Knee Surg Sports Traumatol Arthrosc (2016) 24:350–356
DOI 10.1007/s00167-015-3962-4

SHOULDER

Effect of glenohumeral position on contact pressure between the capsulolabral complex and the glenoid in free ALPSA and Bankart lesions

DooSup Kim[1] · HoeJeong Chung[1] · Chang-Ho Yi[2] · Yeo-Seung Yoon[1] · Jongsang Son[3,4] · Youngho Kim[5] · Myoung-Gi On[1] · JaeHyung Yang[6]

Received: 1 July 2015 / Accepted: 23 December 2015 / Published online: 2 January 2016

Abstract

Purpose Anterior shoulder dislocation is a common injury, but the optimal management of dislocation remains controversial. We hypothesized that reducing the shoulder in externally rotated position would aid the reduction in capsulolabral lesions. Thus, in this study, contact pressure between the capsulolabral lesion and the glenoid in free ALPSA and Bankart lesions was measured using a cadaver model.

Methods In 10 specimens, the humerus was externally rotated by abduction on the coronal plane to measure the contact pressure between the capsulolabral complex and glenoid in free ALPSA and Bankart lesions using a Tekscan pressure system. Stability of the joint was confirmed using the Vicon motion analysis system.

Results In the normal shoulder joint, the peak pressure between the subscapularis muscle and the anterior capsule according to the location of the glenohumeral joint decreased to 83.4 ± 21.2 kPa in the 0° abduction and −30° external rotation positions and showed a 300.7 ± 42.9 kPa peak value in the 60° abduction and 60° external rotation positions. In both free ALPSA and Bankart lesions, the lowest pressure between the labral lesion and the glenoid was measured at 0° abduction and −30° external rotation, and the highest pressure was recorded at 60° external rotation and 60° abduction.

Conclusion The contact pressure between the capsulolabral complex and the glenoid significantly increased when the abduction and external rotation angles were increased. Based on our results, the conservative management in free ALPSA lesions would respond better than Bankart lesions.

IRB or ethical committee approval YWMR-12-0-038.

Keywords Free ALPSA lesion · Bankart lesion · Shoulder dislocation · Cadaver study · Biomechanical study

✉ HoeJeong Chung
hjchung29@yonsei.ac.kr

1 Department of Orthopedic Surgery, Wonju Christian Severance Hospital, Wonju College of Medicine, Yonsei University, Ilsan-ro 20, Wonju-si, Gangwon-do 220-701, Republic of Korea

2 Department of Orthopaedic Surgery, DaeGu Armed Forced Hospital, Daegu, Republic of Korea

3 Sensory Motor Performance Program, Rehabilitation Institute of Chicago, Chicago, IL, USA

4 Department of Physical Medicine and Rehabilitation, Northwestern University, Chicago, IL, USA

5 Department of Biomechanical Engineering, Yonsei University, Seoul, Republic of Korea

6 Department of Orthopaedic Surgery, Gangdong Yonsei Hospital, Seoul, Republic of Korea

Introduction

Although anterior shoulder dislocation is a common pathologic condition, no treatment method has been identified as the gold standard [3]. One of the most widely used treatment methods is immobilization using an arm sling or brace with adduction and internal rotation, but this treatment results in a high recurrence rate [20], especially in young or athletic patients [2].

In 1999, Itoi et al. [9] reported the presence of a 'coaptation zone' during the immobilization period and suggested positions (such as adduction and external rotation or abduction and neutral rotation) for maintaining the zone based on a cadaver study. These suggestions incited new techniques for treating anterior shoulder dislocations and spawned further discussion. In 2003, Itoi et al. [7] suggested a new method of immobilization. They found that patients treated with external rotation had a lower recurrence rate than those treated with internal rotation after initial dislocation of the shoulder. Many other studies have confirmed these findings [5, 13, 23, 25], determining that immobilization with external rotation is more effective than internal rotation. However, other studies [14, 16] and systemic reviews [10, 17, 27] found that the use of conventional immobilization methods with either internal or external rotation did not affect recurrence rates after the initial anterior shoulder dislocation. Moreover, external rotation was associated with low compliance among patients.

