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The role of rotator interval closure in Bankart lesion repair

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A thesis submitted in partial fulfillment of the requirements for the degree in Master of Science

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THE ROLE OF ROTATOR INTERVAL CLOSURE IN BANKART LESION REPAIR

(Thesis format: Monograph)

By

Lauren L. Rainsford

Graduate Program in Health and Rehabilitation Science

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science

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ABSTRACT

Twenty-nine patients who had sustained a traumatic anterior shoulder dislocation were randomly assigned to receive Bankart lesion repair, or Bankart lesion repair with rotator interval closure. External rotation range of motion with 90° of abduction, external rotation range of motion with no abduction, and forward flexion range of motion were measured preoperatively, and at three and six months postoperatively. Quality of life, function, and pain were measured preoperatively, and at three, six, 12 and 24 weeks postoperatively. We found no significant differences between groups for any outcome but the confidence intervals were wide and definitive conclusions could not be made. This thesis represents the preliminary results of a larger continuing study.

Keywords: Arthroscopic Bankart repair, rotator interval, anterior dislocation, shoulder instability
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ABSTRACT.............................................................................................................................. ii

ACKNOWLEDGEMENTS............................................................................................................ iii

LIST OF FIGURES .................................................................................................................... vi

LIST OF TABLES ...................................................................................................................... vii

CHAPTER 1: INTRODUCTION .................................................................................................. 1

CHAPTER 2: LITERATURE REVIEW ......................................................................................... 5

2.1 Anatomy ............................................................................................................................ 5

2.2 Mechanism of Injury ......................................................................................................... 8

2.3 Epidemiology .................................................................................................................... 10

2.3.1 Incidence in Specific Groups ....................................................................................... 12

2.4 Treatment ......................................................................................................................... 15

2.4.1 Surgical Treatment vs. Conservative Treatment ......................................................... 15

2.4.2 Open Surgical Repair versus Arthroscopic Surgical Repair ....................................... 18

2.4.3 Rotator Interval Closure ............................................................................................... 28

2.6 Summary ........................................................................................................................... 35

CHAPTER 3: OBJECTIVES .................................................................................................... 38

CHAPTER 4: MATERIALS AND METHODS ........................................................................... 39

4.1 Ethics Approval and Subject Consent ............................................................................... 39

4.2 Eligibility Requirements .................................................................................................. 39

4.3 Subject Recruitment ......................................................................................................... 40

4.4 Randomization ................................................................................................................ 40

4.5 Interventions .................................................................................................................... 40

4.5.1 Arthroscopic Bankart Repair ...................................................................................... 40

4.5.2 Arthroscopic Rotator Interval Closure ......................................................................... 42
LIST OF FIGURES

Figure 1: Glenohumeral Ligaments ................................................................. 6
Figure 2: The Borders of the Rotator Interval .................................................. 8
Figure 3: Active External Rotation with 90° of Abduction Measurement .......... 45
Figure 4: Passive External Rotation with 90° Abduction Measurement .......... 45
Figure 5: Active External Rotation with 0° of Abduction Measurement .......... 47
Figure 6: Passive External Rotation with 0° of Abduction Measurement ......... 48
Figure 7: Active Forward Flexion Measurement .............................................. 49
Figure 8: Active Forward Flexion Measurement ............................................. 50
Figure 9: Passive Forward Flexion Measurement .......................................... 50
Figure 10: Participant flow through the trial ................................................... 55
Figure 11: Range of Motion - External Rotation with 90° Abduction .............. 58
Figure 12: Range of Motion - External Rotation with 0° Abduction ............... 60
Figure 13: Range of Motion – Forward Flexion ............................................. 61
Figure 14: Western Ontario Shoulder Instability Index Scores ....................... 64
Figure 15: Upper Extremity Functional Index Scores .................................... 65
Figure 16: 4-Item Pain Intensity Measure Scores .......................................... 66
LIST OF TABLES

Table 1: Baseline Demographics ................................................................. 56
Table 2: Side-to-Side Difference: External Rotation in 90° of Abduction .......... 58
Table 3: Side-to-Side Difference: External Rotation with 0° Abduction .......... 59
Table 4: Side-to-Side Difference: Range of Motion - Forward Flexion............. 61
Table 5: Western Ontario Shoulder Instability Index Scores (unadjusted means) .... 62
Table 6: Upper Extremity Functional Index Scores (unadjusted means) ............ 65
Table 7: 4-Item Pain Intensity Measure Scores (unadjusted means) .................. 66
Table 8: Association (Pearson's r, p-value) Between Side-to-Side Difference in Active External Rotation with 90° Abduction and Patient Reported Quality of Life and Function ................................................................. 67
Table 9: Regression Analysis – Side-to-Side Difference in External Rotation With 90° Abduction and Patient Reported Quality of Life and Function ................................................................. 68
Table 10: Association (Pearson's r, p-value) Between Side-to-Side Difference in Active External Rotation with no Abduction and Patient Reported Quality of Life and Function .............................................................................. 68
Table 11: Regression Analysis: Side-to-Side Difference in External Rotation with no Abduction and Patient Reported Quality of Life and Function ................................................................. 69
LIST OF APPENDICES

Appendix A: Ethics Approval ................................................................. 86
Appendix B: Letter of Information and Consent ........................................ 87
Appendix C: Physiotherapy Protocol ........................................................ 91
Appendix D: Image Permissions .............................................................. 102
Appendix E: Curriculum Vitae ................................................................. 104
CHAPTER 1: INTRODUCTION

The shoulder joint is designed for a high degree of mobility at the expense of stability. Comprised of the shallow glenoid fossa of the scapula and the head of the humerus bone, only one third of the head of the humerus is in contact with the glenoid. This affords the shoulder the largest range of motion of any synovial joint in the body.[1, 2] Although the surrounding static and dynamic stabilizing structures help protect against humeral head translation, shoulder dislocations account for almost half of all body joint dislocations.[3] Shoulder dislocation occurs when all articulation between the humeral head and the glenoid is lost. The direction of dislocation can be anterior, posterior or inferior, although most patients sustain anterior dislocations.[4-6]

Recent epidemiological studies evaluating shoulder dislocations have presented prevalence rates of 23.9/100,000 person years for the general population.[7] This includes both initial and recurrent dislocations, and dislocation in all directions. Thomas and Matsen[8] classified two main types of shoulder instability: TUBS (traumatic unilateral dislocations with Bankart lesion requiring surgery) and AMBRII (atraumatic, multidirectional or bilateral dislocations that often responds to rehabilitation but may require inferior capsular shift surgery, and possible rotator interval closure). The prevalence of traumatic anterior shoulder dislocations is higher among younger, active male patients.[9, 10] Cameron et al. (2013)[11] studied shoulder instability in young military athletes, finding the prevalence of anterior dislocation to be 3.0%, while Hovelius et al. (1982)[12] reported the prevalence for shoulder dislocation in the general population to be 1.7%. 
The most important static stabilizing structures of the shoulder include the glenoid labrum and the glenohumeral ligaments. The glenoid labrum is a layer of fibrocartilage that surrounds and deepens glenoid, providing a bumper against humeral head dislocation. The labrum also serves as an attachment point for the glenohumeral ligaments, which prevent anterior dislocation when the arm is in extreme ranges of motion.[13-15] The muscles of the rotator cuff (supraspinatus, infraspinatus, teres minor, and the subscapularis), the deltoid, and the long head of the biceps all contribute to dynamic stability of the shoulder joint by compressing the humeral head into the glenoid during arm movement.[16]

During traumatic anterior dislocation of the humeral head, the anterior inferior portion of the glenoid labrum and its associated glenohumeral ligaments are often torn and displaced from the glenoid rim.[17-20] This tear is known as a Bankart lesion, and predisposes the shoulder to recurrent instability and re-dislocations.[21]. The primary treatment for traumatic anterior shoulder instability is arthroscopic Bankart repair, which involves mobilizing the displaced portion of the labrum and reattaching it to the glenoid.

The rotator interval is a triangular region in the anterior superior portion of the shoulder joint that has recently been shown to play a role in shoulder stability.[22-27] Located between the supraspinatus, and subscapularis muscles, the specific function of the rotator interval is still debated. Patients with AMBRII type instability often exhibit rotator interval laxity, and rotator interval closure has been used as a surgical treatment option for patients with multidirectional instability.[28-30] However, closure of the rotator interval has been shown in cadavers to primarily increase anterior inferior
shoulder stability by decreasing humeral head translation and range of motion. [24, 25, 31]

With no surrounding muscular contribution, the use of cadaveric models however makes it difficult to determine whether the potential loss of range of motion is important to patients. As evidenced by the popularity of open Bankart repair procedures, often patients are willing to compromise external rotation for stability. Several studies including both arthroscopic and open Bankart repair procedures report average external rotation losses of up to $10^\circ$, accompanied by good or excellent quality of life scores.[32-35]

Chechik et al. (2010) [28] retrospectively compared 83 patients who had undergone arthroscopic Bankart repair with and without rotator interval closure. Rotator interval closure was performed in patients where multidirectional shoulder laxity, or systemic joint hyperlaxity was present. Patient quality of life, range of motion, and recurrent instability were not significantly different between groups.

Although initially thought of as a treatment option for atraumatic, multidirectional instability, rotator interval closure has repeatedly shown decreases in anterior and inferior translation of the humeral head.[23-25] For this reason it is hypothesized that the addition of rotator interval closure to arthroscopic Bankart repair could potentially increase postoperative stability of patients with traumatic shoulder instability.

The purpose of our study is to quantify the loss in external rotation in patients with traumatic anterior dislocations undergoing arthroscopic Bankart repair with rotator interval closure compared to those undergoing arthroscopic Bankart repair alone, and
determine whether any lost range correlates to decreased patient quality of life or function.
CHAPTER 2: LITERATURE REVIEW

2.1 Anatomy

The glenohumeral, or shoulder joint, is a ball and socket joint consisting of articulation between the head of the humerus bone and the glenoid fossa of the scapula. The glenoid cavity is shallow compared to ball of the humeral head, providing minimal bony restraint and affording the shoulder the largest range of motion of any synovial joint in the body.\[1, 2\] With only 20-30% of the humeral head in contact with the glenoid at any given time, stabilization of the shoulder joint is heavily reliant on the surrounding static and dynamic stabilizing structures.\[1, 13, 14\] Static stabilizers of the shoulder include the joint capsule itself, the fibrocartilaginous glenoid labrum, and the surrounding ligamentous structures.\[13, 14, 16, 36\] Dynamic stabilization is provided by the surrounding shoulder and rotator cuff musculature.

The joint capsule is comprised of multilayered collagen fibers, is relatively large, lax and filled with synovial fluid. The synovial fluid contained within the capsule contributes a small amount of stability via adhesion and cohesion forces.\[13\] The capsule is sealed tight and negatively pressured, which provides a vacuum and also contributes to stability by resisting humeral head translation.\[1, 13, 14\]

The glenoid labrum is a dense layer of fibrocartilage that surrounds and deepens the concavity of the glenoid fossa, and serves as an attachment point for the glenohumeral ligaments.\[13, 14\] The labrum increases the articulating surface area, and acts as a bumper against humeral head translation. Lippitt \textit{et al.} (1993)\[15\] demonstrated that removing the glenoid labrum increased instability of the shoulder by 20%.\[15\]
Figure 1: Glenohumeral Ligaments

The glenohumeral and coracohumeral ligaments reinforce the joint capsule and contribute to shoulder stability at extremes of motion.[13-15] The glenohumeral ligaments are three fibrous bands that strengthen the joint capsule anteriorly.[32] The superior glenohumeral ligament originates from the anterior superior portion of the labrum, anterior to the long head of the biceps tendon, and extends laterally with the long head of the biceps before inserting above the lesser tuberosity of the humerus.[1, 38, 39] The middle glenohumeral ligament originates adjacent to the superior glenohumeral ligament, extends laterally towards the humerus, and blends with portions of the subscapularis tendon before inserting medially onto the lesser tuberosity of the humerus.[1, 38-42] The inferior glenohumeral ligament consists of both an anterior and posterior band, which are connected by the axillary pouch. The inferior glenohumeral
ligament complex has anchor points on both anterior and posterior portions of the glenoid. The anterior band is thought to be the main static restraint to anterior inferior shoulder dislocation.[38] The coracohumeral ligament is a strong broad band that originates from the lateral surface of the coracoid process, blending with the superior glenohumeral ligament before inserting onto the lesser and greater tuberosity of the humerus.[14, 38]

Dynamic restraints to excessive glenohumeral motion include the muscles of the rotator cuff (supraspinatus, infraspinatus, teres minor, and the subscapularis), the deltotoid, and the long head of the biceps. These muscles work together to stabilize the shoulder by compressing the humeral head into the glenoid during arm movement.[16] The rotator cuff muscles are the primary dynamic stabilizers of the shoulder, forming a musculotendinous cuff around the glenohumeral joint. The rotator cuff muscles control the position and rotation of the arm.[40] The deltotoid is a large, fan-shaped muscle that covers the glenohumeral joint. It consists of anterior, lateral (or middle), and posterior portions. The anterior deltotoid originates from the anterior and superior surfaces of the clavicle and acromion, the lateral deltotoid originates from the lateral region of the acromion, and the posterior deltotoid originates from the scapular spine.[40] All three portions converge and insert onto the deltotoid tuberosity of the humerus.

The rotator interval is another structure that has been demonstrated to play a role in shoulder stability. It is a triangular shaped area in the anterior superior portion of the glenohumeral joint, bordered superiorly by the anterior border of the supraspinatus tendon, inferiorly by the superior border of the subscapularis, medially by the base of the coracoid process, and laterally by the long head of the biceps tendon.[1, 43, 44]
Although numerous studies have shown that the rotator interval plays some role in shoulder stability [22-27], its specific function is still debated.

![Figure 2: The Borders of the Rotator Interval](image)
*Image reproduced with permission from Hakan OM., and Bayramoglu, A. Rotator Interval. Sports Injuries. 2012. 75-78.[45]*

### 2.2 Mechanism of Injury

The minimal bony restraint associated with the glenoid fossa of the shoulder joint allows movement around three axes, and permits flexion-extension, abduction-adduction, and rotation (medial and lateral) of the humerus, as well as circumduction.[36] Shoulder instability is defined as excessive translation of the humeral head that reduces function and is accompanied by pain and/or apprehension.[4, 46] This ranges from subluxation of the humeral head to full joint dislocation. Full joint dislocation occurs when the humeral head is driven out of the glenoid fossa, and all articular contact is lost.[4, 46] The direction of instability can be anterior, posterior or inferior, and patients can exhibit
unidirectional, bidirectional, or multidirectional instability. Most full dislocations are in the anterior direction, and usually occur during a traumatic event with the arm in a position of abduction and external rotation.[4-6] The two most common mechanisms of traumatic anterior dislocation are sports injuries and falls.[47]

As the humeral head dislocates over the anterior glenoid rim the most common pathology to occur is the detachment of the anterior inferior labrum and the anterior band of the inferior glenohumeral ligament from the glenoid rim, known as a Bankart lesion.[17-20] This predisposes the patient to recurrent shoulder dislocations and instability by reducing the concavity of the glenoid, eliminating the protective bumper against humeral head translation, and removing the static stabilization provided by the inferior glenohumeral ligament.[21] Superior labrum anterior-to-posterior (SLAP) tears can occur in conjunction with Bankart lesions, and can include separation of the biceps tendon anchor from the glenoid.[20]

Compression fracture of the anterior inferior glenoid with its attached labrum is termed a Bony Bankart lesion, and can occur during traumatic dislocation. Bony defects that account for more than 25% of the glenoid can cause considerably higher redislocation rates, and may be an indication for augmentation of the glenoid rim.[6, 17]

In addition to fracture of the glenoid rim, the posterior lateral part of the humeral head is often fractured during dislocation, leaving a bony divot known as a Hill-Sachs lesion.[4, 46] Hill-Sachs lesions are present almost 100% of traumatic anterior shoulder dislocations although they are usually small and do not contribute to recurrent instability.[48] Large Hill-Sachs lesions that are likely to engage with the glenoid rim during the typical injury position of external rotation and abduction compromise the
articulating surface area, causing higher recurrent instability rates, and may be an indication for a remplissage procedure to “fill in” the defect.[38]

Rotator cuff tears due to shoulder dislocation are infrequent and tend to occur in patients above the age of 45.[49, 50] Losing the dynamic stabilization provided by the rotator cuff musculature can predispose the patient to recurrent instability.[50]

2.3 Epidemiology

Although the shoulder is the most commonly dislocated joint in the body, few studies have evaluated the epidemiology of shoulder dislocations. In 1982, Hovelius assessed the prevalence of shoulder dislocation in randomly selected Swedish individuals between the ages of 18 and 70.[12] Of the 2092 people interviewed, 35 (37 shoulders) had a positive clinical history of shoulder dislocation, corresponding to a general population prevalence of 1.7%. The male shoulder dislocation prevalence (2.5%), was more than twice the female prevalence (0.8%). Most reported dislocations were solitary traumatic events (28/37, 76%), 8% (3/37) were classified as recurrent, 11% (4/37) as healed recurrent (more than one dislocation, but no current instability issues), and 5% (2/37) reported voluntary shoulder dislocation. Causes of initial dislocation included sports (9/37, 24%), traffic accidents (4/37, 11%), miscellaneous trauma (13/37, 35%), and spontaneous dislocation (7/37, 19%). It is important to note that the investigators included shoulder dislocations in all directions (including posterior and multidirectional instability), and excluded patients under 18 years of age.

