0					
5.	Diagnostic certainty		5	3	0				
6.	Description of surgical procedure given	5		3	0				
7.	Description of postoperative rehabilitation		10	5	0				
Part B.									
1.	Outcome criteria	10							
	A) Outcome measures clearly defined		2						
	B) Timing of outcome assessment clearly stated		2						
	C) Use of outcome criteria reported has good reliability			3					
	D) Use of outcome with good sensitivity		3						
2.	Procedure for assessing outcomes	15							
	A) Subjects recruited		5						
	B) Investigator independent of surgeon		4						
	C) Written assessment		3						
	D) Completion of assessment by subjects		3						
3.	Description of subject selection process	15							
	A) Selection criteria reported and unbiased		5						
	B) Recruitment rate reported: >80% or <80%			5					
	C) Eligible subjects not included in study accounted for or 100% recruitment				5				
Total: 76/100									
Key: Bold Indicates Points Scored									

Table D9. Coleman Method Checklist for Checchia ³⁵

Part A.

1.	Study Size	10	7	4	0
2.	Mean follow-up	5	2	0	
3.	Number of different surgical procedures		10	7	0
4.	Type of Study	15	10	0	
5.	Diagnostic certainty		5	3	0
6.	Description of surgical procedure given	5	3	0	
7.	Description of postoperative rehabilitation		10	5	0

Part B.

1. Outcome criteria 10
 - A) Outcome measures clearly defined **2**
 - B) Timing of outcome assessment clearly stated **2**
 - C) Use of outcome criteria reported has good reliability **3**
 - D) Use of outcome with good sensitivity **3**
2. Procedure for assessing outcomes 15
 - A) Subjects recruited **5**
 - B) Investigator independent of surgeon **4**
 - C) Written assessment **3**
 - D) Completion of assessment by subjects **3**
3. Description of subject selection process 15
 - A) Selection criteria reported and unbiased **5**
 - B) Recruitment rate reported: >80% or <80% **5**
 - C) Eligible subjects not included in study accounted for or 100% recruitment **5**

Total: 42/100

Key: Bold Indicates Points Scored

Table D10. Coleman Method Checklist for Berlemann⁴⁰

Part A.									
1.	Study Size	10	7	4	0				
2.	Mean follow-up	5	2	0					
3.	Number of different surgical procedures		10	7	0				
4.	Type of Study	15	10	0					
5.	Diagnostic certainty		5	3	0				
6.	Description of surgical procedure given 5		3	0					
7.	Description of postoperative rehabilitation		10	5	0				
Part B.									
1.	Outcome criteria	10							
	A) Outcome measures clearly defined		2						
	B) Timing of outcome assessment clearly stated		2						
	C) Use of outcome criteria reported has good reliability		3						
	D) Use of outcome with good sensitivity		3						
2.	Procedure for assessing outcomes	15							
	A) Subjects recruited	5							
	B) Investigator independent of surgeon	4							
	C) Written assessment	3							
	D) Completion of assessment by subjects	3							
3.	Description of subject selection process	15							
	A) Selection criteria reported and unbiased	5							
	B) Recruitment rate reported: >80% or <80%	5							
	C) Eligible subjects not included in study accounted for or 100% recruitment	5							
Total: 12/100									
Key: Bold Indicates Points Scored									

Table D11. Coleman Method Checklist for Boileau³⁷

Part A.

1.	Study Size	10	7	4	0
2.	Mean follow-up	5	2	0	
3.	Number of different surgical procedures		10	7	0
4.	Type of Study	15	10	0	
5.	Diagnostic certainty	5	3	0	
6.	Description of surgical procedure given	5	3	0	
7.	Description of postoperative rehabilitation	10	5	0	

Part B.

1. Outcome criteria 10
 - A) Outcome measures clearly defined 2
 - B) Timing of outcome assessment clearly stated 2
 - C) Use of outcome criteria reported has good reliability 3
 - D) Use of outcome with good sensitivity 3
2. Procedure for assessing outcomes 15
 - A) Subjects recruited 5
 - B) Investigator independent of surgeon 4
 - C) Written assessment 3
 - D) Completion of assessment by subjects 3
3. Description of subject selection process 15
 - A) Selection criteria reported and unbiased 5
 - B) Recruitment rate reported: >80% or <80% 5
 - C) Eligible subjects not included in study accounted for or 100% recruitment 5

Total: 55/100

Key: Bold Indicates Points Scored

Table D12. Coleman Method Checklist for Walch³⁶

Part A.

1.	Study Size	10	7	4	0
2.	Mean follow-up	5	2	0	
3.	Number of different surgical procedures			10	7 0
4.	Type of Study	15	10	0	
5.	Diagnostic certainty		5	3	0
6.	Description of surgical procedure given			5	3 0
7.	Description of postoperative rehabilitation	10		5	0

Part B.

1. Outcome criteria 10
 - A) Outcome measures clearly defined **2**
 - B) Timing of outcome assessment clearly stated 2
 - C) Use of outcome criteria reported has good reliability 3
 - D) Use of outcome with good sensitivity 3
2. Procedure for assessing outcomes 15
 - A) Subjects recruited 5
 - B) Investigator independent of surgeon **4**
 - C) Written assessment **3**
 - D) Completion of assessment by subjects 3
3. Description of subject selection process 15
 - A) Selection criteria reported and unbiased **5**
 - B) Recruitment rate reported: >80% or <80% **5**
 - C) Eligible subjects not included in study accounted for or 100% recruitment **5**

Total: 63/100

Key: Bold Indicates Points Scored

Figure D1. Figure of Studies Used: CINAHL

Figure D2. Figure of Studies Used: MEDLINE

Figure D4. Figure of Studies Used: SPORTSDiscus

Figure D6. Figure of Studies Used: SCIENCE DIRECT

APPENDIX E

RECOMMENDATIONS FOR FUTURE RESEARCH

1. Future studies should utilize studies not written in the English language by search Embase Database for foreign surgical studies.
2. Be more specific in the search terms as to narrow the search to only those studies that apply to the research topic.
3. Look to capture studies that directly compare the surgical outcomes so better conclusions can be made about the functional outcomes of each surgical technique.
4. Perform a meta-analysis to comparing group means, group sizes, and frequency of dichotomous data when available.

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