Current practice divides patients into first-time and recurrent shoulder dislocation groups, and distinct lesions resulting from the first and recurrent dislocations have been described. Such differentiation was first attempted by Antonio et al. [1] and later by Kim et al. [12]. According to these studies, the two most common lesions are free ALPSA and Bankart lesions, and the prevalence of free ALPSA and Bankart lesions in first-time dislocation patients ranges from 23 to 27 %. Thus, it was hypothesized that externally rotating the arm promoted contact pressure in the capsulolabral complex by enhancing the reduction in the capsulolabral lesion. The contact pressures between the capsulolabral lesion and the glenoid were compared between free ALPSA and Bankart lesions during external rotation of the glenohumeral joint using a fresh-frozen cadaver shoulder model. To determine the effects of conservative treatment on two types of lesions (free ALPSA and Bankart lesions) commonly occurred in the first-time shoulder dislocation, the contact pressures at each lesion were observed.

Materials and methods

Experiments were conducted on 14 shoulders of seven fresh-frozen cadavers. All cadaver donors were male, and their mean age was 52.3 ± 2.7 years. Of the 14 shoulders, those with histories of shoulder fracture, shoulder surgery, shoulder dislocation, shoulder joint arthritis, rotator cuff tear, anatomical variation and damage in the labrum, and glenoid deformity were excluded, and the remaining 10 shoulders were selected for this study.

Preparation

The fresh-frozen cadavers were frozen at −20 °C and thawed at room temperature for 36 h before experiments. The humerus and scapula were dissected, excluding the glenohumeral joint capsule and the rotator cuff. When the deltoid muscle was dissected, the centre of the deltoid insertion site of the humerus shaft was marked. The rotation centre of the humerus was marked considering the locations of the medial and lateral epicondyles and excised 10 cm inferior to the deltoid insertion centre. A hole was made at the centre of the deltoid insertion using a drill, and tension was applied using a wire after a screw was inserted (deltoid force was applied to the opposite side using a pulley and a wired screw). The supraspinatus muscle, infraspinatus muscle, subscapularis muscle, and teres minor muscle bellies were detached from the scapula, and the musculotendinous junction was sutured using no. 5 Ethibond Excel (Ethicon, Somerville, NJ, USA) to apply tension separately to the muscles. The muscle loads were determined based on the outcomes of previous studies on the cross-sectional area (Table 1) [19]. The humerus shaft was fixed on a custom-made jig, and the scapula was fixed on the jig after four holes were made in the body with the medial border perpendicular to the ground.

Table 1 Static weights loaded to rotator cuff muscles

Muscle	Loads (N)
Deltoid	43
Suprascapularis	9
Subscapularis	26
Infrascapularis and teres minor	22

A three-dimensional motion capture system (Vicon Nexus, Vicon Motion System Ltd., UK) with six cameras (MX-T10, Vicon Motion System Ltd., UK) was used to determine the joint stability, glenohumeral abduction, and rotation angle. The accuracy of the system was proven in previous studies [28]. Based on the results of a study by Poitras et al. [19], six reflective markers were attached to the anatomical locations of the scapula (trigonum spinae scapulae, angulus inferior, and angulus acromialis) and the humerus (glenohumeral rotation centre, lateral epicondyle, and medial epicondyle) to define the coordinate system of the scapula and humerus according to the recommendations of the International Society of Biomechanics [29]. The coordinate system of the scapula and the humerus was defined using the trajectories of the reflective markers obtained during the experiments. The glenohumeral angle was calculated using the *Y*–*X*–*Y* Euler rotation sequence.

Pressure was measured using a Tekscan pressure sensor model 4205 (Tekscan Inc., MA, USA) of the K-scan™ system (Tekscan Inc., MA, USA). This sensor was 45.7 mm wide, 41.9 mm tall, and 0.178 mm thick and could minimize interference in normal joint movement. In prior real testing, the sensor was calibrated with the maximum pressure of 2068 kPa using an Instron® (Illinois Tool Works

Inc., MA, USA); thus, the minimum pressure was 8.1 kPa. The pressure data were recorded using an I-scan® software (Tekscan Inc., MA, USA).