Simonet et al. (1983)[51] studied the incidence of anterior shoulder dislocations in Olmsted County, Minnesota. By reviewing the medical records of the Mayo Clinic and
its two affiliated hospitals, the authors identified all residents of Olmsted County who had been treated for initial traumatic anterior shoulder dislocation from January 1, 1970 to December 31, 1979. Sixty-six patients were identified, which equated to an overall incidence of 8.2 per 100,000 person years (95% CI 6.2-10.2) when adjusted to the population of the United States (US) in 1980. The male incidence (11.2/100,000 person years) was significantly greater than the female incidence (5.0/100,000 person years) (p<.05). The most common causes for initial dislocation were athletic activities (47.0%), and falls (45.5%). Most initial dislocations occurred between the ages of 10 and 39 for men (54.1%) and over the age of 60 for women (15.5%). The incidence rate for all traumatic dislocation instances (initial and recurrent dislocations) was adjusted to 11.2/100,000 person years. After 198 person years of follow up, 25 patients sustained recurrent dislocations. Using this data, the recurrent dislocation rate after five years was estimated at 40.2%. The authors estimated the prevalence of anterior shoulder dislocations in Olmsted County to be 0.7% for males, and 0.3% for females.

More recently, Zacchilli et al. (2010)[7] studied the epidemiology of dislocation-type injuries presenting to the emergency departments of 100 hospitals in the United States. Investigators searched shoulder dislocation cases in the National Electronic Injury Surveillance System (NEISS) database from January 1, 2002 to December 31, 2006. The sample included 100 randomly selected hospitals with emergency departments. Following refinement, 8940 shoulder dislocation injuries were found, corresponding to an estimated 349,486 dislocations throughout the United States population, and an incidence rate of 23.9/100,000 person years (95% CI 20.8-27.0). The calculated male incidence rate (34.90/100,000 person years, 95% CI 30.08-39.73) was more than double the female
incidence (13.23/100,000 person years, 95% CI 11.56-14.96). Similar to the results found by Simonet et al., male incidence rates peaked between 20-29 years of age (79.2/100,000 person years, 95% CI 67.4-90.9), whereas female incidence rates were highest between 80-89 years (38.8/100,000 person years, 95% CI 30.8-46.7). Most dislocations involving males occurred at a place of sports/recreation (86.7%), and most cases involving females occurred at home (42.5%). The mechanism of injury was only sufficiently reported in 77.0% of cases. The most common mechanisms were falls (58.8%), and direct blows (8.9%). Zacchilli et al. included both initial and recurrent shoulder dislocations in their study, and direction of dislocation was not specified. Only including patients presenting to ER departments, however, excluded patients presenting to other health care providers, such as primary care physicians and orthopaedic surgeons.

### 2.3.1 Incidence in Specific Groups

Most anterior shoulder dislocations occur during falls and sporting activities. Several studies report the incidence of shoulder dislocation in specific “high risk” groups. Owens et al (2007)[10] investigated the incidence and characteristics of shoulder instability in the United States military academy (a young, active population). Authors prospectively gathered information from all new traumatic shoulder instability events from September 1, 2004 to May 31, 2005 at the Academy. New events were defined as all shoulder dislocations or subluxations that occurred during the study period. Patients who had experienced additional instability events prior to the study period were excluded. Out of 4141 students, 117 (2.8%) experienced new traumatic instability events. Ninety-four of these (80%, 2.3% prevalence) were in the anterior direction, 12(10%) posterior,
and 11 (10%) were classified as multidirectional. Overall, 101 (86.3%) patients were male, and 16 (13.7%) were female. Of the 117 instability events, only 16 (15.4%) were reported as full dislocation (to be classified as a full dislocation, the shoulder had to require reduction by a health care provider). The prevalence of full joint dislocation in the anterior direction was then calculated to be 0.4%, similar to the estimated prevalence reported by Simonet et al. (0.5%). All instability events occurred during athletic events, except for one which was sustained during a motor vehicle accident. The most common reported mechanism of injury was a fall (15.4%), followed by collision (14.5%) and a thrown or missed punch (14.5%).

A separate study by Owens et al. (2009)[9] evaluated the incidence of shoulder dislocation in the United States military. Investigators searched the Defence Medical Epidemiology Database for “first occurrence” acute shoulder dislocations between 1998 and 2006. Over the 9 year study period, 19,730 shoulder dislocations were documented. Using a population at risk of 11,680,893 person years, this equated to an incidence rate of 1.69 per 1000 person years, much higher than the incidence rate reported by Simonet et al. (0.08/1000 person-years) The male incidence rate (1.82 per 1000 person years) was significantly greater than the female incidence rate (0.90 per 1000 person years) (p<.0001). When separated by age, the highest rate ratios were reported in young patients (using the over 40 year old group as the referent group). When adjusted for sex, race, service and rank, the rate ratio was 1.75 (95% CI 1.61-1.90) for patients less than 20 and 1.66 (95% CI 1.54-1.78) for patients 20-24 years of age. The authors reported male gender, white race, and an age under 30 years as risk factors for shoulder dislocations.
Owens et al. (2009)[52] evaluated the incidence of shoulder instability in collegiate athletes. The National Collegiate Athletic Association Injury database was searched for all shoulder instability events between 1989 and 2004. A total of 4080 shoulder instability events were reported from 32,843,226 athlete exposures from 16 sports, giving an overall incidence rate of 0.12 per 1000 athlete exposures (95% CI 0.12-0.13). The male incidence rate (0.15 per 1000 athlete exposures, 95% CI 0.14-0.15) was significantly higher than the female incidence rate (0.06 per 100 athlete exposures, 95% CI 0.05-0.06)(p<.05). Contact with another athlete was the most common reported cause (68%), followed by contact with an object (20%). Reporting incidence rates per athlete exposure causes epidemiological data reported in this study to be difficult to compare to previous studies.

Recently, Cameron et al. (2013)[11] studied young athletes in the US military academy with a history of shoulder instability. The primary outcome evaluated was time to subsequent instability event. A total of 714 individuals met the study criteria and were followed from June 26, 2006 to May 22, 2010. Of the 1428 shoulders for which data was available, 8 were excluded for having previous surgical repair. This left 1310 shoulders, 118 with reported histories of instability. The primary outcome evaluated was time to shoulder instability. During the follow up period, 46 athletes (3.5%) reported shoulder instability events. Thirty nine were in the anterior direction, equating to an anterior shoulder instability (including dislocation and subluxation) prevalence of 3.0%, similar to the reported 2.4% reported by Owens et al. in 2007. Fifteen of these were among the 118 with a history of shoulder dislocation (12.7%), while the remaining 31 were sustained by patients with no reported history of shoulder instability (2.4%). Authors concluded that
patients with a history of shoulder instability were five times more likely to sustain recurrent instability events. However, instability history events were patient-reported, which could have caused reporting bias.

2.4 Treatment

Traditional conservative treatment methods for shoulder instability, such as immobilization and rehabilitation, have shown little benefit in reducing the rate of recurrent dislocations and improving patient quality of life. Surgical Bankart repair restores stability by mobilizing the displaced anterior inferior capsulo-labral complex and reattaching it to the glenoid rim. Both open and arthroscopic surgical treatment methods have been established.

2.4.1 Surgical Treatment vs. Conservative Treatment

Arciero et al. (1994)[53] conducted a prospective study on all young (average age 20 years) athletes at the US military academy who sustained acute, initial anterior shoulder dislocations between September 1988 and October 1991. A total of 36 patients elected whether they received conservative treatment, consisting of 4 weeks immobilization followed by rehabilitation (n = 15), or arthroscopic Bankart repair using transglenoid sutures, followed by the same immobilization and rehabilitation protocol (n = 21). Significantly more patients in the conservative group sustained recurrent instability compared to the arthroscopic group (p=.001). Additionally, seven patients in the conservative group went on to receive open Bankart lesion repair, compared to one patient in the arthroscopic group (p=.005).
In 1999, Kirkley et al. [54] published an RCT comparing surgical to traditional (conservative) treatment on patients under 30 with first-time traumatic anterior shoulder dislocations. A total of 40 patients were randomly assigned to receive 3 weeks of immobilization followed by rehabilitation (n=21), or arthroscopic stabilization surgery using transglenoid sutures, followed by the same immobilization and rehabilitation protocol (n=19). After an average follow up of 33.1 months, all patients in the surgical group, and 19 of the 21 patients in the conservative group were available for follow up. Outcome measures included any re-dislocations, disease specific quality of life using the Western Ontario Shoulder Instability Index (WOSI) and range of motion (including forward flexion, external rotation in neutral, external rotation with 90° of abduction and internal rotation with 90° of abduction). Rate of recurrent dislocation for the conservative group was 47% (9/19), significantly higher than the 15.9% (3/19) in the surgical group (p=.03). Additionally, patients in the arthroscopic group reported significantly better WOSI scores (p=.03). No significant between group differences were reported for range of motion (measured as a percentage of the unaffected side). The authors concluded that arthroscopic stabilization reduces the rate of redislocation in patients less than 30 years who have sustained initial, traumatic anterior shoulder dislocations significantly more than conservative treatment.

Kirkley et al. (2005)[55] evaluated the same study participants again at 75 months follow up. Of the original 40 patients, 31 were available and agreed to participate. WOSI scores for the conservative group had improved slightly from the 32 month follow up, lowering the between group difference from 16% to 11%. No additional re-dislocations were reported in either group, although seven patients in the traditional group had
undergone subsequent stabilization surgery. An intention to treat analysis was performed for these patients, which could have caused the smaller between group differences in WOSI scores.

Bottoni et al. (2002)[56] conducted another RCT comparing arthroscopic Bankart repair to conservative treatment in young (18-26 years), active military personnel stationed in Oahu with initial traumatic anterior shoulder dislocations. A total of 24 patients were randomized to receive four weeks of immobilization followed by supervised rehabilitation (n=14) or arthroscopic repair using bioabsorbable tacks, followed by the same rehabilitation protocol (n = 10). Outcome measures included treatment failure (defined as redislocation, symptomatic subluxation or instability preventing return to full activity), range of motion, Single Assessment Numeral Evaluation (SANE) scores, and L’Instalata scores. After an average of 36 months, 3 patients were lost to follow up, leaving 12 patients in the conservative group and 9 in the operative group. Treatment failure occurred for 9/12 patients (75.0%) in the conservative group, compared to 1/9 (11.1%) patient in the arthroscopic group. Six patients in the conservative group for whom treatment had failed went on to receive open Bankart surgery versus one in the surgical group. Additionally, patients in the conservative group reported significantly lower SANE scores (p<.002) and L’Insalata scores (p<.002) than patients in the operative group. No significant between group differences were found for range of motion. Bottoni et al. also concluded that arthroscopic stabilization surgery significantly reduced the rate of redislocation in patients with initial anterior shoulder dislocations compared to conservative treatment.
2.4.2 Open Surgical Repair versus Arthroscopic Surgical Repair

In 1997, Geiger et al.[57] published a prospective study comparing open to arthroscopic Bankart lesion repair using nonabsorbable sutures in patients with anterior shoulder instability. Thirty-four patients aged 15-34 were given the choice of open Bankart repair (n=18) or arthroscopic Bankart repair (n =16). Both groups underwent similar rehabilitation protocols. After an average 34 months follow up in the open group, and 23 months follow up in the arthroscopic group, investigators evaluated recurrence of instability, range of motion (measured as a percentage of the nonoperative side), and the Rowe shoulder score for instability. No significant between group differences were observed for range of motion. No patients in the open group sustained any recurrent dislocations, or underwent any further surgery, although 3 patients reported recurrent subluxations. Three patients in the arthroscopic group sustained recurrent dislocations, four reported recurrent subluxations, and four patients underwent a second stabilization operation. Postoperative Rowe scores were also significantly better for patients in the open group (p=.05), although the non-randomized study design could have lead to a sampling bias. Additionally, the authors mentioned poor-compliance (patients attempting high risk activities too soon postoperatively) in the arthroscopically treated patients, which could have caused higher recurrent instability rates.

Kartus et al. (1998)[34] conducted another prospective study comparing open and arthroscopic shoulder stabilization surgery in patients with traumatic recurrent anterior shoulder instability. Aiming to evenly distribute demographic data, thirty-six shoulders
(33 patients) were advised to undergo either open Bankart repair (n=18) or arthroscopic Bankart repair (n=18), both using absorbable implants. After a median follow up period of 29 months, patients were evaluated using the Rowe and Constant shoulder scores, and range of motion. No redislocations were reported in either group. Two patients in the open group underwent second surgeries (one arthroscopy due to severe ROM restrictions, and one arthroscopic labral fixation). Postoperative Rowe scores were significantly better in the arthroscopic group (p=.05). Each group lost a significant amount of external rotation with the shoulder in 90° of abduction compared to the unaffected shoulder (open group p=.0001, arthroscopic group p=.0089). Patients in the open group lost significantly more external rotation in this position compared to the arthroscopic group (p=.0017). No significant between group differences were observed for Constant scores, or internal rotation, flexion or abduction. Again, with a non-randomized study design, selection bias could have occurred during group allocation.

Jorgensen et al. (1999) [58] published an RCT comparing open Bankart repair using suture anchors to arthroscopic Bankart repair with additional capsular plication. A total of 41 patients (average age 28) with posttraumatic recurrent unilateral anterior shoulder dislocations were assigned by area to either the open group (n=20), or the arthroscopic group (n=21). Postoperatively, shoulders in both groups were immobilized for 3 weeks and followed the same rehabilitation protocol. Outcomes measured included mean surgical and hospitalization times, surgical complications, cosmetic complaints, Rowe shoulder scores, modified Constant scores, any recurrent instability, activity level, and anterior posterior translation of the shoulder joint. Significantly more patients in the open group injured their dominant shoulder (p=.03). Although this could have caused
patients to report lower functional and quality of life scores in that group, this was not
observed. Both mean surgical and hospitalization times were significantly longer for the
open group (p=.00008, p=.000002, respectively). After a median follow up period of 36
months, significantly more patients in the open group had cosmetic complaints following
the procedure (p=.003). Authors concluded that arthroscopic Bankart repair with
additional capsular plication caused fewer postoperative restrictions, and was superior to
open repair in this patient group, although no significant between group differences were
found for any other outcome measures. Further, with the addition of a capsular plication
procedure in the arthroscopic group, open and arthroscopic Bankart repair techniques
were not directly compared.

Sperber et al. (2001)[59] conducted a multicenter study comparing open Bankart
repair with suture anchors to arthroscopic Bankart repair with bioabsorbable tacks. Upon
arthroscopic confirmation of a Bankart lesion, 56 patients aged 18-51 with recurrent
posttraumatic anterior shoulder dislocations were randomly assigned to the open group
(n=30) or the arthroscopic group (n=26). Both groups underwent identical postoperative
rehabilitation protocols. After a two year follow up period, recurrent instability, range of
motion, Constant and Rowe shoulder scores were evaluated. No significant differences
between groups were found for any of the outcome measures, although different repair
techniques were used between groups.

Also in 2001, Karlsson et al.[60] published a study in which 117 patients with
recurrent posttraumatic unidirectional anterior shoulder instability were able to choose
between open Bankart repair using suture anchors (n=48) or arthroscopic Bankart repair
using bioabsorbable tacks (n=60). If the patient did not wish to choose a procedure, the
surgeon suggested one while aiming to maintain demographic homogeneity between groups. The average follow up period was significantly longer for patients in the open group (P<.0001). Outcome measures included the Rowe score, the Constant score, external rotation in abduction, strength in abduction, and treatment failure. As reported by Kartus et al.[34] in 1998, postoperative external rotation was significantly better for patients in the arthroscopic group, even with the shorter follow up period (p=.0001). No significant between group differences were found for any other outcome measure. The allocation procedure utilized in this study could have allowed for sampling and selection bias, and the repair technique was different between groups.

Kim et al. (2002)[61] retrospectively compared patients with traumatic, recurrent anterior shoulder instability who had undergone open Bankart repair using suture anchors to patients who had undergone arthroscopic Bankart repair using suture anchors plus a capsular plication. Between January 1994 and December 1994, 93 anterior stabilization surgeries were performed by a single surgeon. After an average of 39 months, 89 shoulders were available for follow up (open n = 30, arthroscopic n=59). Outcome measures included the Rowe score, the UCLA shoulder rating scale, range of motion, and whether successful return to previous work or sport activity was attained. Both groups’ Rowe and UCLA scores improved significantly postoperatively (p<.05), though patients in the arthroscopic group reported significantly higher scores for both measures (Rowe p=.041, UCLA p = .026). The number of recurrent dislocations, return to activity and average loss of external rotation (both in neutral and with 90° of abduction) were similar between groups. However, the proportion of patients who lost more than 10° of external rotation with the arm in 90° of abduction was significantly higher in the open group.
Authors concluded that, with no large glenoid rim fracture present, arthroscopic Bankart repair using suture anchors was comparable to open Bankart repair. However, similar to the results published by Jorgensen *et al.* (1999), with the additional capsular plication in the arthroscopic group, open and arthroscopic techniques were not directly compared.

In 2004, Freedman *et al.* [62] conducted a meta-analysis of published studies comparing open and arthroscopic Bankart repair techniques, including most studies previously mentioned. The authors searched Medline for all randomized controlled trials or cohort studies comparing the two procedures on patients with posttraumatic recurrent anterior shoulder instability. Six studies (2 randomized trials, 3 prospective cohort, and one retrospective cohort) met the inclusion criteria, leaving a total of 156 patients in the open group, and 172 in the arthroscopic group. The rate of recurrent instability (redislocation and/or subluxation) was significantly higher for the arthroscopic group (p<.0001). Additionally, postoperative Rowe scores were significantly better for patients who had received open surgery (p<.0001). Postoperative range of motion could not be effectively compared between studies due to differences in technique, and arm positions. Investigators concluded that arthroscopic Bankart repair caused higher recurrent instability rates compared to open techniques, although it should be noted that the arthroscopic group included a mixture of transglenoid sutures, bioabsorbable tacks, and suture anchor techniques. Investigators also included a 1998 study by Steinbeck and Jerosch in which the type of procedure was determined by the quality of tissue.