The Tekscan pressure sensor was inserted between the subscapularis muscle and the anterior capsule of 10 normal fresh-frozen shoulders. The humerus was externally rotated in 0°, 30°, 45°, and 60° coronal abduction positions to −30° (internal rotation), 0° (neutral), 30°, 45°, and 60° to measure the pressures at the respective angles. Then, posterior capsulectomy was performed. The posterior capsule was medially displaced, and the labrum was almost detached freely, but still remained through the intact anterior glenoid periosteum to the scapula in five shoulders to make free ALPSA lesion (not adherent ALPSA) (Fig. 1) in the 3 to 6 o'clock position of the labrum (the anteroinferior labrum) using a curved periosteal elevator. We surgically detached the labrum and tore the anterior glenoid periosteum of the five remaining shoulders to make Bankart lesions (Fig. 2). The Tekscan pressure sensor was positioned between the capsulolabral complex and the glenoid with the labral lesion to measure the pressure at the same positions as in previous experiments.

This study was approved by the Institutional Review Board of Wonju College of Medicine, Yonsei University (Approval No. YWMR-12-0-038).

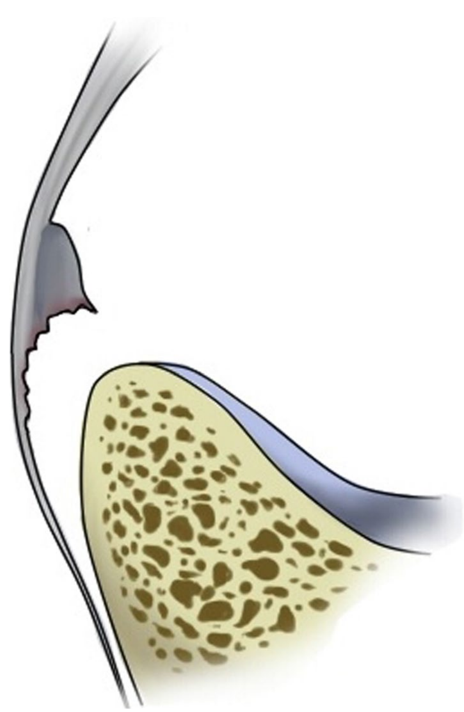

Fig. 1 Schematic view of free ALPSA lesion

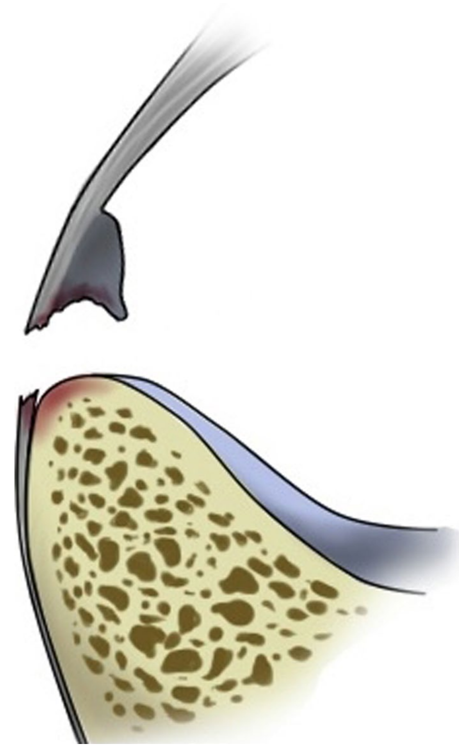

Fig. 2 Schematic view of Bankart lesion

Statistical analysis

Two-way ANOVA was performed to determine whether there were any interactions between the abduction and rotation angles on the peak pressure. Then, post hoc analysis was performed using Tukey's method for multiple comparisons of mean differences in peak pressure. The significance level was set at 0.05 ($p < 0.05$), and all statistical analyses were performed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA).

Results

The mean area of the surgically formed free ALPSA lesions was 2.5 ± 0.2 cm^2, and of the Bankart lesions was 2.9 ± 0.1 cm^2. The average humeral head translation was 4.0 ± 0.2 mm superiorly and 2.5 ± 0.2 mm anteriorly. The angular repeatability in abduction was 1.6° ± 0.3° and 1.1° ± 0.3° in external rotation.

In the normal shoulder joint, the peak pressure between the subscapularis muscle and the anterior capsule according to the location of the glenohumeral joint decreased to 83.4 ± 21.2 kPa in 0° abduction and −30° external rotation positions and showed a 300.7 ± 42.9 kPa peak value in the 60° abduction and 60° external rotation positions (Table 2). Generally, as the glenohumeral joint was

Table 2 Contact pressure between the subscapularis and the anterior capsule (normal shoulder)

ER	ABD			
	0°	30°	45°	60°
−30°	83.4 ± 21.2	106.7 ± 30.5	110.5 ± 27.6	110.3 ± 24.9
0°	95.5 ± 23.5	152.1 ± 34.8	163.6 ± 43.2	157.3 ± 33.7
30°	197.9 ± 31.2	229.9 ± 32.7	243.1 ± 35.4	262.8 ± 39.5
45°	217.4 ± 37.5	252.2 ± 37.7	259.9 ± 32.7	275.4 ± 36.7
60°	240.2 ± 36.1	275.2 ± 34.7	283.5 ± 35.5	300.7 ± 42.9

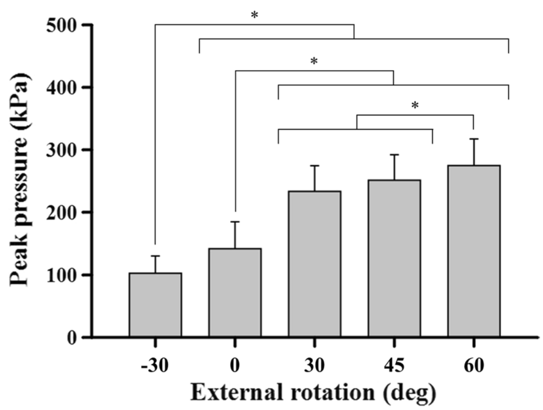

Fig. 3 Contact pressure in normal shoulder among the external rotation angles. *The mean is $p < 0.05$

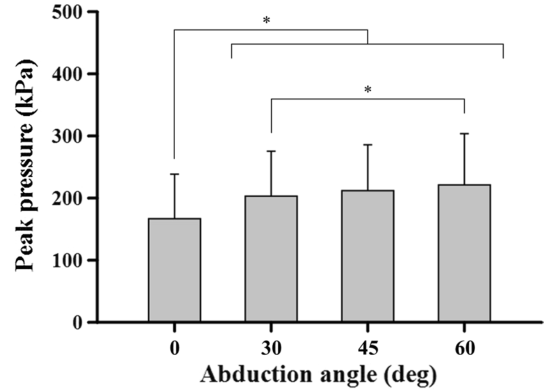

Fig. 4 Contact pressure in normal shoulder among the abduction angles. *The mean is $p < 0.05$

Table 3 Contact pressure between the capsulolabral complex and the glenoid in free ALPSA lesions

ER	ABD			
	0°	30°	45°	60°
−30°	122.1 ± 26.7	164.6 ± 32.1	182.5 ± 32.8	236.9 ± 36.8
0°	134.6 ± 35.8	173.8 ± 40.7	208.9 ± 43.3	267.7 ± 40.4
30°	242.2 ± 49.4	255.3 ± 46.8	276.6 ± 47.7	303.8 ± 54.4
45°	267.3 ± 36.5	296.4 ± 45.5	298.4 ± 55.1	330.1 ± 45.8
60°	289.8 ± 41.1	312.7 ± 47.3	329.3 ± 47.3	382.4 ± 57.3

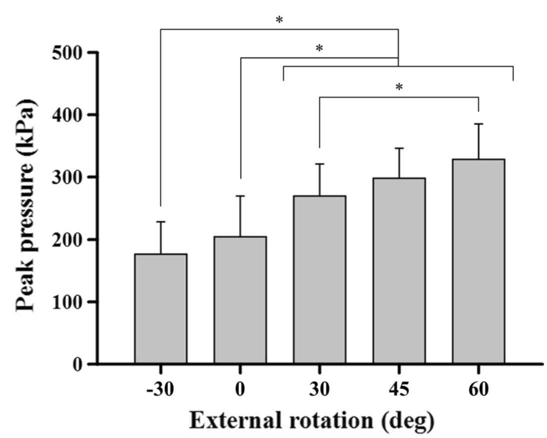

Fig. 5 Contact pressure in free ALPSA lesions among the external rotation angles. *The mean is $p < 0.05$