Fabbriciani *et al.* (2004)[63] published an RCT comparing open to arthroscopic Bankart repair, both using metallic suture anchors with nonabsorbable braided sutures.
Following diagnostic arthroscopy, 60 patients with traumatic anterior shoulder instability were randomized to receive open repair (n=30) or arthroscopic repair (n=30). Outcome measures included recurrent instability, Constant and Rowe scores. After two years, no recurrent dislocations were reported in either group. Similarly, no significant between group differences were found in relative total score, for improvement in points for the Constant scores, or in total Rowe scores. When broken into domains, the arthroscopic group demonstrated significantly better ROM results on the Constant score (p=.017), which compares with previous results found by Kim et al. (2002), Karlsson et al. (2001) and Kartus et al. (1998). Authors concluded that arthroscopic Bankart repair is an effective surgical option for treatment of an isolated Bankart lesion.

Wang et al. (2005)[64] retrospectively compared patients with recurrent, posttraumatic anterior shoulder instability who had received open Bankart repair to those who had received arthroscopic Bankart repair, both using suture anchors. The average age of patients in the open group was 23±8 years, compared to 35±14 years in the arthroscopic group (p<.05). After a minimum of 24 months, 17 patients in the open group, and 18 patients in the arthroscopic group were available for follow up. Outcome measures included operating time, total OR time, OR equipment charges, total charges, and patient-important outcomes including the American Shoulder and Elbow Surgeons (ASES) functional scores, and any episode of recurrent instability. Both operating time and total OR times were significantly longer for the open group (p<.001). Although OR equipment charges were higher for the arthroscopic group (p<.001), total charges (including OR service charge, anaesthesia charge, inpatient charge, and OR charge) were significantly higher for the open group (p<.001). Four patients in the open group
sustained recurrent dislocations compared to 1 in the arthroscopic group, and no significant between group differences were reported for ASES scores. Limitations of this study include its retrospective design, the small size of patient groups, and the age difference between groups. As recurrent dislocations are more prevalent in younger populations, it is difficult to conclude that the low recurrent rate reported in the arthroscopic group is due to the surgery itself. Additionally, the two procedures were performed by different surgeons, which could have introduced expertise bias.

Mohtadi et al. (2005)[65] conducted a meta-analysis of the literature comparing open to arthroscopic repair for patients with traumatic recurrent anterior shoulder instability. Investigators searched Medline/Pubmed from 1966 to October 31, 2003, and identified 11 studies that met the inclusion criteria (1 RCT, 2 pseudo-experimental trials, 4 prospective cohort studies, 3 retrospective cohort studies, and 1 case-control study). All studies reported recurrent instability. The Mantel-Haenzel pooled odds ratio for recurrent instability was 2.04, significantly in favour of the open group (p=.027). The authors concluded that open stabilization procedures were more favorable than arthroscopic. Although, as with the previously reported meta-analysis performed by Freedman et al. (2004) the arthroscopic group consisted of a mixture of transglenoid sutures, anchors and tacks, included one study where surgery assignment was based on tissue quality, and one study in which patients with anterior and inferior translation were assigned to the open group, while patients with anterior translation only were assigned to the arthroscopic group.

Bottoni et al. (2006)[32] published an RCT comparing open to arthroscopic shoulder stabilization with bioabsorbable suture anchors on patients with recurrent
anterior shoulder instability. Following initial diagnostic arthroscopy, patients were randomized to the open group (n=29) or the arthroscopic group (n=32). Average total operative time for the arthroscopic repair was 59 ± 11.5 minutes, compared to 149 ± 38.4 minutes for the open surgery (p<.001). Outcome measures included recurrent instability, range of motion, SANE scores, the simple shoulder test (SST), the WOSI, and the UCLA score. After 29 months follow up, no significant between group differences were found for postoperative UCLA, SST, Rowe or WOSI scores. Similarly, range of motion (compared to the other side) was not significantly different between groups in positions of forward flexion, external or internal rotation at 90° of abduction. Patients’ postoperative SANE scores had improved significantly from baseline (preoperatively) for both groups (p<.001). No recurrent dislocations were reported in either group, although two patients in the open group (6.9%) and one in the arthroscopic group (3.1%) failed according to the established criteria (recurrent subluxation or instability symptoms preventing return to previous work or duty). Investigators concluded that arthroscopic Bankart repair was comparable to open procedures.

Lenters et al. (2007)[66] published a systematic review and meta-analysis comparing open to arthroscopic repair of recurrent anterior shoulder instability. The authors searched Medline between 1966 and November 2004, the Cochrane collaboration library, and the Arthroscopy Association of North America meeting abstracts from 1998 to 2004, the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) meeting abstracts for 1997, 1999, and 2001, the American Academy of Orthopaedic Surgeons (AAOS) annual meeting abstracts from 2000 to 2005, and the American Shoulder and Elbow Surgeons (ASES) annual open meeting abstracts from
1996 to 2005. A total of 18 studies met the inclusion criteria (4 RCTs, 10 non-randomized comparative trials, 4 studies in which treatment was based on pathological findings). Six of the included studies involved arthroscopic repair with suture anchors, four with bioabsorbable tacks, and five with transglenoid sutures. Pooled estimates from all studies associated arthroscopic repair with a significantly higher risk of recurrent instability (p<.00001), re-dislocation (p<.00001), and re-operation (p=.002). Similarly, open repair was associated with a significantly higher amount of patients who returned to previous sport/activity (p=.03). No significant between group differences were found for Rowe scores. Investigators also completed a sub-group analysis comparing each arthroscopy type to open repair. Patients who received arthroscopic repair with suture anchors or bioabsorbable tacks had significantly better postoperative Rowe Scores. Arthroscopic repair using suture anchors and transglenoid sutures demonstrated significantly higher recurrent instability rates than open repair (suture anchor p=.010, transglenoid sutures p=.0006). When split by study design, RCTs showed significantly better Rowe scores for the arthroscopic group and recurrence rates were similar between groups. Authors concluded that arthroscopic techniques are not as effective as open approaches, although both arthroscopic technique, and study design varied the results of the analysis.

Brophy and Marx (2009)[67] published another systematic review of the literature for all studies published in English that compared nonoperative treatment of shoulder instability to operative treatment, and open surgical treatment to arthroscopic treatment using suture anchors. Investigators searched the Medline database from 1966 to May 2008. A total of 6 studies met the inclusion criteria for the conservative versus operative
comparison (4 prospective RCTs, 2 prospective cohort studies). Recurrent shoulder dislocations were reported in 58.4% of patients who had undergone conservative treatment, compared to 9.7% in the surgical group. Other outcome measures (including the SANE shoulder score, the WOSI, the Oxford score, and the Constant score) were all significantly higher for the surgical group. Eight studies met the inclusion criteria for the open versus arthroscopic comparison (two RCTs, two retrospective cohort studies, one case control, two prospective cohort studies and one retrospective case control).

Recurrent instability rates were similar between groups (open = 8.2%, arthroscopic = 6.4%). The Rowe shoulder score was reported in five of the eight studies, and all but one study demonstrated significantly higher Rowe scores in the arthroscopic group compared to the open group. Authors concluded that surgical treatment after initial anterior shoulder dislocations reduced recurrent instability more than nonoperative treatment, and arthroscopic surgical techniques were comparable to open techniques when using suture anchors.

Most recently, Netto et al. (2012)[35] conducted an RCT comparing open to arthroscopic Bankart repair with metallic suture anchors on young (below 40 years of age) patients with recurrent anterior shoulder instability and an isolated Bankart lesion. Following diagnostic arthroscopy, 50 patients were randomized to receive open or arthroscopic surgery. Both groups underwent similar rehabilitation protocols. Outcome measures included the DASH (primary outcome), UCLA, and Rowe scores, range of motion (elevation, external and internal rotation), and recurrent instability. After an average of 38 months, 42 of the 50 patients (open n=25, arthroscopic n=17) were available for follow up. DASH scores were significantly higher in the arthroscopic group.
(p=.031), although this was not determined to be clinically relevant. No significant between group differences were found in any of the secondary outcome measures. Authors concluded that arthroscopic Bankart lesion repair was as effective as open Bankart lesion repair in terms of recurrent instability.

### 2.4.3 Rotator Interval Closure

In 1987, Nobuhara and Ikeda were the first to surgically repair rotator interval lesions in 101 patients with inferiorly unstable shoulders.[68] Authors described two types of rotator interval lesions: type I - associated with inflammation and pain of the shoulder; and type II - associated with inferior instability and subluxation. After closure of the rotator interval lesion between the supraspinatus and the subscapularis with non-absorbable sutures, 78 shoulders were available for follow up. Seventy-five patients (96%) were postoperatively relieved of their pain symptoms. Seven (9%) experienced a slight decrease in range of motion, and 55 patients (70%) reported good postoperative stability. The authors concluded that RI closure is important in patients with RI lesions and accompanying pain in the shoulder.

Harryman et al. (1992)[22] subsequently studied the role of the rotator interval in shoulder stability. Using eight cadaver shoulders, investigators measured glenohumeral translation, range of motion, and stability with the rotator interval intact, after sectioning, and after medial-lateral closure of the interval. Sectioning the rotator interval significantly increased external rotation with the shoulder in 60° of flexion (p<.05). Closure of the rotator interval significantly decreased adduction, flexion, extension, external rotation (with the shoulder both in neutral, and at 60° of flexion) compared to the
intact interval (p<.05). Rotator interval closure also significantly increased anterior and superior translation of the humeral head, whereas sectioning of the RI significantly decreased anterior translation with the shoulder in a position of flexion (p<.05). Additionally, inferior sulcus translation was increased significantly with the RI sectioned, and decreased with the RI closed (p<.05). Stability of the shoulder during the posterior drawer test was significantly increased with the RI closed, with the shoulder in neutral, in 60° of flexion, and in 60° of flexion with 60° of external rotation (p<.05). Similarly, stability during the anterior drawer test was significantly increased with the shoulder in 60° of flexion when the RI was closed (p<.05). Authors of this study theorized that the role of the RI was to protect against posterior translation of the humeral head, and that a tight RI may cause unwanted anterior-superior translation. They suggested that the RI plays an important role in shoulder stability, and sectioning of the RI may improve range of motion in shoulders with limited flexion and external rotation. As with all cadaver studies, the role of the surrounding shoulder musculature was not present, and therefore the results are difficult to extrapolate to living patients.

Field et al. (1995)[69] published a retrospective analysis of patients who had undergone isolated superior-inferior rotator interval closure between January 1986 and June 1991. Fifteen patients (average age 24 years) were evaluated postoperatively using the ASES shoulder form and the Rowe scale after an average of 3.3 years. Eleven patients reported preoperative instability symptoms (apprehension and pain), although only two patients reported traumatic inciting events, and pain was the sole symptom for four patients. Both postoperative ASES and Rowe score had significantly improved from baseline (p<.01). No loss of range of motion restricting patient activity was reported.
Investigators concluded that isolated RI closure may sufficiently restore stability in patients with RI defects.

Yamamoto et al. (2005)[24] published another cadaveric study comparing RI closure between the superior glenohumeral ligament (SGHL) and the subscapularis tendon (SSC) or between the SGHL and middle glenohumeral ligament (MGHL). Outcome measures included humeral head translation and range of motion. Fourteen cadaver shoulders with no evidence of rotator cuff tear or glenohumeral osteoarthritis were included. Measurements were taken with the RI intact, imbricated between the SGHL and SSC (SGHL/SSC closure), or between the SGHL and MGHL (SGHL/MGHL closure).

Sectioning the RI significantly increased anterior translation with the shoulder in 0° of abduction (p<.05). Both SGHL/SSC and SGHL/MGHL closure significantly decreased anterior translation of the humeral head compared to the sectioned RI with the shoulder in 0° of abduction (p<.05). SGHL/MGHL closure significantly decreased anterior translation of the humeral head in the same position compared to the intact RI (p<.05). Similarly, SGHL/MGHL closure significantly decreased anterior translation in 60° of abduction and external rotation compared to the sectioned RI (p<.05), and compared to the intact RI (p<.05). SGHL/MGHL closure decreased posterior translation of the humeral head in 0° of abduction significantly more than SGHL/SSC closure (p<.05). No significant differences were observed for inferior translation of the humeral head with the shoulder in 0° of abduction.

SGHL/MGHL closure significantly decreased external rotation at 0° of abduction and 60° of abduction, internal rotation in 60° abduction, and horizontal abduction.
compared to the intact RI (p<.05). SGHL/SSC closure significantly decreased external rotation in 60° of abduction, and horizontal abduction compared to the intact RI (p<0.05). Furthermore, SGHL/MGHL closure decreased external rotation in 60° of abduction significantly more than SGHL/SSC closure (p=.0268).

Yamamoto et al. concluded that RI closure reduces anterior and posterior instability, improving clinical outcomes following arthroscopic stabilization procedures, although the loss of external rotation and abduction should be considered in overhead throwing athletes. Limitations of this study include the use of cadaver shoulders, and simulated instability models.

Plausinis et al. (2006)[23] published a study evaluating the effect of positioning and placement of arthroscopic rotator interval closure sutures on glenohumeral range of motion and humeral head translation. Investigators used 12 fresh-frozen cadaver shoulders with no evidence of rotator cuff disease. A custom testing apparatus was used to measure flexion in the sagittal plane, along with external and internal rotation in neutral. Measurements were taken at baseline, after one isolated medial suture between the subscapularis tendon and the superior glenohumeral ligament, one isolated lateral suture between the subscapularis tendon and superior glenohumeral ligament, both sutures, and after removal of all sutures. No significant differences were found between stitch types for range of motion or translation. Both suture types significantly decreased external rotation (p<.009), flexion (p<.0001), and anterior translation (p<.009). All measurements returned to baseline following suture removal. Authors concluded that both lateral and medial suture closures were similar to the use of two sutures, and that all techniques significantly decreased range of motion and anterior-posterior translation of...
the humeral head. Limitations of this study include the use of normal cadaver shoulders, as opposed to in vivo shoulders with instability symptoms.

Provencher et al. (2007) conducted a study comparing open medial-lateral rotator interval closure to arthroscopic superior-inferior rotator interval closure on 14 cadaver shoulders. Outcome measures included range of motion and humeral head translation. Both arthroscopic and open RI closure reduced anterior translation at neutral compared to the intact RI (open $p=.001$, arthroscopic $p=.029$), and open RI closure decreased anterior translation in this position significantly more than arthroscopic closure ($p<0.05$). Arthroscopic RI closure also significantly decreased anterior translation in abduction and external rotation compared to the intact RI closure ($p=.0425$), and compared to open RI closure ($p=.0163$). With the shoulder in neutral, both RI closure types significantly decreased external rotation (open $p=.0116$, arthroscopic $p=.0180$), while open RI closure decreased external rotation significantly more than arthroscopic RI closure ($p=.050$). Additionally, arthroscopic RI course significantly decreased external rotation in abduction compared to the intact RI ($p=.0180$). Authors concluded that both types of RI closure may improve anterior stability of the shoulder, although there is potential for simultaneous loss in external range of motion. It should also be noted that although authors attempted to reproduce the results reported by Harryman et al. (increased anterior and superior translation with open medial-lateral rotator interval closure), RI closure decreased anterior translation of the humeral head.

Mologne et al. (2007) published another cadaveric study in 2007 evaluating the addition of RI closure to both anterior and posterior stabilization procedures. Fourteen cadaver should have been tested for stability with the shoulder capsule vented, after
randomly being assigned to arthroscopic anterior (group 1) or posterior (group 2) stabilization with suture anchors, and following RI closure. Outcome measures included range of motion and humeral head translation (anterior translation for group 2, posterior translation for group 2).

The anterior stabilization procedure significantly reduced anterior translation of the humeral head in neutral (p<.05), and in abduction and external rotation (ABD-ER)(p<.01). Following RI closure, anterior translation was further significantly reduced in both positions (neutral p<.05, ABD-ER p=.044). Posterior anchor stabilization significantly reduced posterior translation in neutral (p<.05), and in flexion plus internal rotation (p<0.05). RI closure did not further reduce posterior translation in any position.

Anterior stabilization significantly decreased external rotation in neutral (p=.013) and abduction (p=.0001). RI closure further decreased external rotation with the shoulder in neutral only (p=.021). Posterior stabilization significantly decreased internal rotation in neutral (p=.007) and abduction (p=.016). External rotation in neutral was decreased significantly more after RI closure compared to posterior stabilization alone (p=.007). Inferior sulcus translation was significantly reduced in both groups following stabilization repair only (p=.002). The authors concluded that arthroscopic RI closure improved anterior instability when performed in conjunction with anterior stabilization procedures. However, as with previous studies, the use of cadaver shoulders excludes the dynamic functioning of the surrounding musculature. Additionally, in simulating unstable shoulders, investigators did not fully dislocate the cadaver shoulders, making the results difficult to relate to patients with traumatic shoulder instability.
Farber *et al* (2009)[31] used cadaver shoulders to create a multidirectional instability model, and more arthroscopic RI closure using a superior inferior stitch (SI closure) versus a medial-lateral stitch (ML closure). Outcome measures included range of motion and humeral head translation. The instability model was created via capsular stretching, which significantly increased all range of motion measurements (*p*<.05).

With the shoulder in 0° of abduction, both ML and SI closure significantly decreased external rotation (*p*<.01) compared to the stretched capsule, and internal rotation (*p*<.05) compared to the intact capsule. In 60° of abduction, both RI closure types significantly decreased external and internal rotation compared to the stretched capsule (*p*<.01), while SI closure decreased external and internal rotation significantly compared to the intact capsule (ER *p*=.0002, IR *p*=.01).