externally rotated, the mean peak pressure was significantly increased ($p < 0.05$) except between the 30° and 45° (n.s.) (Fig. 3). Similarly, the glenohumeral abduction resulted in the increase in the peak pressure, showing a significance between the 0° and others (i.e. 30°, 45° and 60°) ($p < 0.01$), and the 30° and 60° ($p < 0.043$) only (Fig. 4). Table 3 shows the peak pressures between the capsulolabral complex and the glenoid according to glenohumeral joint location in the free ALPSA lesion. The lowest pressure of 122.1 ± 26.7 kPa was observed at 0° abduction and −30° external rotation, and the highest pressure of 382.4 ± 57.7 kPa at 60° abduction and 60° external rotation. As the glenohumeral joint externally rotated, the peak pressure was significantly increased ($p < 0.01$) except between −30° and 0°(n.s.), 30° and 45° (n.s.), and 45° and 60° (n.s.) (Fig. 5). Similarly, the peak pressures at 60° abduction were significantly greater than other abduction positions ($p < 0.01$) (Fig. 6). The peak pressures between the capsulolabral complex and the glenoid according to glenohumeral joint location in the Bankart lesion are shown in Table 4. The lowest pressure of 91.6 ± 30.1 kPa was observed at 0° abduction, −30° external rotation, and 60° abduction, and the highest pressure of 363.1 ± 49.3 kPa at 60° external rotation. The differences between the −30° and 0° (n.s.), 30° and 45° (n.s.), and 45° and 60° (n.s.) external rotations were not significant, but those between all other external rotation angles were significant ($p < 0.01$) (Fig. 7). The difference between the 0° and 30° abductions (n.s.) was not significant but tended to increase, while the differences between all the other abduction angles were significant ($p < 0.01$) (Fig. 8).

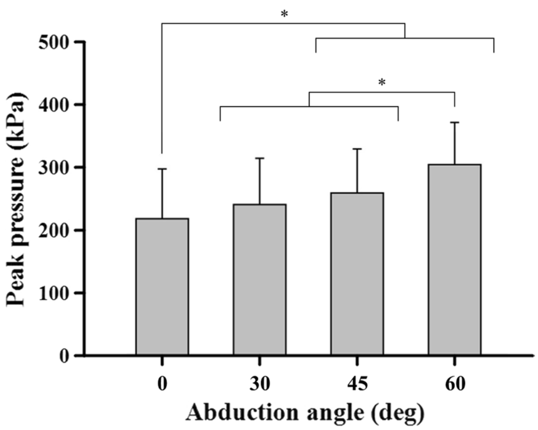

Fig. 6 Contact pressure in free ALPSA lesions among the abduction angles. *The mean is $p < 0.05$

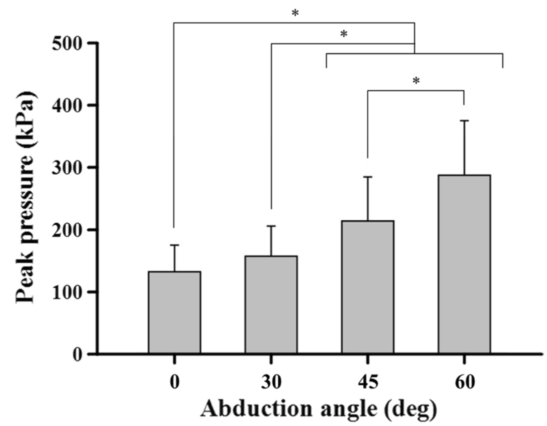

Fig. 8 Contact pressure in Bankart lesions among the abduction angles. *The mean is $p < 0.05$

Table 4 Contact pressure between the capsulolabral complex and the glenoid in Bankart lesions

ER	ABD			
	0°	30°	45°	60°
−30°	91.6 ± 30.1	108.8 ± 33.2	122.8 ± 32.4	183.8 ± 38.3
0°	109.6 ± 33.0	130.7 ± 35.6	176.5 ± 41.3	211.1 ± 51.5
30°	143.8 ± 37.2	166.4 ± 40.4	230.3 ± 39.9	327.4 ± 49.3
45°	154.6 ± 39.5	181.4 ± 39.5	251.5 ± 45.0	351.6 ± 46.5
60°	163.4 ± 36.5	200.2 ± 40.0	288.3 ± 49.4	363.1 ± 49.3

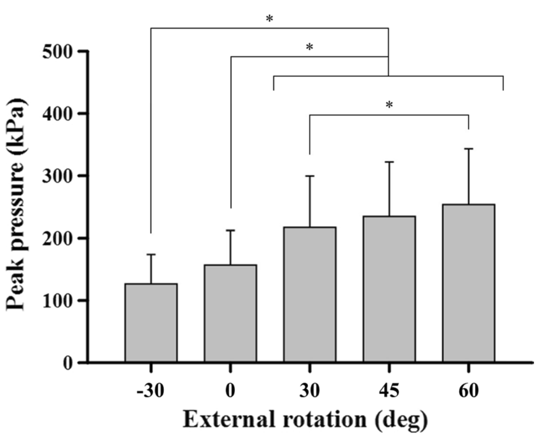

Fig. 7 Contact pressure in Bankart lesions among the external rotation angles. *The mean is $p < 0.05$

Discussion

The purpose of this study was to examine the effects of the conservative treatment on free ALPSA and Bankart lesions through direct measurement of contact pressure between the capsulolabral lesion and glenoid. As a result, the contact pressure significantly increased as the abduction and external rotation angles were increased, and the increase in contact pressure was greater in free ALPSA lesions than in Bankart lesions. These could lead that free ALPSA lesions would be better in reduction than Bankart lesions through immobilization in external rotation in first-time anterior shoulder dislocation.

Anterior shoulder dislocation frequently develops in association with high-energy trauma or sports activities with mean recurrence rates of 33–52 %, which can increase to up to 66–82 % in patients 20 years of age or younger and in athletes [6, 24]. Due to high recurrence rates, new approaches that are unlike conservative treatments for first-time anterior shoulder dislocation have been suggested.

Hart and Kelly [4] performed arthroscopy to treat first-time anterior shoulder dislocation and observed improvements in external rotation of the arm and tightening of the anteroinferior portion of the capsulolabral complex. These improvements in the external rotation of the arm consequently enhanced the reduction in Bankart lesions. Itoi et al. [8] supported that result, showing that capsulolabral complex reduction with 10° external rotation immobilization could reduce the recurrence rate of shoulder dislocation. Pennecamp et al. [18] found that MRI of anterior shoulder dislocation patients showed that labrum location was more physiologic in the external rotation than in other positions. Seybold et al. [22] confirmed that the capsulolabral complex was more significantly reduced in the external rotation position than in the internal rotation position using MRI. In the present study, the peak pressure between the capsulolabral complex and the glenoid showed increases in external rotation. In free ALPSA and Bankart lesions, the peak pressure significantly increased between the 0° and 30° rotations and also increased, but not significantly, between the −30° and 0° external rotations. Therefore, 30° external rotation in the neutral position may be better than internal rotation for maintaining reduction in the capsulolabral complex and the glenoid.

The coaptation effect of the subscapularis muscle is required for capsulolabral complex reduction through external rotation. Limpisvasti et al. [16] denied that coaptation of the subscapularis muscle occurs in external rotation, while Itoi et al. [9] proposed that the coaptation effect was unlikely due to bony geometry, as the lesser tuberosity protrudes anteriorly. However, coaptation pressure caused by the subscapularis muscle was observed in the abduction and external rotation of the glenohumeral joint in the present study. The coaptation power tended to increase with external rotation angle rather than abduction angle. We confirmed that the peak pressure significantly increased at −30° in the 0°, 30°, 45°, and 60° external rotations, but pressure differences were nonsignificant between the 30° and 45°, and 45° and 60° abductions.