Capsular stretching significantly increased anterior translation with the shoulder in neutral and in 60° of abduction (*p*<.05). Posterior and superior translation in neutral, and in 60° of abduction were also significantly increased (*p*<.05). ML closure decreased anterior and posterior translation in 60° of abduction and 90° of external rotation significantly compared to the stretched capsule (*p*<.05). Compared to the intact capsule, ML closure significantly decreased posterior translation (*p*<.05). SI closure significantly decreased anterior and posterior translation in neutral compared to the stretched capsule (*p*<.05). Authors concluded that ML RI closure may be beneficial in patients with multidirectional instability.

Chechik *et al* (2010)[28] were the first to retrospectively compare arthroscopic Bankart repair (ABR+ RIC) with rotator interval closure to arthroscopic Bankart repair
alone (ABR). Between 1999 and 2007, 83 patients met the inclusion criteria (ABR + RIC = 37, ABR n = 46). Group allocation was decided by the surgeon: if multidirectional shoulder laxity, systemic joint hyperlaxity, RI laxity, or a large RI were present, patients were assigned to the ABR + RIC group. Outcome measures included the Walch-Dupley shoulder assessment tool, range of motion, and recurrent instability. The follow up period was significantly longer for patients in the ABR group (p<.05), and there were significantly more patients with multidirectional shoulder laxity in the ABR+ RIC group (p<.0001). Otherwise, patient demographics were balanced between groups. No significant differences were determined for any of the outcome measures. Chechik et al. concluded that the addition of RI closure to arthroscopic Bankart repair could provide additional postoperative stability compared to arthroscopic Bankart repair alone. Limitations of this study include its retrospective design, and the allocation method.

2.6 Summary

The glenoid cavity of the shoulder joint is shallow in comparison to head of the humerus, allowing the shoulder significant range of motion. The significant range of motion associated with the shoulder predisposes the joint to instability. Although the surrounding static and dynamic structures help to stabilize the humeral head in the socket of the glenoid, the shoulder is the most commonly dislocated joint of the body. The majority of shoulder dislocations occur in the anterior direction, causing the anterior inferior portion of fibrocartilaginous glenoid labrum to be torn from the bone, along with the associated inferior glenohumeral ligament (a static stabilizing structure). This tear is known as a Bankart lesion, and causes recurrent instability and dislocations of the
shoulder. Anterior instability is most common in young males (aged 25 and younger) during sporting activities or falls.

Traditional conservative methods for treating traumatic shoulder instability have shown little success, and poor postoperative outcome scores compared to surgical treatment options. Initial studies comparing open surgical repair to arthroscopic Bankart repair associated the arthroscopic technique with higher recurrence, and reoperation rates. However, early arthroscopic techniques involved less viable transglenoid sutures, or bioabsorbable tacks. More recent studies in which suture anchors are used for both techniques show similar recurrent instability rates between arthroscopic and open groups. Additionally, in some cases open procedures are associated with worse postoperative quality of life scores, and more significant losses in external rotation when compared to arthroscopic surgery. Additionally, shorter operating and hospitalization times, and a lesser cost, arthroscopic Bankart is thought of as the primary treatment for anterior shoulder instability.

The rotator interval of the shoulder plays a role in shoulder stability, although the specific function is debated. Cadaveric studies in which rotator interval closure has been perform isolated, or in conjunction with stabilization procedures have shown decreased range of motion, and translation of the humeral head. Therefore, it is queried whether the addition of rotator interval closure to arthroscopic Bankart repair would provide additional stability, and lower redislocation rates after stabilization surgery for patients with traumatic shoulder instability. Retrospective comparison of patients who have received arthroscopic Bankart repair with or without rotator interval closure have not
shown definitive results, and therefore a prospective trial is needed to determine the role of rotator interval closure when performed with Bankart lesion repair.
CHAPTER 3: OBJECTIVES

Our primary objective was to compare external rotation range of motion at 90 degrees abduction in patients with traumatic anterior shoulder instability who underwent rotator interval closure and Bankart lesion repair to those who underwent Bankart lesion repair alone. Our secondary outcome measures included external rotation range of motion without abduction, forward flexion range of motion, disease-specific quality of life, function and pain.
CHAPTER 4: MATERIALS AND METHODS

4.1 Ethics Approval and Subject Consent

We obtained approval from the University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (Appendix A).

4.2 Eligibility Requirements

Eligible patients were those between the ages of 15 and 50 years who had suffered at least one traumatic anterior shoulder dislocation, resulting Bankart lesion who were scheduled to undergo arthroscopic Bankart lesion repair. We excluded patients if any of the following were present: (1) multidirectional or bidirectional instability diagnosed clinically with positive apprehension tests in two or more directions; (2) posterior instability diagnosed clinically with a positive posterior apprehension test; (3) significant bone lesions greater than 25% of the humeral head anterior-to-posterior, diagnosed via radiograph; (4) evidence of other concomitant conditions of the shoulder (excluding SLAP lesions); (5) previous surgery on the study shoulder; (6) inability to speak, understand, or read English; (7) cognitive impairment or psychiatric illness that precluded informed consent or renders patient unable to complete questionnaires; (8) no fixed address and no means of contact; (9) medical illness where life expectancy is less than two years; or (10) incompetency or unwillingness to provide informed consent. The traumatic etiology of instability was confirmed with the identification of a traumatic labial tear during arthroscopic surgery.
4.3 Subject Recruitment

We recruited from the practices of two orthopaedic surgeons at the Fowler Kennedy Sports Medicine Clinic (FKSMC) in London, Ontario. A total of 202 patients visiting FKSMC between January 2011 and September 2013 for shoulder instability were screened for eligibility. Of these, 121 patients were deemed ineligible for the study (see Figure 3). Seventy eligible patients were contacted by a member of the research team, who explained the study and obtained consent. Twenty-nine patients who had reached six month postoperative were included in this analysis.

4.4 Randomization

Randomization took place in the operating room after eligibility was fully confirmed following diagnostic arthroscopy of the shoulder joint. Patients were randomized in permuted block sizes of two and four on a one-to-one basis into one of two groups: (1) arthroscopic Bankart lesion repair with rotator interval closure (experimental), or (2) arthroscopic Bankart lesion repair alone (control). Randomization was stratified by surgeon (RL, KW), and by the presence or absence of a SLAP lesion requiring repair.

4.5 Interventions

4.5.1 Arthroscopic Bankart Repair

Both treatment groups initially received the same Bankart lesion repair. Patients were placed under general anaesthesia while the surgery was performed in lateral
decubitus with distal traction, lateral decubitus with distal and proximal lateral traction, or beach chair positions.

A posterior portal was utilized to perform a diagnostic arthroscopy, confirming the presence of a Bankart lesion while ruling out any other pathologic conditions of the shoulder (excluding SLAP lesions). A low anterior portal and an anterior superior portal were then fashioned and used to mobilize the displaced anterior capsulolabral complex from the anterior inferior glenoid neck using a liberator knife/elevator, radiofrequency device, and/or electrical shaver.

A rasp was then used to create a raw bleeding bony surface throughout the length of the lesion. The number and placement of suture anchors and stitches was determined, taking into account the condition and extent of the lesion. The labrum and adjacent capsule were repaired anatomically by inserting non-metallic suture anchors with high strength sutures on the articular surface one to two millimeters from the anterior and anterior inferior rim via the low anterior portal. Sutures were tightened using sliding knots, followed by three alternating half-hitches. The final half-hitch was “flipped” to prevent knot slipping. The number and type of anchors used was recorded for each patient. Any other associated lesions that still allowed inclusion into the study were assessed and treated. Documentary photographs were taken of the Bankart repair and any other repair that was needed. Sterile dressing was applied and Marcaine was instilled around the portals.

Patients assigned to group 2 were then transferred to the recovery room after application of an abduction pillow sling. Patients assigned to group 1 received the rotator cuff interval suture following the Bankart lesion repair.
4.5.2 Arthroscopic Rotator Interval Closure

To place the interval suture, an IDEAL Suture Grasper™ was used to capture capsular tissue from the superior glenohumeral ligament and the middle glenohumeral ligament. An absorbable #1 PDS™ (polydioxanone) suture from the spinal needle was then passed to the IDEAL Suture Grasper™ and brought out through the low anterior portal. A switching stick was then used to bring the cannula up into the subacromial space on top of the rotator cuff. A crochet hook was utilized in a blind fashion to retrieve the suture going through the cuff into the superior soft tissue. The suture was brought out through the low anterior portal, and a modified Roeder knot was used to secure the closed rotator cuff interval. Gentle debridement of the rotator cuff interval was completed at the surgeon’s discretion prior to closing the interval. Documentary photographs were taken of the rotator interval closure, the Bankart repair, and any other repairs that were required. Sterile dressing was applied and Marcaine was instilled around the portals.

Patients were transferred to the recovery room after application of an abduction pillow sling. All surgical treatments were performed by one of two orthopaedic surgeons, RL or KW at London Health Sciences University Hospital in London, Ontario. Following a three week postoperative immobilization period, all patients participated in an identical rehabilitation protocol developed by physical therapists in the Fowler Kennedy Sports Medicine Clinic Physical Therapy Department (Appendix C).
4.6 Outcome Measures

All patients were measured preoperatively and at 3 and 6 weeks postoperatively and 3, 6, 12, and 24 months postoperatively. For the purposes of this thesis, we report the results at 6 months postoperative.

4.6.1 Primary Outcome Measure

Using a universal goniometer, patients’ active and passive glenohumeral range of motion was measured for external rotation with 90° by a single blinded athletic therapist and single blinded research assistant. Universal goniometer ROM measurements have shown consistently better reliability when performed by the same assessor, and with the patient supine to control for scapular and trunk compensation[71] To maximize reliability, a standardized measurement protocol was established. Beginning on the non-operative shoulder, each measurement was taken twice. If the difference between the two measurements was greater than five degrees, a third measurement was taken. Range of motion measurements were taken at baseline (pre-operatively) and postoperatively at three and six months. Within group minimal clinically important differences (MCID) in range of motion were pre-determined to be 15° for external rotation, and 20° for forward flexion by interviewing senior physiotherapists at the Fowler Kennedy Sport Medicine Clinic with expertise in treating shoulder patients postoperatively. Using the method described by Goldsmith et al.[72], between group MCIDs were classified as six degrees for external rotation measurements, and eight degrees for forward flexion measurements.
**External Rotation with 90° of Abduction**

To measure external rotation with the shoulder in 90° of abduction, the patient was positioned supine with the shoulder and elbow abducted 90° (Figures 3 and 4). The distal humerus was manually supported to maintain a position parallel to the floor. For active measurements, the patient was instructed to externally rotate the forearm in the sagittal plane, while a blinded athletic therapist placed a gentle restraining force on the coracoid process and the anterior aspect of the acromion to stabilize the scapula, to control for scapular compensation and isolate glenohumeral range of motion. A second, blinded research assistant placed the axis of the goniometer at the olecranon process of the ulna, the stationary arm perpendicular to the floor, and the moving arm along the longitudinal axis of the ulna pointing towards the styloid process. For passive measurements, the patient remained relaxed while the blinded athletic therapist externally rotated the shoulder until a firm endpoint was reached, or scapular movement was appreciated.
Figure 3: Active External Rotation with 90° of Abduction Measurement

Figure 4: Passive External Rotation with 90° Abduction Measurement
4.7 Secondary Outcome Measures

4.7.1 Range of Motion (ROM)

Using a universal goniometer, patients’ active and passive glenohumeral range of motion was measured for external rotation in neutral and forward flexion by a single blinded athletic therapist, and a single blinded research assistant using a standardized protocol. Beginning on the non-operative shoulder, each measurement was taken twice. If the difference between the two measurements was greater than five degrees, a third measurement was taken. Range of motion measurements were taken at baseline (pre-operatively) and postoperatively at three and six months.

4.7.1a External Rotation With 0° Of Abduction

For external rotation measurements at neutral, the patient was positioned supine on the examination table with the humerus parallel to the floor along the trunk of the body and the elbow at 90° of flexion (Figures 5 and 6). For active measurements, the patient was instructed to rotate the forearm in the transverse plane while maintaining pressure on a rolled up towel between the distal humerus and the trunk of the body to ensure no abduction assisted in rotation. A blinded athletic therapist applied a gentle restraining force to the coracoid process and the anterior aspect of the acromion to stabilize the scapula to control for scapular compensation and isolate glenohumeral range of motion. A blinded research assistant placed the axis of the goniometer over the olecranon process of the elbow, the stationary arm perpendicular to the floor, and the
distal arm along the longitudinal axis of the ulna, toward the styloid process. For passive movements the patient remained relaxed while the blinded athletic therapist externally rotated the forearm until a firm endpoint was reached or scapular movement was appreciated.

Figure 5: Active External Rotation with 0° of Abduction Measurement
4.7.1b Forward Flexion in the Scapular Plane.

For shoulder flexion measurements, the patient was placed supine on the examination table with the arm at neutral and the elbow fully extended. The forearm was placed in 0° of supination and pronation with the palm facing the trunk of the body. For active measurements, the patient was instructed to lift the arm in the scapular plane, while a blinded athletic therapist placed a stabilizing force to the trunk of the body to isolate glenohumeral flexion. A blinded research assistant placed the stationary arm of the goniometer parallel to the midaxillary line of the trunk, and the moving arm parallel to the longitudinal axis of the humerus, toward the lateral epicondyle (Figures 7 and 8). For passive measurements the patient remained relaxed while the blinded athletic therapist...
lifted the humerus in flexion until a firm endpoint was reached, or scapular movement was appreciated (Figures 7-9).

Figure 7: Active Forward Flexion Measurement
4.7.2 Patient-Reported Outcomes

Secondary patient-reported outcomes included the Western Ontario Shoulder Instability Index (WOSI); the Upper Extremity Functional Index (UEFI); the 4-Item Pain Intensity Measure (P4); and any postoperative adverse events (including re-dislocations). Patient reported outcomes were evaluated at baseline (pre-operatively), and postoperatively at three, six, 12 and 24 weeks.

4.7.2a Disease Specific Quality of Life: WOSI

The Western Ontario Shoulder Instability Index (WOSI) is a patient-reported, disease-specific quality of life questionnaire for patients with symptomatic instability of
the shoulder. The WOSI has been shown to be valid, reliable and responsive in the same patient population sampled in this study.[73] In 2011, Kemp et al. reported better responsiveness and discriminant validity with the WOSI than with either the Constant Score[74], and the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment form (ASES)[75] in patients receiving arthroscopic shoulder stabilization surgery.[76]

The WOSI consists of 21 items in four domains: physical symptoms and pain (ten items), sports, recreation and work (four items), lifestyle (four items) and emotions (three items). Items are rated on a 100mm visual analog scale (VAS) from 0-100, with 0 being the best possible score, and 100 being the worst possible score. Scores can be represented as a percentage of best possible score for easier interpretation. Minimal clinically important difference (MCID) for within patient mean WOSI scores from development studies has been set at 10%. If we ascribe to the method of Goldsmith et al.[72], then the between group MCID is approximately 4%. According to Normal et al.(2003), minimum important differences in most health-related quality of life measures can be estimated with one half a standard deviation. With a lack of published MCIDs for UEFI and P4 scores, we calculated within group MCIDs for the UEFI, and P4 were calculated to be 8 points (10%), and 4 points (10%), respectively, using standard deviations from development studies. We then calculated between-group MCID for the UEFI to be 4 points (5%), and the between group MCID for the P4 was calculated to be 2 points (5%).[72]
4.7.2b Function: Upper Extremity Function Index

The Upper Extremity Function Index (UEFI) is a valid, reliable and responsive patient-reported functional scale for patients with upper extremity (shoulder, elbow, wrist or hand) symptoms. It consists of 20 questions where patients rate their ability to perform tasks from 0 (extreme difficulty or unable to perform) to 4 (no difficulty). The total score ranges from a minimum of 0, representing the most dysfunction to a maximum of 80, representing the least dysfunction.

4.7.2c Pain: Four Item Pain Intensity Measure

The Four Item Pain Intensity Measure (P4) is a patient-reported questionnaire addressing pain in the affected limb in the morning, afternoon, evening, and with activity over the previous two days. Each item is rated on a VAS from 0 to 10 for a total score of 0 (no pain) to 40 (worst possible pain). The P4 has been shown to be more valid, reliable and sensitive to change than single-item numeric pain rating scales.[77]

4.8 Sample Size

We conducted a formal sample size calculation using a two-sided alpha error rate of 0.05 with statistical power of 80% to detect a patient-important moderate effect size of 0.5.[78] We inflated the sample size to 71 patients per group to account for an expected drop-out rate of 10%.
4.9 Plan for Analysis

We used SPSS version 21 to perform analyses of the data. We used descriptive statistics to present the demographic characteristics of each group using means and standard deviations for continuous variables (age, height, weight) and proportions for nominal variables (arm dominance, sex, mechanism of injury, and primary sport). We conducted an analysis of covariance (ANCOVA) to statistically compare the two groups for each outcome, using the preoperative score as the covariate, the postoperative score as the dependent variable, and study group as the independent variable. We used last outcome carried forward to fill any missing data points with the last observed value of that variable. We reported the unadjusted mean with standard deviation and mean difference with 95% confidence interval in tables and figures and the adjusted mean with standard error and the adjusted mean difference between groups with 95% confidence interval within the text.