It was necessary to confirm whether the coaptation pressure that functioned on the capsulolabral complex actually reduced capsulolabral complex lesions. Unlike previous studies [21, 26], which suggested that Bankart lesions are the most common lesions in shoulder dislocation, recent studies suggested that shoulder dislocations are observed in conjunction with various intra-articular lesions. Kim et al. [12] reported the presence of various intra-articular lesions in patients with first-time shoulder dislocations, and of these, free ALPSA (27.2 %) and Bankart (24.2 %) lesions were most common pathologies. There are many discrepant results among previous studies because of their methodology of approaching the shoulder dislocation as a whole instead of accounting the particular lesions occurring within the dislocation. Thus, it is our thought that without considering the particular lesions found within first-time shoulder dislocations, past studies inevitably obtained contradictory outcomes. Seybold et al. [23] support this perspective as well, noting that significant improvements were observed using external rotation for labroligamentous lesions on the glenoid rim. Perthes lesions showed better reduction than Bankart lesions in external rotation. Considering these results, we chose to examine free ALPSA and Bankart lesions in this study, because reduction was expected to occur through coaptation pressure of the subscapularis muscle only in bony Bankart, Bankart, and free ALPSA lesions, which are near the glenoid, whereas capsular tear and HAGL lesions were not effectively reduced through external rotation. Although the Bankart and free ALPSA lesions are representative capsulolabral lesions caused by anterior shoulder dislocations, they differ because in free ALPSA lesions, the labrum is attached to the periosteum, so lesion reduction is possible not only through coaptation pressure of the subscapularis muscle, but also through tension of the capsule connected to the periosteum via the external rotation of the glenohumeral joint. However, Bankart lesions are not connected to the labrum and the periosteum and therefore can only be reduced by coaptation pressure. Bankart and free ALPSA lesions are most frequently targeted in studies of intra-articular lesions after first-time anterior shoulder dislocation, so we used these lesions in the present study [1, 11, 12, 15].

In Bankart and free ALPSA lesions, the pressure between the capsulolabral complex and the glenoid increased with abduction and external rotation. Free ALPSA lesions showed greater peak pressure and increased pressure compared to Bankart lesions, because the tightening of the anterior capsulolabral complex in the external rotation position on the lesions was the same, but the periosteal ligamentotaxic effect was significantly reduced in the free ALPSA lesions. The pressure also increased in Bankart lesions according to glenohumeral position, but according to studies examining the usefulness of external rotation, the pressure was fixed at the 0° abduction and 10° external rotation positions. Accordingly, the increase in pressure in the Bankart lesion was not significant and was also nonsignificant between −30° and 0° because Bankart lesions showed less pronounced ligamentotaxic effects than did free ALPSA lesions, which consequently showed less reduction. These diverse results for immobilization in external rotation drawn from the previous studies of Bankart lesions are explained by the diversity of intra-articular lesions and ligamentotaxic effects.

The limitations of this study included its small sample size, the fact that it was not an in vivo study, but a cadaveric study, the restrictions in scapular dynamic movement according to shoulder motion, and measurements of passive motion instead of active motion according to muscle power. In addition, we created labral lesions to incite shoulder instability, but gross evaluations of the degree of instability were not possible. Pressure measurement using the K-scan™ system (Tekscan Inc., MA, USA) is inaccurate on surfaces compared to planes. Nevertheless, our results suggest that first-time anterior shoulder dislocations may be successfully treated by reducing the shoulder in the externally rotated position. Our study is meaningful because we have shown that in anterior shoulder dislocation patients, free ALPSA lesions exhibited better reduction and recovery than Bankart lesions through immobilization in external rotation. Thus, differential diagnoses of intra-articular lesions through MRA and MRI are essential, since the identification of these intra-articular injuries may be helpful when selecting patients who may benefit from bracing in the externally rotated position.

Conclusion

Contact pressure between the capsulolabral complex and the glenoid was significantly increased with abduction and increases in the external rotation angle. The increase in contact pressure was much higher in free ALPSA lesions than in Bankart lesions. In first-time anterior shoulder dislocation patients, free ALPSA lesions showed better reduction than Bankart lesions through immobilization in external rotation, indicating that differential diagnosis of intra-articular lesions through MRA or MRI is essential.

Disclaimer This work was supported by a Grant from Yonsei University Wonju College of Medicine (YUWCM-2012-21).