Because some patients may perceive a worse outcome if their range of motion is different between the nonoperative and operative shoulder, we used a Pearson’s r to express the magnitude of the association between the side-to-side difference in external rotation at six months postoperative and the six months postoperative quality of life and function scores. We used a linear regression to determine the proportion of the variance in the patient reported outcomes that could be explained by the difference in side-to-side range of motion was and whether this effect was modified by treatment group. A p <0.05 was considered statistically significant.
CHAPTER 5: RESULTS

5.1 Participant Flow

The flow of patients through each stage of the study is outlined in Figure 3. From January 2011 to September 2013, 150 patients were screened for this study. Of these, 85 patients did not meet the eligibility criteria, seven canceled surgery, three refused to participate, 18 could not be contacted (unable to reach patient prior to surgery), and five did not live in London and would not be returning regularly for follow up.

We excluded patients if they fell outside the age range (n=19), had not sustained at least one frank dislocation (n=18), had undergone previous surgery on the study shoulder (n=29), required bilateral stabilization procedures (n=1), exhibited multidirectional instability (n=7), required posterior stabilization surgery (n=15), had a significant bone lesion accounting for more than 25% of the humeral head (n=1), exhibited other concomitant conditions of the shoulder (n=30), had a major medical illness where life expectancy was less than two years (n=1). Some patients were excluded for more than one reason.

Thirty-two eligible patients gave consent to participate in the study. Three patients were withdrawn at the time of surgery after detection of a posterior labral tear during diagnostic arthroscopy.
**Figure 10: Participant flow through the trial**

Assessed for eligibility (n=202)

- Randomized (n=50)
  - Bankart Repair (n=26)
    - 3-week postop (n=26)
    - 6-week postop (n=25)
      - 1 missed (LOCF)*
    - 3-month postop (n=18)
      - 3 missed (LOCF)
    - 6-month postop (n=12)
      - 2 missed (LOCF)
  - Bankart Repair + RIC (n=24)
    - 3-week postop (n=24)
    - 6-week postop (n=24)
    - 3-month postop (n=16)
      - 1 missed (LOCF)
    - 6-month postop (n=14)
      - 1 missed (LOCF)

- Awaiting Surgery (n=20)
  - Ineligible (n=121)
    - Age (n=19)
    - Multidirectional instability (n=7)
    - Concomitant conditions (n=30)
    - Previous surgery (n=29)
    - Required posterior labral repair (n=5)
    - Significant bone lesion (n=1)
    - Required bilateral stabilization (n=1)
    - Major illness (n=1)
    - Unavailable for follow up (n=5)
    - Withdrawn at surgery (n=5)
    - Cancelled surgery (n=7)
    - Declined to participate (n=7)
    - Missed patient (n=18)

- Included in analysis (n=14)
  - 1-year postop (n=9)
  - 2-year postop (n=6)

- Included in analysis (n=14)
  - 1-year postop (n=9)
  - 2-year postop (n=6)

*LOCF = Last Outcome Carried Forward*
5.2 Demographic Information

At the time of analysis, 29 patients had completed six month follow up measurements. Patient demographic characteristics were balanced between groups (Table 1).

Table 1: Baseline Demographics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Control (n=14)</th>
<th>Experimental (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, n(%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12 (85.7)</td>
<td>10 (66.7)</td>
</tr>
<tr>
<td>Female</td>
<td>2 (14.3)</td>
<td>5 (33.3)</td>
</tr>
<tr>
<td>Mean age ± SD, y</td>
<td>25.45 ± 5.46</td>
<td>23.81 ± 3.85</td>
</tr>
<tr>
<td>Mean height ± SD, m</td>
<td>178.6 ± 4.67</td>
<td>177.27 ± 6.88</td>
</tr>
<tr>
<td>Mean weight ± SD, kg</td>
<td>78.34 ± 10.41</td>
<td>81.83 ± 15.57</td>
</tr>
<tr>
<td>Mean time from injury to surgery ± SD, months</td>
<td>62.04 ± 48.09</td>
<td>52.73 ± 49.81</td>
</tr>
<tr>
<td>Injured shoulder, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>7 (50.0)</td>
<td>11 (73.3)</td>
</tr>
<tr>
<td>Non-dominant</td>
<td>7 (50.0)</td>
<td>4 (26.7)</td>
</tr>
<tr>
<td>Number of dislocations, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>5 (35.7)</td>
<td>5 (33.3)</td>
</tr>
<tr>
<td>2-10</td>
<td>6 (42.9)</td>
<td>5 (33.3)</td>
</tr>
<tr>
<td>&gt;10</td>
<td>3 (21.4)</td>
<td>5 (33.3)</td>
</tr>
<tr>
<td>Activity at Injury, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sports</td>
<td>12 (85.7)</td>
<td>14 (93.3)</td>
</tr>
<tr>
<td>Fall</td>
<td>2 (14.3)</td>
<td>1 (0.07)</td>
</tr>
<tr>
<td>SLAP lesion, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repaired</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Not present or not-repaired</td>
<td>14 (100)</td>
<td>15 (100)</td>
</tr>
<tr>
<td>Hill-Sachs lesion, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>14 (100)</td>
<td>14 (93.3)</td>
</tr>
<tr>
<td>Absent</td>
<td>0</td>
<td>1 (6.7)</td>
</tr>
<tr>
<td>Bony Bankart lesion, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>3 (21.4)</td>
<td>3 (20.0)</td>
</tr>
<tr>
<td>Absent</td>
<td>11 (78.6)</td>
<td>12 (80.0)</td>
</tr>
</tbody>
</table>

Abbreviations. SD = standard deviation; SLAP = Superior Labrum Anterior to Posterior
5.3 Adverse Events

One patient in the control group sustained a traumatic re-dislocation of the operative shoulder during a contact injury while playing soccer. This patient underwent a subsequent Latarjet procedure. One patient in the experimental group reported excessive stiffness five months postoperatively, and underwent revision surgery to remove the rotator interval stitch. At the six month follow up appointment, this patient had regained most of her range (side-to-side difference of 28.5° in external rotation at 90° of abduction; side to side difference of 19.5° in external rotation with no abduction). We analyzed this patient in the experimental group according to the intention-to-treat (ITT) principle.

5.4 Primary Outcome Measure

5.4.1 External Rotation with 90° of abduction

At three and six months postoperative, the loss in active and passive external rotation in 90° of abduction compared to the contralateral limb was not significantly different between groups (Table 2). Patients in the control group maintained a smaller but non-statistically significant deficit in side-to-side difference for active external rotation with 90° of abduction at all recorded intervals. When adjusting for baseline measurements, the three month postoperative deficit was 35 ± 5°, in the control group, and 40 ± 5° in the experimental group, reducing the between group difference to 5° (95% CI -12 to 11), p=0.35. At six months postoperative, the adjusted mean side-to-side difference was 25 ± 4° in the control group and 26 ± 4° in the experimental group for an adjusted mean difference of 1° (95% CI -12 to 11), p=0.96. Figure 4 presents external
rotation with 90° abduction for the operative and non-operative shoulder for each group at all follow-ups. Regardless of group, the nonoperative shoulder maintained a similar range of motion throughout the study, while the average range in the operative shoulder remained deficient at three months postoperative but improved to values similar to preoperative values by six months postoperative.

Table 2: Side-to-Side Difference: External Rotation in 90° of Abduction

<table>
<thead>
<tr>
<th>Time</th>
<th>ROM</th>
<th>Control (mean ± SD)</th>
<th>Experimental (mean ± SD)</th>
<th>Mean Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Active(*)</td>
<td>Passive(*)</td>
<td></td>
</tr>
<tr>
<td>Preop</td>
<td></td>
<td>18 ± 19</td>
<td>16 ± 24</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>19 ± 21</td>
<td>17 ± 17</td>
<td>1 (-15 to 17)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32 ± 20</td>
<td>31 ± 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 ± 26</td>
<td>41 ± 27</td>
<td>8 (-11 to 26)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26 ± 18</td>
<td>28 ± 23</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>27 ± 17</td>
<td>27 ± 18</td>
<td>1 (-14 to 14)</td>
</tr>
</tbody>
</table>

Abbreviations. CI = Confidence Interval; SD = standard deviation
*Range values reported as difference from contralateral to operative limb. A positive mean difference demonstrates a smaller side-to-side deficit in favor of the control group.

Figure 11: Range of Motion- External Rotation with 90° Abduction

BR = Bankart repair group, BR + RIC = Bankart repair with rotator interval closure group.
5.5 Secondary Outcome Measures

5.5.1 Range of Motion (ROM)

5.5.1a External Rotation with 0° of abduction

At three and six months postoperative, the loss in active and passive external rotation in 0° of abduction compared to the contralateral limb was not significantly different between groups (Table 3). The adjusted mean side-to-side difference in active external rotation in 0° of abduction at the six month postoperative interval was 12 ± 4° in the control group and 13 ± 4° in the experimental group for an adjusted mean difference of 1° (95% CI -11 to 15), p=0.76. Figure 5 presents average external rotation in 0° abduction for the operative and non-operative shoulder for each group at all follow-ups. Regardless of group, the non-operative shoulders maintained their range of motion compared to preoperative measurements, while the average range in the operative shoulder was deficient at three months postoperative, but approached preoperative values by six months postoperative.

| Table 3: Side-to-Side Difference: External Rotation with 0° Abduction |
|---|---|---|---|---|
| Time | ROM | Control (mean ± SD) | Experimental (mean ± SD) | Mean Difference (95% CI) |
| Preop | Active (*) | 11 ± 17 | 14 ± 16 | 3 (-10 to 16) |
| | Passive (*) | 16 ± 13 | 18 ± 14 | 2 (-9 to 13) |
| 3m | Active (*) | 19 ± 12 | 29 ± 22 | 10 (-4 to 23) |
| | Passive (*) | 24 ± 13 | 35 ± 21 | 11 (-3 to 25) |
| 6m | Active (*) | 12 ± 16 | 14 ± 15 | 2 (-10 to 14) |
| | Passive (*) | 16 ± 14 | 16 ± 14 | 0 (-11 to 12) |

*Abbreviations. SD = standard deviation

*Range values reported as difference from contralateral to operative limb. A positive mean difference demonstrates a smaller side-to-side deficit in favor of the control group.
5.5.1.1 Forward Flexion

At three and six months postoperative, the difference in loss of active and passive forward flexion compared to the contralateral limb was not significantly different between groups. At six months postoperative, the adjusted mean side-to-side difference for active forward flexion was $10 \pm 3^\circ$ in the control group and $9 \pm 3^\circ$ in the experimental group for an adjusted mean difference of $-1^\circ$ (95% CI -10 to 8), $p=0.86$. Patients in the control group maintained a smaller and non-statistically significant deficit in active forward flexion range of motion at baseline, and three months postoperative. At six months postoperative, patients in the experimental group maintained a slightly better but non-statistically significant active and passive forward flexion compared to the control.
group. Figure 6 presents average forward flexion for the operative and non-operative shoulder for each group at all follow-ups. Regardless of group, the non-operative shoulder maintained the preoperative range of motion, while the average range in the operative shoulder was deficient at three months postoperative, but improved to beyond preoperative measurements by six months postoperative.

**Table 4: Side-to-Side Difference: Range of Motion - Forward Flexion**

<table>
<thead>
<tr>
<th>Time</th>
<th>ROM</th>
<th>Control (mean ± SD)</th>
<th>Experimental (mean ± SD)</th>
<th>Mean Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Active (*)</td>
<td>7 ± 16</td>
<td>9 ± 12</td>
<td>6 (-10 to 13)</td>
</tr>
<tr>
<td></td>
<td>Passive (*)</td>
<td>7 ± 17</td>
<td>6 ± 11</td>
<td>1 (-13 to 10)</td>
</tr>
<tr>
<td>3m</td>
<td>Active (*)</td>
<td>13 ± 10</td>
<td>26 ± 18</td>
<td>1 (-2 to 25)</td>
</tr>
<tr>
<td></td>
<td>Passive (*)</td>
<td>11 ± 9</td>
<td>22 ± 23</td>
<td>11 (-3 to 24)</td>
</tr>
<tr>
<td>6m</td>
<td>Active (*)</td>
<td>10 ± 10</td>
<td>9 ± 11</td>
<td>-1 (-10 to 8)</td>
</tr>
<tr>
<td></td>
<td>Passive (*)</td>
<td>12 ± 8</td>
<td>7 ± 11</td>
<td>-5 (-12 to 3)</td>
</tr>
</tbody>
</table>

*Abbreviations. SD = standard deviation

*Range values reported as difference from contralateral to operative limb. A positive mean difference demonstrates a smaller side-to-side deficit in favor of the control group*

**Figure 13: Range of Motion – Forward Flexion**

BR = Bankart repair group, BR + RIC = Bankart repair with rotator interval closure group.
5.5.2 Patient-Reported Outcomes

5.5.2a Western Ontario Shoulder Instability Index

At three, six, 12 and 24 weeks postoperative, the between-group difference in total WOSI score and scores for each of the four domains (physical symptoms and pain; sports, recreation and work; lifestyle and emotion were not statistically significant (Table 5). Figure 7 presents unadjusted mean WOSI scores at all follow-ups. Compared to preoperative scores, mean scores for both groups worsen at three weeks postoperative but surpass preoperative scores at six months postoperative. When adjusted for baseline scores the mean total WOSI score at 6 months postoperative was 29.3 ± 4.9 in the control group and 27.0 ± 5.1 in the experimental group for an adjusted mean difference of -2.3 (95% CI -17.5 to 15.1), p=0.86.

Table 5: Western Ontario Shoulder Instability Index Scores (unadjusted means)

<table>
<thead>
<tr>
<th>Time</th>
<th>Subscale Measure</th>
<th>Control (mean ± SD)</th>
<th>Experimental (mean ± SD)</th>
<th>Mean Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop</td>
<td>Physical symptoms and pain (%)</td>
<td>42.5 ± 22.5</td>
<td>52.6 ± 25.0</td>
<td>10.1 (-8.8 to 29.1)</td>
</tr>
<tr>
<td></td>
<td>Sports, recreation and work (%)</td>
<td>59.4 ± 20.3</td>
<td>60.2 ± 23.8</td>
<td>0.8 (-16.8 to 18.3)</td>
</tr>
<tr>
<td></td>
<td>Lifestyle (%)</td>
<td>46.3 ± 19.5</td>
<td>51.7 ± 24.1</td>
<td>5.4 (-11.9 to 22.8)</td>
</tr>
<tr>
<td></td>
<td>Emotions (%)</td>
<td>69.8 ± 20.0</td>
<td>72.8 ± 23.9</td>
<td>3.0 (-14.4 to 20.5)</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong> (%)</td>
<td><strong>50.3 ± 17.7</strong></td>
<td><strong>56.8 ± 22.8</strong></td>
<td><strong>6.5 -16.3 to 15.4</strong></td>
</tr>
<tr>
<td>3w</td>
<td>Physical symptoms and pain (%)</td>
<td>56.7 ± 21.2</td>
<td>54.1 ± 13.7</td>
<td>-2.8 (-16.9 to 11.7)</td>
</tr>
<tr>
<td></td>
<td>Sports, recreation and work (%)</td>
<td>79.6 ± 26.1</td>
<td>81.8 ± 12.9</td>
<td>2.2 (-14.3 to 18.7)</td>
</tr>
<tr>
<td></td>
<td>Lifestyle (%)</td>
<td>71.4 ± 21.8</td>
<td>71.2 ± 14.5</td>
<td>-0.2 (-15.0 to 14.7)</td>
</tr>
<tr>
<td></td>
<td>Emotions (%)</td>
<td>72.9 ± 18.0</td>
<td>67.0 ± 21.4</td>
<td>-5.9 (-21.5 to 9.8)</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong> (%)</td>
<td><strong>66.1 ± 19.8</strong></td>
<td><strong>64.5 ± 10.3</strong></td>
<td><strong>-1.6 -9.6 to 13.9</strong></td>
</tr>
<tr>
<td>Time</td>
<td>Subscale Measure</td>
<td>Control (mean ± SD)</td>
<td>Experimental (mean ± SD)</td>
<td>Mean Difference (95% CI)</td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------------</td>
<td>---------------------</td>
<td>--------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td></td>
<td>Physical symptoms and pain (%)</td>
<td>39.5 ± 21.3</td>
<td>43.3 ± 20.2</td>
<td>3.8 (-12.6 to 20.3)</td>
</tr>
<tr>
<td></td>
<td>Sports, recreation and work (%)</td>
<td>60.1 ± 24.1</td>
<td>61.5 ± 27.3</td>
<td>-3.1 (-18.8 to 21.7)</td>
</tr>
<tr>
<td></td>
<td>Lifestyle (%)</td>
<td>53.1 ± 24.3</td>
<td>53.2 ± 25.2</td>
<td>0.1 (-19.6 to 19.7)</td>
</tr>
<tr>
<td></td>
<td>Emotions (%)</td>
<td>57.2 ± 25.7</td>
<td>53.8 ± 17.8</td>
<td>-0.1 (-21.1 to 14.3)</td>
</tr>
<tr>
<td></td>
<td><strong>Total (%)</strong></td>
<td>48.5 ± 21.4</td>
<td>50.2 ± 20.6</td>
<td>1.7 (-19.4 to 13.0)</td>
</tr>
<tr>
<td>3m</td>
<td>Physical symptoms and pain (%)</td>
<td>24.6 ± 20.8</td>
<td>27.7 ± 16.1</td>
<td>5.9 (-11.7 to 18.0)</td>
</tr>
<tr>
<td></td>
<td>Sports, recreation and work (%)</td>
<td>39.9 ± 25.0</td>
<td>48.9 ± 22.8</td>
<td>9 (-10.1 to 28.0)</td>
</tr>
<tr>
<td></td>
<td>Lifestyle (%)</td>
<td>34.9 ± 26.3</td>
<td>38.0 ± 20.6</td>
<td>3.1 (-15.8 to 21.9)</td>
</tr>
<tr>
<td></td>
<td>Emotions (%)</td>
<td>37.0 ± 24.7</td>
<td>45.5 ± 21.1</td>
<td>8.5 (-9.8 to 26.8)</td>
</tr>
<tr>
<td></td>
<td><strong>Total (%)</strong></td>
<td>31.2 ± 22.0</td>
<td>36.2 ± 17.0</td>
<td>5 (-23.5 to 9.3)</td>
</tr>
<tr>
<td>6m</td>
<td>Physical symptoms and pain (%)</td>
<td>9.3 ± 18.1</td>
<td>6.5 ± 10.8</td>
<td>-2.3 (-14.7 to 9.1)</td>
</tr>
<tr>
<td></td>
<td>Sports, recreation and work (%)</td>
<td>34.8 ± 28.4</td>
<td>32.3 ± 23.4</td>
<td>-2.5 (-23.1 to 88.1)</td>
</tr>
<tr>
<td></td>
<td>Lifestyle (%)</td>
<td>29.6 ± 25.4</td>
<td>25.0 ± 21.9</td>
<td>-4.6 (-23.5 to 14.3)</td>
</tr>
<tr>
<td></td>
<td>Emotions (%)</td>
<td>29.3 ± 24.7</td>
<td>45.5 ± 21.1</td>
<td>16.2 (-8.1 to 36.7)</td>
</tr>
<tr>
<td></td>
<td><strong>Total (%)</strong></td>
<td>27.4 ± 22.0</td>
<td>29.0 ± 21.1</td>
<td>3.6 (-23.2 to 9.3)</td>
</tr>
</tbody>
</table>

*Abbreviations. SD = standard deviation
*A positive mean difference demonstrates a better WOSI score in favor of the control group.*
**Figure 14: Western Ontario Shoulder Instability Index Scores**
BR = Bankart repair group, BR RIC = Bankart repair with rotator interval closure group.

5.5.2b Upper Extremity Functional Index

At three, six, 12 and 24 weeks postoperative, UEFI scores were not significantly different between groups (Table 6). Figure 8 presents unadjusted mean UEFI scores at all follow-ups. Mean scores for both groups worsen at three weeks postoperative but show improvement beyond preoperative pain by six months postoperative. When adjusted for baseline scores, the average UEFI scores at six months postoperative were 89.3 ± 2.4 in the control group and 90.1 ± 2.5 in the experimental group for an adjusted mean difference of 0.9 (95%CI -8.1 to 6.4), p=0.81
Table 6: Upper Extremity Functional Index Scores (unadjusted means)

<table>
<thead>
<tr>
<th>Time</th>
<th>Control (mean ± SD)</th>
<th>Experimental (mean ± SD)</th>
<th>Mean Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop</td>
<td>77.1 ± 16.6</td>
<td>76.1 ± 20.5</td>
<td>-1.0 (-15.8 to 13.7)</td>
</tr>
<tr>
<td>3w</td>
<td>40.9 ± 22.2</td>
<td>39.9 ± 21.2</td>
<td>-1.0 (-18.2 to 16.2)</td>
</tr>
<tr>
<td>6w</td>
<td>67.1 ± 18.9</td>
<td>65.6 ± 22.3</td>
<td>-1.5 (-17.9 to 14.8)</td>
</tr>
<tr>
<td>3m</td>
<td>81.0 ± 16.9</td>
<td>80.6 ± 12.2</td>
<td>-0.4 (-12.2 to 11.4)</td>
</tr>
<tr>
<td>6m</td>
<td>89.4 ± 9.2</td>
<td>90.0 ± 10.6</td>
<td>0.4 (-7.2 to 8.5)</td>
</tr>
</tbody>
</table>

*Abbreviations. SD = standard deviation

* A positive mean differences demonstrates a greater UEFI scores in favour of the experimental group

**Figure 15: Upper Extremity Functional Index Scores**

BR = Bankart repair group, BR RIC = Bankart repair with rotator interval closure group

---

**5.5.2c Four-Item Pain Intensity Measure (P4)**

At three, six, 12 and 24 weeks postoperative, the difference between groups in P4 scores was not statistically significant (Table 7). When adjusted for baseline scores, pain levels at the 6-month postoperative interval were 7.2 ± 1.6 in the control and 7.0 ± 1.7 in the experimental for an adjusted mean difference of 0.2 (95%CI -4.6 to 4.9), p=0.95.

Figure 9 presents unadjusted mean P4 scores at all follow-ups. Average scores for both
groups worsen at three weeks postoperative and improve beyond baseline levels at six months postoperative.

**Table 7: 4-Item Pain Intensity Measure Scores (unadjusted means)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Control (mean ± SD)</th>
<th>Experimental (mean ± SD)</th>
<th>Mean Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop</td>
<td>11.4 ± 8.5</td>
<td>11.8 ± 7.2</td>
<td>0.2 (-5.9 to 6.5)</td>
</tr>
<tr>
<td>3w</td>
<td>14.6 ±10.2</td>
<td>13.4 ± 7.8</td>
<td>-1.2 (-8.4 to 6.1)</td>
</tr>
<tr>
<td>6w</td>
<td>9.4 ± 7.8</td>
<td>11.1 ± 6.8</td>
<td>1.7 (-4.2 to 7.5)</td>
</tr>
<tr>
<td>3m</td>
<td>8.9 ± 7.1</td>
<td>7.1 ± 5.0</td>
<td>-1.8 (-6.7 to 3.0)</td>
</tr>
<tr>
<td>6m</td>
<td>7.1 ± 6.6</td>
<td>7.1 ± 5.6</td>
<td>0 (-4.9 to 4.8)</td>
</tr>
</tbody>
</table>

*Abbreviations.* SD = standard deviation
* A positive mean difference demonstrates a better P4 score in favor of the experimental group

**Figure 16: 4-Item Pain Intensity Measure Scores**

BR = Bankart Repair group, BR RIC = Bankart repair with rotator interval closure group.
5.6 Associations

5.6.1 External rotation with 90° of abduction

At six months postoperative, the magnitude of the association between side to side difference in active external rotation with 90° of abduction and quality of life was weak in the control, and moderate in the experimental group, suggesting an effect by group (Table 8). However, the regression analysis indicates that only 2% (adj. $R^2 = -0.07$) of the variance in WOSI scores is explained by group and range of motion deficit (Table 9). Similarly, the magnitude of the association between active external rotation with 90° of abduction in the operative arm and function was weak in the control, and moderate in the experimental group (Table 8). Similarly, the regression analysis suggests that only 1% (adj. $R^2 = -0.07$) of the variance in UEFI scores is explained by group and side-to-side difference in external rotation with 90° abduction (Table 9).

Table 8: Association (Pearson's $r$, p-value) Between Side-to-Side Difference in Active External Rotation with 90° Abduction and Patient Reported Quality of Life and Function

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>WOSI</td>
<td>0.11, 0.70</td>
<td>0.25, 0.44</td>
</tr>
<tr>
<td>UEFI</td>
<td>0.03, 0.92</td>
<td>0.24, 0.45</td>
</tr>
</tbody>
</table>
Table 9: Regression Analysis – Side-to-Side Difference in External Rotation With 90° Abduction and Patient Reported Quality of Life and Function

<table>
<thead>
<tr>
<th>WOSI</th>
<th>Unstandardized coefficients</th>
<th>Standardized coefficients</th>
<th>t</th>
<th>Sig. 0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>B Standard Error Beta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Constant)</td>
<td>81.31 14.75 5.51</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROM deficit</td>
<td>-0.12 0.25 -0.1</td>
<td>-0.49 0.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>-3.53 8.47 -0.08</td>
<td>-0.42 0.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UEFI</td>
<td>(Constant)</td>
<td>90.29 6.72 13.44</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>ROM deficit</td>
<td>-0.06 0.11 -0.11</td>
<td>-0.52 0.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>0.63 3.860 0.03</td>
<td>0.16 0.87</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.6.2 External rotation with 0° abduction

At six months postoperative, the magnitude of the association between side-to-side difference in active external rotation with no abduction and quality of life was weak in the control, and moderate in the experimental group, suggesting an effect by group (Table 10). However, the regression analysis indicates that only 2% (adj. $R^2 = -0.06$) of the variance in WOSI scores is explained by group and the deficit in external rotation (Table 11). Similarly, the magnitude of the association between the difference in external rotation with no abduction and function was weak in the control, and moderate in the experimental group, suggesting an effect by group (Table 10). The regression analysis however, indicates that only 2% (adj. $R^2 = -0.07$) of the variance in UEFI scores is explained by group and side to side deficit in external rotation (Table 11).

Table 10: Association (Pearson's $r$, p-value) Between Side–to-Side Difference in Active External Rotation with no Abduction and Patient Reported Quality of Life and Function

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>WOSI</td>
<td>0.08, 0.79</td>
<td>0.35, 0.20</td>
</tr>
<tr>
<td>UEFI</td>
<td>0.03, 0.92</td>
<td>0.24, 0.45</td>
</tr>
</tbody>
</table>
Table 11: Regression Analysis: Side-to-Side Difference in External Rotation with no Abduction and Patient Reported Quality of Life and Function

<table>
<thead>
<tr>
<th>WOSI</th>
<th>Unstandardized coefficients</th>
<th>Standardized coefficients</th>
<th>t</th>
<th>Sig. 0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>B</td>
<td>Standard Error</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>(Constant)</td>
<td>79.87</td>
<td>13.46</td>
<td>5.93</td>
<td>0.00</td>
</tr>
<tr>
<td>ROM deficit</td>
<td>-3.17</td>
<td>8.46</td>
<td>-0.08</td>
<td>-0.38</td>
</tr>
<tr>
<td>Group</td>
<td>-0.18</td>
<td>0.28</td>
<td>-0.13</td>
<td>-0.65</td>
</tr>
<tr>
<td>UEFI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Constant)</td>
<td>89.54</td>
<td>6.14</td>
<td>14.59</td>
<td>0.00</td>
</tr>
<tr>
<td>ROM deficit</td>
<td>0.79</td>
<td>3.85</td>
<td>0.04</td>
<td>0.21</td>
</tr>
<tr>
<td>Group</td>
<td>-0.08</td>
<td>0.13</td>
<td>-0.13</td>
<td>-0.64</td>
</tr>
</tbody>
</table>
CHAPTER 6: DISCUSSION

The purpose of this analysis was to compare the preliminary results at six months postoperative for patients with anterior shoulder instability who were randomized to receive arthroscopic Bankart lesion repair with rotator interval closure (experimental group), or arthroscopic Bankart lesion repair alone (control group). Patient range of motion (including external rotation with 90° of abduction, external rotation with no abduction, and forward flexion), quality of life, function and pain were assessed. At this early analysis, we found no significant difference between treatment groups for any outcome.

Rotator interval closure in most cadaver shoulders has shown increased stability, along with decreased range of motion.[23-25, 31] The increased translation and range of motion reported in the cadaveric study performed by Harryman et al.[22] was never replicated. This is most likely because Harryman et al. performed a medial-lateral suture of the rotator interval, while most other studies report a superior-inferior suture, which is the technique most often performed. Most notable range of motion deficits are reported in external rotation in abduction, although using cadaver shoulders makes it difficult to discern whether the loss in range would be important to patients.

In our study, rotator interval closure was performed using a single #1 PDS suture between the middle glenohumeral and superior glenohumeral ligaments, which has been shown in cadaver studies to decrease external rotation in 60° of abduction significantly more than closure between the superior glenohumeral ligament and the subscapularis.
tendon, or medial-lateral imbrication of the rotator interval.[24, 70] Additionally, single superior-inferior rotator interval suture has shown almost identical decreases in range of motion, and humeral head anterior translation as the use of two superior-inferior sutures.[23]

In 2010, Chechik et al. retrospectively compared human subjects who had undergone arthroscopic Bankart repair with rotator interval closure (BR + RIC, n=37) to those who had undergone arthroscopic Bankart repair only (BR, n=46). Group allocation was decided by the surgeon: if the patient was diagnosed with multidirectional instability, systemic joint hyperlaxity, rotator interval laxity or a large rotator interval, the patient was allocated to the BR+RIC group. Otherwise the patient received only the Bankart repair. Range of motion, stability and subjective and objective clinical outcome (measured using Walch-Duplay scores) were evaluated after an average follow up of 45.6 ± 24.1 months in the ABR + RIC group and 86.3 ± 20.8 months in the ABR group.

Chechik reported that three patients (8.1%) in the BR + RIC group re-dislocated their operative shoulder, compared to six patients (13%) in the BR group. Additionally, three (8.1%) patients in the BR + RIC group reported symptomatic shoulder subluxations, compared to four patients (8.7%) in the BR group. In our study, one patient in the control group sustained a recurrent dislocation at six months postoperative, and no recurrent dislocations were reported in the experimental group. No recurrent subluxations were reported in either group. While Chechik et al. included patients with multidirectional instability and excessive laxity, which has been shown to decrease success rates following stabilization procedures[79, 80], our study excluded patients with
multidirectional or bidirectional instability, which could explain the differences between studies in recurrent instability rates.

Chechik et al. reported 75.7% of patients as having good or excellent clinical outcome scores (Walch-Duplay score) in the BR + RIC group, slightly higher than the 73.9% with good or excellent scores in the BR group. This is similar to the quality of life scores reported by patients in our study at six months postoperative. While patients in the experimental group reported adjusted mean WOSI scores of 29.3 ± 4.9%, patients in the control group reported average WOSI scores of 27.0 ± 5.1%. The Walch-Duplay score has been shown to have good correlation to WOSI scores.[81]

Our study also included patient reported function and pain scores. Average UEFI scores at six months postoperative were similar between groups (adj. mean difference of 0.9%, 95% CI -8.1 to 6.4, p=0.81) as were pain levels at the 6-month postoperative interval (adj. mean difference of 0.2%, 95% CI -4.6 to 4.9, p=0.95).

In terms of range of motion, patients in both groups of Chechik’s study lost range of motion compared to the contralateral limb (BR+RIC group lost 7.8 ± 14.2°, BR group lost 5.7±10.7°). Chechik et al. did not specify whether patients’ shoulders were in neutral or abduction during external rotation measurements making the comparison to our study more difficult. In our study however, we found greater average side-to-side range of motion deficits in both groups for external rotation in 90° of abduction (26 ± 4° in the experimental group, 25 ± 4° in the control group), and rotation with no abduction (13 ± 4° in the experimental group, 12 ± 4° in the control group). It should be noted that patients in our study were only six months postoperative, whereas patients in the Chechik study were at a minimum of 42 months. Patients in our study could expect to gain more range
in their operative limb by two years postoperative resulting in a smaller side-to-side difference.

Patients in the BR+RIC group of Chechik study maintained a greater side-to-side deficit in range of motion compared to patients in the BR group (mean difference of 2.1° 95% CI -3.3 to 7.5°). This between group difference is similar to the differences found in our study for external rotation with 90° abduction (adj. mean difference of 1°, 95% CI -12 to 11), and external with no abduction (adj. mean difference of 1°, 95% CI -11 to 15).

Although the adjusted mean difference in side-to-side range of motion deficit was slightly larger in the experimental group of our study for external rotation with 90° abduction, this difference does not appear to be clinically important and the wide confidence intervals of these measurements restrict our ability to make definitive conclusions.

During abduction and external rotation of the shoulder joint, the primary restraint to humeral head dislocation is the anterior band of the inferior glenohumeral ligament.\[38\] During Bankart repair, the glenoid labrum – inferior glenohumeral ligament (IGHL) complex is reattached to the glenoid rim, restoring the stabilizing contribution of the labrum-IGHL complex, and tightening the anterior capsule in the process. This often results in a loss of about 5° external rotation range of motion.\[60, 61, 82\]

During full external rotation with 90° of abduction, the humeral head is translated anteriorly.\[83\] We can assume that tightening the anterior portion of the capsule restricts some humeral head motion, limiting external rotation, but also preventing anterior dislocation. Similarly, rotator interval closure between the middle and superior
The most common shoulder position during initial traumatic shoulder dislocation is external rotation with 90° abduction.[5, 46] Although no significant associations were detected between range of motion deficit and quality of life scores, good quality of life scores observed at six months postoperative indicate that patients are willing to sacrifice some range of motion in the apprehension position for the stability and confidence gained along with the stiffness their shoulder following both procedures. It is possible, then, that the addition of the rotator interval stitch adds additional stiffness and reduces the volume of the joint capsule, restoring proprioception and potentially contributing to the postoperative confidence experienced by patients.

The magnitudes of association found between side-to-side deficit in external rotation with 90° abduction and both quality of life and function scores were weak in the control group, and moderate in the experimental group, suggesting an effect by group. However, regression analysis indicates only a small percentage of variance in WOSI and UEFI scores can be explained by group. Similar results were observed for the magnitudes of association between external rotation with no abduction, and both WOSI and UEFI scores. A larger sample size and complete follow up is required to minimize random variance and allow more certain conclusions to be drawn regarding the association of patient quality of life, and loss in external rotation.

One patient in the control group reported recurrent traumatic dislocation during a contact injury playing soccer, and subsequently underwent a Latarjet procedure.
Alternatively, one patient in the experimental group reported excessive stiffness, and underwent revision surgery to remove the rotator interval stitch. A much larger study is required to fully understand the complication profiles of each procedure.

To the best of our knowledge, this is the first randomized-controlled trial comparing arthroscopic Bankart repair with and without rotator interval closure in this population. Strengths of this study include randomization and allocation concealment, both methods are used to reduce the chance of selection bias, which is present in the study by Chechik et al. (2010)[28]. Within our randomization schema, we used blocking to ensure equal numbers of patients between groups and stratification to increase the probability of achieving a prognostic balance between groups. We also included valid and reliable patient reported outcome measures to provide a more comprehensive assessment of patient health and well-being post arthroscopic Bankart repair and to explore the relationship between range of motion deficits and patients’ perceptions of outcome.

Additional methods to reduce bias included employing a blinded athletic therapist to conduct all range of motion measurements in a standardized fashion. Further, patients were blinded to treatment allocation to minimize subject-expectancy bias, which occurs when a research subject expects a given result, and unconsciously reports the expected results.

Finally, intention to treat analysis was implemented for all patients, whereby each patient was analyzed within the group to which they had been randomized regardless of whether the patient required revision surgery. Although this method is conservative, increasing the probability of making a type 2 error, it reduces the probability of creating a
prognostic imbalance by analyzing patients according to treatment received and potentially making the more serious type 1 error.

6.1 Limitations

Range of motion measurements, quality of life, function and pain results were not significantly different between treatment groups at six months postoperative; however, the results remain uncertain due to small sample size. Precision was represented using a 95% confidence interval around each estimate. This study reports wide confidence intervals for all outcome measures, making it difficult to definitively conclude whether the addition of rotator interval closure is beneficial or harmful.

Additionally, small sample sizes increase the probability that influential data points remain undetected and produce misleading results. For example, although no significant associations between range of motion and quality of life or function were found, the magnitude of the association appears to be quite different between groups. Upon closer look, however, the magnitude of the association becomes similar between groups with the removal of a single data point. A larger sample size provides greater certainty about the pattern of outcomes within each group such that evaluation of regression diagnostics including outliers and influential data points is valid.

Each patient was given a standardized rehabilitation protocol, but compliance was not measured. Although we expect compliance to be balanced through random assignment to treatment groups once the study reaches maturity, an imbalance is possible. Without directly measuring compliance we are unable to correct for any imbalance, nor can we reduce any variability caused by different levels of compliance even if the groups
are well balanced in terms of compliance. However, the act of measuring compliance could in itself serve as an intervention reducing the pragmatic nature of our study.
CHAPTER 7: CONCLUSION

This study compared range of motion, quality of life, function, and pain at six months postoperative in 29 patients who had undergone arthroscopic Bankart repair (n=14) or arthroscopic Bankart repair with rotator interval closure (n=15). The findings reported in this thesis are underpowered, but suggest that any difference in outcome due to the interval stitch is unlikely to be a large effect. However, the results are preliminary and therefore definitive conclusions cannot be made at this time. Definitive conclusions will follow the completion of the full trial.

7.1 Directions for Future Research

A. A continuation of the current study to meet the projected sample size will be beneficial in improving the precision of the estimate of the difference in treatment effect between groups in range of motion, quality of life, function and pain.

B. Follow-up measurements at one and two years that evaluate patient range of motion, quality of life, function and pain will provide more information about the long-term effects of the addition of rotator interval closure to Bankart lesion repair.

C. Further study in this area should include rate of return to sports to evaluate whether patients are able to return back to their desired level of sport and activity.
REFERENCES


APPENDICES

Appendix A: Ethics Approval

![Ethics Approval Image]

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Comments</th>
<th>Version Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition of Co-investigator</td>
<td>A. Getgood has been added to the study team.</td>
<td></td>
</tr>
<tr>
<td>Change in Study Personnel</td>
<td>L. Rainsford has been added to the study team.</td>
<td></td>
</tr>
<tr>
<td>Revised Letter of Information &amp; Consent</td>
<td></td>
<td>2012/12/11</td>
</tr>
</tbody>
</table>

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research involving Human Subjects (HSREB), which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines, and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB’s as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB’s periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the University of Western Ontario Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000042.

Signatures

[Signature]

[Signature]

[Signature]

For inquiries, please contact the Research Ethics Office at [Contact Information].

This is an official document. Please retain the original in your files.
Appendix B: Letter of Information and Consent

Letter of Information

Title of Research: The role of rotator interval closure in Bankart lesion repair

Researchers: The researchers who are conducting this study are: Dianne Bryant, PhD; A. Getgood, MD, R. Litchfield, MD; K. Willits, MD; L. Rainsford, MSc candidate

Introduction
You are being invited to participate in a research study comparing the effectiveness of Bankart lesion repair alone to Bankart lesion repair plus rotator interval closure. Bankart lesion repair is a proven and effective surgical treatment for patients with a Bankart lesion. There are four major muscles that contribute to the stability of the shoulder joint. Some surgeons believe that sewing together two of the muscles at the rotator cuff interval will offer patients better results than a Bankart repair alone. It is also possible however, that sewing these muscles together will reduce the range of motion and as a result decrease patients’ quality of life and functional ability.

In order to know whether Bankart lesion repair in addition to rotator interval closure improves recurrence rates with a similar decrease in range of motion, it must be compared to Bankart lesion repair alone. In this study, a random selection process, like flipping a coin, will indicate which surgical treatment you will receive. One-hundred and forty-two (142) patients will take part in this study at the Fowler Kennedy Sports medicine Clinic (London, Ontario, Canada); 71 will receive Bankart lesion repair and 71 will receive Bankart lesion repair and rotator interval closure.

Procedures
All patients with a Bankart lesion and at least one episode of demonstrated dislocation scheduled to have surgical treatment will be invited to take part in this study. If you choose not to participate in this study, you will receive the surgical treatment recommended by your orthopaedic surgeon.
Depending on your scheduled visits to your surgeon, your participation in this study may require additional visits. You will be asked to complete three questionnaires at 3 weeks, 6 weeks, 3 months, 6 months, 1 year and 2 years post-surgery. These can be completed at the time of scheduled visits with your surgeon or sent to you by mail or by e-mail, whichever your prefer. Completing the questionnaires will take approximately 15-20 minutes of your time. At 3 months, 6 months, 1 year and 2 years you will also be asked to come to the Fowler Kennedy Sports Medicine Clinic to undergo a pain-free range of motion assessment (total completion times of 15-20 minutes). This can also be completed at the same scheduled visit with your surgeon or a physiotherapy appointment depending on your schedule. During this time post-surgery, you will be asked to complete a standard rehabilitation protocol developed and practiced at the Fowler Kennedy Sports Medicine Clinic.

**Risks**
Much like any surgical procedure, both operations involve similar elements of risk. Complications relating to the aesthetic, infection and damage to nerves or blood vessels around the shoulder are rare and usually minor. Stiffness and/or pain around the shoulder are more common, but expected to decline with time and physiotherapy. Stiffness may be more prevalent in the surgical procedure involving Bankart lesion repair and rotator interval closure, however evidence for this is presently inconclusive. Finally, both surgeries are unsuccessful in 2-10% of cases, and thus a second surgery may be needed to achieve the desired stability.

**Benefits**
There are no additional benefits to you for participating in this study.

**Cost/Compensation**
You will not be compensated for your participation in this study. The assessments for this study may attempt to coincide with your routine follow ups after your surgery, so your participation in this study should not cost you any additional money.

**Voluntary Participation**
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your future care. You may choose to withdraw your consent at any time.

**Alternatives to Study Participation**
Refusal to participate in this study will not affect the surgical treatment or care you receive. If you choose to not participate in this study you could have either surgical option that is described in this letter of information.

**Request for Study Results**
Should you decide to participate and want to receive a copy of the study results, we will keep the contact information that you provide to us on the Letter of Consent until the study is complete. At that time, we will mail a copy of the published article to you. Please realize that the results of this study are not expected for at least 5 years. Should your mailing information change, please let us know.

**Confidentiality**
Your confidentiality will be respected. The electronic data that is collected from you is protected by a username and password. It travels in a scrambled format to a server (storage computer) that is located in Toronto. The company that houses the server is a profession company with extremely high standards of physical and virtual security. We want to let you know however, that even with this high level of security, there is always a remote chance that your information could be accessed or ‘hacked’ by someone who is not supposed to have your information. If we become aware that this has happened, we will inform you immediately. If the results of the study are published, your name will not be used and no information that discloses your identity will be released or published.

Representatives of The University of Western Ontario Health Sciences Research Ethics Board may require access to your study related records or may follow up with you to monitor the conduct of the study.

If you have questions or concerns about your surgery, please contact your orthopaedic surgeon. If you have any questions about this research, please contact the Principal Investigators or Dr. Dianne Bryant at (519) 661-2111 x83947 or Dianne.Bryant@uwo.ca.

If you have any questions about your rights as a study participant, please contact Dr. David Hill, Scientific Director, Lawson Health Research Institute at (519) 667-6649.

You do not waive any legal rights by signing the consent form.

This letter is yours to keep.

Sincerely,

Dr. Robert Litchfield
Dr. Kevin Willits
Dr. Alan Getgood
Dianne Bryant, PhD
Lauren Rainsford, MSc
Title of Research: The role of rotator interval closure in Bankart lesion repair

I have read the accompanying letter of information and have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction

Date ___________________________  Participant’s Signature ___________________________

Print Name ___________________________

Date ___________________________  Parent or Legal Guardian’s Signature (if required) ___________________________

Print Name ___________________________

Date ___________________________  Signature of Person Obtaining Informed Consent ___________________________

Print Name ___________________________

☐ I would like to receive a copy of the results of this study. Please mail to:

____________________________________

____________________________________
Appendix C: Physiotherapy Protocol

ARTHROSCOPIC ANTERIOR STABILIZATION

The intent of this protocol is to provide the clinician with instruction, direction, rehabilitative guidelines and functional goals for all stabilization procedures. It is not intended to be a substitute for clinical decision making regarding the progression of a patient’s post-operative course based on physical exam/findings and individual progress. The physiotherapist must exercise their best professional judgment to determine how to integrate this protocol into an appropriate treatment plan. The general treatment for a variety of shoulder procedures involves protection of the repair, stretching/mobilizing tight or restricted structures, strengthening the rotator cuff and strengthening and retraining the scapular musculature. Progression of treatment from one phase to the next is based on achieving the appropriate level of soft tissue healing and physical performance criteria. As an individual’s progress is variable and each will possess various pre-operative deficiencies, this protocol must be individualized for optimal return to activity. Some exercises may be adapted depending on the equipment availability at each facility. There may be slight variations in this protocol or additional restrictions placed by the surgeon post-operatively depending on findings at the time of the surgery. If a clinician requires assistance in treatment progression please contact the referring physician or the physiotherapy department.

KEY POINTS

DEFINITIONS

- **Bankart**: detachment of the anteroinferior glenohumeral ligament complex from the glenoid
- **Hill-Sachs**: cortical depression on the posterior lateral aspect of the humeral head from impaction against the anteroinferior glenoid rim with an anterior shoulder dislocation. This lesion has been reported in as many as 80% of traumatic anterior dislocations and 88% in recurrent dislocations\(^1\).
- **SLAP**: Superior Labrum lesion from Anterior to Posterior in the shoulder. The 4 types are surgically managed in different ways and post surgical rehabilitation is strongly dependent on the stability of the biceps origin:
  - Type I: debridement
  - Type II: sutured/tacked
  - Type III: excision of bucket handle tear
  - Type IV: excision of bucket handle tear and the attached bicep if < 30-40% of tendon\(^2,4\)

**HEALING TIMELINES**

After the initial inflammatory phase (1-3 days post surgery), tissue repair begins by laying down collagen/scar tissue along the surgical sites and repaired areas (days 3-20) and only minimal stress is tolerated. In the first 3 weeks post surgery, the rehabilitation program is designed to relieve pain, minimize inflammation and normalize scapulothoracic movement. From 3-12 weeks, the scar tissue is progressively stronger and more responsive to remodelling. At this point gradual stress can be placed on the surgical repair areas and glenohumeral joint range of motion (ROM) can be progressed\(^5\).

\(^1\) Oct 2009
STRUCTURES WHICH REQUIRE PROTECTION DURING REHABILITATION

With the arthroscopic nature of this surgery, the rotator cuff is not significantly disturbed. As a result, active range of motion (AROM), dynamic stability activities, and strengthening does not need to be delayed to protect the rotator cuff. However, sutures, anchors, capsule, ligament and labrum need significant protection for undue stress for a period of time (usually 6 weeks) to facilitate appropriate tissue healing. As a result, specific restrictions will be outlined by the surgeon depending on the associated injuries found at the time of surgery.

GLENOHUMERAL LIGAMENTS

The glenohumeral joint is stabilized by the capsuloligamentous complex. The 3 anterior stabilizing structures are the superior, middle and inferior glenohumeral ligament. The inferior glenohumeral ligament consists of an anterior and posterior band and an axillary pouch. With an anterior dislocation, it is typical to have a disruption of the inferior glenohumeral ligament which consists of an anterior band, an axillary pouch and a posterior band. At 90° of abduction with external rotation (ER), the anterior band is the main restraint that consequently gets damaged.

ROM GUIDELINES

Generally, 2-4 weeks of immobilization is common after arthroscopic instability repair. There is evidence that immediate staged ROM is safe and may provide earlier return to functional activity and ROM, however; long term results are not significantly different.

Surgeon preferences for ROM goals and timelines should be followed. If no limits are given, the following table can be used as a general guideline for staged ROM:

<table>
<thead>
<tr>
<th>Post op wk</th>
<th>Passive flexion (in scapular plane*)</th>
<th>Passive ER at 20° abd (in scapular plane)</th>
<th>Passive ER at 90° abd</th>
<th>Active flexion (in scapular plane)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>90°</td>
<td>10° - 30°</td>
<td>Contraindicated</td>
<td>85-90°</td>
</tr>
<tr>
<td>6</td>
<td>135°</td>
<td>35° - 50°</td>
<td>45°</td>
<td>120°</td>
</tr>
<tr>
<td>9</td>
<td>155°</td>
<td>Unaffected -10°</td>
<td>75°</td>
<td>150°</td>
</tr>
<tr>
<td>12</td>
<td>*WNL</td>
<td>*WNL</td>
<td>*WNL</td>
<td>*WNL</td>
</tr>
</tbody>
</table>

ER: External rotation
Abd: Abduction
*Scapular plane/plane of the scapula: 30° off of the sagittal plane
*WNL: within normal limits (allow pt to regain last 15° on own)

Rehabilitation aims to restore full active ROM by 12 weeks post arthroscopic stabilization. ROM and strengthening activities should be slowly increased and not forceful or painful to ensure adequate healing. Gaining ROM too quickly (especially ER) may result in recurrent laxity, while gaining ROM too slowly may result in residual stiffness. During this early time period, terminal/end-range stretching should NOT be performed as these motions increase tension on the anteroinferior shoulder capsule and protection of the surgical repair is vital. Conversely, with an open stabilization procedure the most common complication is loss of motion with external rotation and elevation.
ROLE OF THE ROTATOR CUFF
The main role of the rotator cuff is to centralize and compress the humeral head in the glenoid fossa to maintain the instantaneous centre of rotation of the glenohumeral joint during arm movement. To be effective there must be an equal anterior/posterior balance of the rotator cuff (subscapularis = infraspinatus+teres minor) as well as an equal superior/inferior balance between the entire cuff and the deltoid muscles (subscapularis+infraspinatus+teres minor = deltoid)\textsuperscript{11}. If one part of the cuff is deficient an imbalance will result and the translatory force of the deltoid will pull the humerus in a superior direction up under the acromion leading to mechanical impingement. Therefore, exercises that produce the most supraspinatus and least deltoid activity may avoid potential deleterious superior humeral head migration associated with high deltoid activity.

SCAPULAR MOVEMENT
The scapula moves around three axes and has six movements: up/downward rotation, internal/external rotation, anterior/posterior tipping through muscle control (protraction/retraction refers to movement around the thorax). With the arm at side, the glenoid fossa is tilted 5° into upward rotation. At 90° of abduction the glenoid fossa is tilted enough to provide a stable platform to prevent inferior translation. In full abduction, the glenoid fossa is in upward rotation, external rotation and posterior tilt\textsuperscript{12, 13}. Subjects with shoulder pain have been shown to lack upward rotation and posterior tilt\textsuperscript{14, 15} resulting in less clearance space for the rotator cuff during elevation.

SCAPULAR FORCE COUPLES
There is a moving axis of rotation that commences at the root of the spine of the scapula on initiation of movement and travels along the spine of the scapula to the AC joint at the end range of elevation and abduction\textsuperscript{16}. The main muscles that control scapular movement are trapezius, serratus anterior, rhomboids, levator scapula and pectoralis minor (see chart below). The most influential force couple that acts to upwardly rotate the scapula (glenoid fossa) is the trapezius (upper and lower fibres) and serratus anterior. From a pathology standpoint, this force couple is often the problem source and can become dyskinetic during either/both concentric or eccentric phases of movement\textsuperscript{17, 18}.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Trapezius</td>
<td>Upward rotation, retraction, elevation</td>
</tr>
<tr>
<td>Middle Trapezius</td>
<td>Upward rotation, retraction</td>
</tr>
<tr>
<td>Lower Trapezius</td>
<td>Upward rotation, retraction, depression</td>
</tr>
<tr>
<td>Serratus Anterior</td>
<td>Upward rotation, protraction</td>
</tr>
<tr>
<td>Rhomboids</td>
<td>Downward rotation, retraction, elevation</td>
</tr>
<tr>
<td>Levator Scapulae</td>
<td>Downward rotation, elevation</td>
</tr>
<tr>
<td>Pectoralis Minor</td>
<td>Anterior tipping</td>
</tr>
</tbody>
</table>
**PROPRIOCEPTIVE RETRAINING**

Intact joint position sense (proprioception) is necessary for normal muscle coordination and timing. Joint proprioception plays an important role in stabilizing the glenohumeral joint by providing information from mechanoreceptors in the musculotendinous and capsuloligamentous structures to the central nervous system for the coordination of muscular activity and optimal joint positioning. Subjects with traumatic anterior shoulder instability have been found to have decreased joint position awareness\(^{19}\) and muscle activation abnormalities of the dynamic shoulder stabilizers\(^ {20}\) compared to subjects with normal shoulders. When these structures are injured, proprioceptive deficits and altered neuromuscular control can cause faulty movement patterns, functional instability and pain in the shoulder complex \(^ {20-22}\). In a non-athletic population, a long term follow-up study demonstrated that joint position sense can be restored after surgical stabilization\(^ {23}\). However, 30% of overhead athletes continue to have impaired joint position sense post stabilization and, as a result, are unable to return to their previous sporting level\(^ {24, 25}\). This may be accounted for by the different demands place on the shoulder in these two populations.

**QUALITY VS. COMPENSATION**

Physiotherapists often feel compelled to progress patients by giving them new exercises each time they are in for therapy. It cannot be stressed enough that it is *not* beneficial to give patients exercises they are not neuromuscularly ready for. It is very important to observe the *quality* of the exercises that are being performed, specifically with rotator cuff and scapular stabilization exercises. Weaknesses in specific muscle groups lead to compensations, which produce faulty movement patterns. These faulty patterns are then integrated into unconscious motor programs, which perpetuate the original weakness.
Phase I  
(General timeline: 0-6 weeks)

GOALS
- Patient Education: posture, joint protection, positioning, hygiene, restrictions
- Immobilization to protect surgical procedure (capsule, ligaments, labrum, sutures)
- Minimize shoulder pain and inflammatory response
- Achieve staged ROM goals through gentle ROM activities
- Active ROM uninvolved joints (elbow, wrist, hand)
- Normalize scapular position, mobility and dynamic stability
- Maintain cardiovascular fitness and lower limb and trunk muscle condition

PRECAUTIONS
- Weeks 0-4: Remain in sling (include sleeping), remove for showering, range of motion
- Weeks 5-6: Sling use when moving around for longer periods of time or out in public
- Limit ER and extension
- No lifting objects with operative shoulder or arm use beyond ROM restrictions

EXERCISE SUGGESTIONS:
PROM & AAROM
- Elbow: Active & passive - flexion (if SLAP repair wait 6 wks) /extension/pronation/supination
- Wrist: Active & passive - flexion/extension/radial & ulnar deviation
- Neck: general ROM if needed
- Shoulder: use pulleys, cane, stick, opposite arm (all in scapular plane to maximize humeral head/glenoid congruency
  - P/AAROM flexion: 45-70° (wks 1-2), 90° (wk 3), 135° (wk 6)
  - P/AAROM ER: 0-5° (wks 1-2), 10-30° (wk 3), 35-50° (wk 6)
  - P/AAROM IR: 15-20°, hand behind back: posterior belt line (wk 5-6)

Muscle Activation / Strength Maintenance
General:
- Ball squeezes
- Pendulums for pain control (use body sway to move extremity: forward/back, side/side)
- Posture awareness / exercises
- Scar management

Rotator Cuff:
- Week 2: (if pain free) Sub maximal isometrics in neutral as tolerated
  - *caution with IR if open Bankart with subscapularis reattached
- Week 4: Sidelying ER with towel – no weight

Scapula:
- Bilateral elevation/depression/protraction/retraction
- Supine serratus anterior protraction/retraction at 90° flexion → progress with small weights
- Rhythmic stabilization supine 90° flexion submaximal resistance on upper arm for all planes of movement
- Supine bent elbows barrel hug
- Scapular clock exercises and progress to scapular strengthening at tolerated
Proprioceptive Retraining
- Week 3: Upper extremity weight-bearing exercises for scapular movements at GH angles below 60 degrees elevation\textsuperscript{10}
  - i.e. Standing with swiss ball on floor – hand on ball with pressure forward/backward, side to side, circles,
  - Standing weight-bearing shifts with hands on bed/plinth \rightarrow progress to single arm weight-bearing\textsuperscript{27}

Modalities
- Ice 15 minutes every few hours for pain relief\textsuperscript{4, 10}
- Interferential current therapy (pain relief)

Cardiovascular Fitness
- Bicycle, elliptical, stairmaster, walking

MILESTONES TO PROGRESS TO PHASE II
1. Appropriate tissue healing from surgery by following precautions and immobilization guidelines
2. ROM guidelines met but not significantly exceeded.
3. Pain control within allowed ROM.
Phase II
(General timeline: 6-12 weeks)

GOALS
- Continued patient education: ADL’s in painfree range (waist level activities → progress to shoulder level → overhead activities), avoid heavy lifting or positions of instability during ADL’s i.e. end range ER and combined abduction/ER
- P/AAROM to achieve staged ROM goals, may have -10° loss of motion at ends of range from surgical procedure (esp. ER and flexion)
- Progression of exercise: passive (P) → active assisted (AA) → active (A) → addition of resistance (tubing or weights)
- Establish basic rotator cuff endurance and scapular neuromuscular control
- Later in phase, introduce functional patterns of movement

PRECAUTIONS
- Avoid terminal stretches at end range ER or in 90/90 positions. (Most times only light stretching or no stretching is needed)
- Avoid exercises that load the anterior capsular structures in a position of horizontal abduction or combined abduction and ER (i.e. NO push-ups, pec flys) during this timeframe
- Avoid heavy lifting or plyometrics
- Avoid exercises that may cause impingement i.e. empty can
- Ensure exercises are performed pain free and without substitutions or altered movement patterns (Exercise quality)

EXERCISE SUGGESTIONS:

PROM & AAROM
- Neck: general ROM if needed
- Thoracic spine: ensure proper extension to facilitate shoulder ROM
- Shoulder P/AAROM: Use pulleys, cane, stick, opposite arm.....
  - Flexion (scapular plane): 135° (wk 6), 155° (wk 9), near end range/160° (wk 12)
  - ER at 20° abduction (scapular plane): 35-50° (wk 6), 50-65° (wk 9), near end range/70° (wk 12)
  - ER at 90° abduction: 45° (wk 6), 75° (wk 9.), near end range/80° (wk 12)
  - IR at 20° abduction (scapular plane): 30-60°
- IR stretches: towel/cane assisted hand behind back (combination of ext/IR/hor add), sidelying sleeper stretch, cross arm stretch
- If ROM is significantly less than goals, joint mobilizations may be performed into the limited direction
- Finger wall walking into flexion and scaption
- Arm bike/ergometer no resistance
Muscle Strength & Endurance

**Rotator Cuff:**
- Light isotonics with emphasis on high repetitions (4 sets of 15-20 reps) and low resistance (1-2 lbs):
  - Sidelying ER with towel → progress to 1lb
  - Standing ER & IR with towel: pulleys or light resistance tubing
- Rhythmic stabilization techniques for rotator cuff strengthening (ER/IR at 45° abduction in scapular plane)
- Standing long lever (elbow extension) slides up wall

**Scapula:**
- Continue with protraction, retraction, elevation, depression
- Supine rhythmic stabilization 90-100° flexion / joint perturbations in randomized directions → progressions: eyes closed, holding medicine ball
- Closed kinetic chain rhythmic stabilization:
  - Ball stabilization on wall
  - Static holds in push-up position on ball
- Light resistance extension, adduction, forward flexion (not past plane of body)
- Progress closed chain scapulohumeral mobility to shoulder level and then to overhead i.e.:
  - Quadruped scapular protraction/retraction 90° progress to 120°
  - Quadruped to tripod (2 to 1 arm)
  - Standing short lever (elbow flexed) slides up wall → long lever → no wall support
- Strengthen scapular retractors and upward rotators i.e.:
  - Prone arm raises at 0° progress to 90° and 120°
  - Prone or seated rows → progress with resistance or weight
- Strengthen serratus
  - Forward punch
  - Push up with plus progress from wall to floor, on knees to feet
  - Supine protraction/retraction with heavier weights

**Proprioceptive Retraining**
- Standing swiss ball on the wall at 90° flexion/scaption/abduction: circles, side to side, up and down, alphabet→ progress 2 arms to 1 arm and ROM from 90° to 120°
- Therapist assisted joint/limb positioning with patient reproduction of position → mid ranges → end ranges→ progress to eyes closed
- Weight-bearing activities on knees on unstable base i.e. Bosu, Wobble board, Airex pad, slider board
- Supine weighted ball drop at 90° shoulder flexion
- Supine weighted ball throw/catch → progress 2 arms to 1 arm
  - Quadruped maintain proper scapula position
- Bodyblade: arm at side → 30, 90, 120, 160° in scaption and frontal plane → progress using PNF patterning
- Ball dribbles on wall

*To increase proprioceptive input and difficulty, progression of exercises can be performed with eyes closed*
Modalities
- Ice 15-25 minutes
- Biofeedback: auditory, visual, tactile or machine
- Muscle Stimulation for posterior rotator cuff

Cardiovascular Fitness
- Bicycle, elliptical, stairmaster, treadmill jog→run, train specific to demand of sport

MILESTONES TO PROGRESS TO PHASE III
1. AROM guidelines met without pain or substitution patterns.
2. Good resting scapular posture and dynamic scapular control with ROM and strengthening exercises.
3. Able to perform recommended strengthening exercises without pain or difficulty.
Phase III
(General timeline: 12-24 weeks)

GOALS
- Ensure ROM requirements are met
- Progressive strengthening, endurance, power and neuromuscular control exercises
- Progressive exercises in terms of speed once proficiency is demonstrated at slower speeds
- Activity specific progression: sport, work, hobbies
- Gradual and planned increase in stress to anterior capsule and labral tissues
- Gradual return to full ADL's, work and recreational activities
- Suggested Guidelines:
  - 3-4 months: may begin golfing
  - 4 months+: Interval Sports Programs: throwing, swimming, tennis, volleyball, gymnastics (surgeon approval)

PRECAUTIONS
- Avoid stress to the shoulder in a short period of time or in an uncontrolled manner
- Avoid advanced rehabilitation exercises (such as plyometrics or exercises at end range ER/Abd if the patient does not perform this activities during ADL's, work, or recreation
- Do not progress into activity specific training until the patient has nearly full ROM and strength
- Avoid weightlifting activities which place excessive stress on the anterior capsule i.e. lat pull downs and military press with hands behind the head and wide grip bench press. Exercises, such as dips, which encourage shoulder hyperextension, should be avoided. These exercises do not have any additional benefit in terms of muscle activity and other exercises can be substituted. Hand placement and depth on bench and incline press should be more narrow than normal to prevent stress on the anterior capsule when lowering weights. The elbow should not pass the plane of the body - be sure to “always see your elbows” = Elbow Rule.

EXERCISE SUGGESTIONS:
ROM
- PROM/Stretching/Joint Mobilizations as needed to address any remaining deficits

Muscle Strength/Endurance/Power
Rotator Cuff:
- Progress ER/IR at side → to 45° → eventually to 90°
Scapula:
- Rhythmic stabilization / joint perturbations in positions of function and vulnerability
- PNF diagonal patterns with bands/pulleys/manual resistance:
  - D1 extension (high back hand to down to hitch hike position)
  - D1 flexion (hitch hike to high back hand position)
  - D2 extension (carry tray to hand in opposite front socket position)
  - D2 flexion (hand in opposite front socket to carry tray position)
- Continue with shoulder strengthening program as initiated in Phase II with emphasis on faster speed, multiplanar activities which incorporate the kinetic chain
Proprioceptive Retraining *(open and closed kinetic chain)*
- Weight-bearing activities on knees on unstable base i.e. Bosu, Wobble board, Airex pad, slider board
- Swiss ball prone walk out
- U/E wobble board stability → progress to small push-up on board

Strength / Endurance / Power
- Replicate ADL / work activities / sport requirements
- Progressive return to weight-lifting program for larger upper extremity muscles (i.e. deltoid, lat dorsi, pec major): start with light weight / high reps (20-30 reps) → gradually increase weight and decrease repetitions.
  - Suggestions for *early in Phase III* (3-4 months):
    - Biceps/Triceps (arm at side)
    - Shoulder shrugs
    - Rows (scapular retraction)
    - Lat pull downs (hands in front)
    - Shoulder press with hands in front of shoulders (not abducted/externally rotated)
    - Push-up (only to 90° elbow flexion)
  - Suggestions for *intermediate Phase III* (4-5 months):
    - Chest press / incline
    - Rows with shoulder elevation
    - Machine / Barbell shoulder press (no end range abduction/external rotation
    - Prone horizontal abduction
    - Prone ER at 90° abduction → progress weight as able
  - Suggestions for *late in Phase III* (5-6+ months):
    - Military Press
    - Flys
    - Dead Lifts
    - Power Cleans

Plyometric Program (if needed)
- Initiate in intermediate to late phase III (5-6+ months):
  - Suggestions/ideas:
    - Tubing plyometrics for ER/IR at 90° abduction with varying speeds
    - 2 handed tosses: waist/chest level → overhead → diagonal
    - 1 handed tosses: begin throw with shoulder flexion and mostly elbow extension → progress by increasing the amount of shoulder abduction/ER
    - Begin with towel, beach ball, kid’s ball, tennis ball → progression to lightly weighted balls (plyoballs)

Cardiovascular Fitness
- Train specific to demand of sport (aerobic, anaerobic)

**MILESTONES TO RETURN TO SPORT, WORK, HOBBIES**
1. Therapist/Physician clearance
2. No complaints of pain or instability
3. Sufficient ROM to meet task demands
4. Good/Full strength and endurance of rotator cuff and scapular muscles for desired activities including adequate neuromuscular control
Appendix D: Image Permissions

Hello Dr. O’Brien,

I am a graduate student at Western University in Ontario Canada. For my Master’s thesis I am conducting a study comparing Bankart repair alone versus Bankart repair with rotator interval closure for patients with anterior shoulder instability. I was wondering if I could use Figure 4 (a schematic drawing of the shoulder capsule illustrating the location and extent of the IGHLC) from your paper “The anatomy and histology of the inferior glenohumeral ligament complex of the shoulder” published in the American Journal of Sports Medicine (Vol 18, No. 5)? Usage would be in the literature review section of my thesis, and full credit would be cited.

Thank you so much!

--
Lauren Rainsford  
M.Sc candidate  
Health & Rehabilitation Sciences  
Western University

Hi Lauren,

I'm Dr. O'Brien's assistant-- I just wanted to send you a note letting you know that he read your email and welcomes you to use whichever images you like, provided they are cited. Let me know if you need anything else.

Best,  
Mary

--

Mary Shorey  
Clinical Research Coordinator  
Office of Dr. Stephen J. O'Brien  
Hospital for Special Surgery  
535 E 70th Street  
New York, NY 10021  
Work
Dear Rainsford
Yes you can use the figure.
Best wishes

M. Hakan ÖZSOY

18 Şubat 2014 tarihinde 20:28 saatinde, Lauren Rainsford şunları yazdı:

Hello Dr. Hakan Ozsoy,

I am a graduate student at Western University in Ontario Canada. For my Master’s thesis I am conducting a study comparing Bankart repair alone versus Bankart repair with rotator interval closure for patients with anterior shoulder instability. I was wondering if I could use Figure 2 (Diagram of the left shoulder showing the borders of the rotator interval area) from “Rotator Interval” printed in Sports Injuries: Prevention, Diagnosis, Treatment and Rehabilitation 2012 pp 75-79)? Usage would be in the literature review section of my thesis, and full credit would be cited.

Thank you so much!

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Lauren Rainsford
M.Sc candidate
Health & Rehabilitation Sciences
Western University
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Appendix E: Curriculum Vitae

LAUREN RAINSFORD

EDUCATION

Master of Science  
Health and Rehabilitation Science  
Western University, London ON  
September 2012 – May 2014

Bachelor of Science  
Chemistry  
With Distinction  
University of Victoria, Victoria BC  
Class of 2012

RESEARCH EXPERIENCE

Western University  
Fowler Kennedy Sport Medicine Clinic  
London, ON  
**Thesis Project**  
2012 – Present

*Under the supervision of Dr. Dianne Bryant and co-advisory of orthopaedic surgeon Dr. Kevin Willits*

Conduct a randomized controlled trial evaluating the role of rotator interval closure in Bankart lesion repair. Responsible for patient recruitment, follow-up and scheduling, data collection and entry, statistical analysis, manuscript writing.

Western University  
London, ON  
**Work Study Researcher**  

*Under the joint supervision of Dr. Wankei Wan and Dr. Robert Scott.*

Investigated gold-bacterial cellulose catalysis cycle, successfully functionalized and selectively dissociated bacterial cellulose using the ionic liquid ethylimidizolium acetate.

University of Victoria  
Victoria, BC  
**Undergraduate Researcher**  
May 2011 – Aug. 2011

*Under the supervision of Dr. Robin G. Hicks*

Pursued synthesis and characterization of novel tridentate “Nindigo” ligands derived from the dye molecule Indigo

CONFERENCES

London, ON  
**Presenter**  
Jan. 2014

*Bone and Joint Injury and Repair Conference*

Presented thesis work regarding the role of rotator interval closure in Bankart lesion repair on patient quality of life and range of motion

Squamish, BC  
**Presenter**  
May 2011

*BC Inorganic Weekend*

Presented seminar regarding tridentate Nindigo ligands, and participated in student symposium on inorganic chemistry.
TEACHING EXPERIENCE

Western University  
London, ON  
**Teaching Assistant**  

- **Functional Anatomy Part II**  
  Health Science 3300

- **The Aging Mind**  
  Health Science 4701

Western University  
London, ON  
**Teaching Assistant**  
Jan. 2013 – Apr 2013

AWARDS & CERTIFICATIONS

- 2012-2014  
  Western University Graduate Research Scholarship

- May 2013  
  Certified Personal Trainer (NCCPT)

- May 2013  
  Emergency First Aid, CPR Level C