References

1. Antonio GE, Griffith JF, Yu AB, Yung PS, Chan KM, Ahuja AT (2007) First-time shoulder dislocation: high prevalence of labral injury and age-related differences revealed by MR arthrography. J Magn Reson Imaging 26(4):983–991
2. Arciero RA, Taylor DC (1998) Primary anterior dislocation of the shoulder in young patients. A 10-year prospective study. J Bone Joint Surg Am 80(2):299–300
3. Cutts S, Prempeh M, Drew S (2009) Anterior shoulder dislocation. Ann R Coll Surg Engl 91(1):2–7
4. Hart WJ, Kelly CP (2005) Arthroscopic observation of capsulolabral reduction after shoulder dislocation. J Shoulder Elb Surg 14(2):134–137
5. Heidari K, Asadollahi S, Vafaee R, Barfehei A, Kamalifar H, Chaboksavar ZA, Sabbaghi M (2014) Immobilization in external rotation combined with abduction reduces the risk of recurrence after primary anterior shoulder dislocation. J Shoulder Elb Surg 23(6):759–766
6. Hovelius L, Augustini BG, Fredin H, Johansson O, Norlin R, Thorling J (1996) Primary anterior dislocation of the shoulder in young patients. A 10-year prospective study. J Bone Joint Surg Am 78(11):1677–1684
7. Itoi E, Hatakeyama Y, Kido T, Sato T, Minagawa H, Wakabayashi I, Kobayashi M (2003) A new method of immobilization after traumatic anterior dislocation of the shoulder: a preliminary study. J Shoulder Elb Surg 12(5):413–415
8. Itoi E, Hatakeyama Y, Sato T, Kido T, Minagawa H, Yamamoto N, Wakabayashi I, Nozaka K (2007) Immobilization in external rotation after shoulder dislocation reduces the risk of recurrence. A randomized controlled trial. J Bone Joint Surg Am 89(10):2124–2131
9. Itoi E, Hatakeyama Y, Urayama M, Pradhan RL, Kido T, Sato K (1999) Position of immobilization after dislocation of the shoulder. A cadaveric study. J Bone Joint Surg Am 81(3):385–390
10. Jordan RW, Saithna A, Old J, MacDonald P (2015) Does external rotation bracing for anterior shoulder dislocation actually result in reduction of the labrum? A systematic review. Am J Sports Med 43(9):2328–2333
11. Kim DS, Yoon YS, Kwon SM (2010) The spectrum of lesions and clinical results of arthroscopic stabilization of acute anterior shoulder instability. Yonsei Med J 51(3):421–426
12. Kim DS, Yoon YS, Yi CH (2010) Prevalence comparison of accompanying lesions between primary and recurrent anterior dislocation in the shoulder. Am J Sports Med 38(10):2071–2076
13. Konigshausen M, Schliemann B, Schildhauer TA, Seybold D (2014) Evaluation of immobilization in external rotation after primary traumatic anterior shoulder dislocation: 5-year results. Musculoskelet Surg 98(2):143–151
14. Liavaag S, Brox JI, Pripp AH, Enger M, Soldal LA, Svenningsen S (2011) Immobilization in external rotation after primary shoulder dislocation did not reduce the risk of recurrence: a randomized controlled trial. J Bone Joint Surg Am 93(10):897–904
15. Liavaag S, Stiris MG, Svenningsen S, Enger M, Pripp AH, Brox JI (2011) Capsular lesions with glenohumeral ligament injuries in patients with primary shoulder dislocation: magnetic resonance imaging and magnetic resonance arthrography evaluation. Scand J Med Sci Sports 21(6):e291–e297
16. Limpisvasti O, Yang BY, Hosseinzadeh P, Leba TB, Tibone JE, Lee TQ (2008) The effect of glenohumeral position on the shoulder after traumatic anterior dislocation. Am J Sports Med 36(4):775–780
17. Liu A, Xue X, Chen Y, Bi F, Yan S (2014) The external rotation immobilisation does not reduce recurrence rates or improve quality of life after primary anterior shoulder dislocation: a systematic review and meta-analysis. Injury 45(12):1842–1847
18. Pennekamp W, Gekle C, Nicolas V, Seybold D (2006) Initial results of shoulder MRI in external rotation after primary shoulder dislocation and after immobilization in external rotation. Rofo 178(4):410–415
19. Poitras P, Kingwell SP, Ramadan O, Russell DL, Uhthoff HK, Lapner P (2010) The effect of posterior capsular tightening on peak subacromial contact pressure during simulated active abduction in the scapular plane. J Shoulder Elb Surg 19(3):406–413
20. Robinson CM, Howes J, Murdoch H, Will E, Graham C (2006) Functional outcome and risk of recurrent instability after primary traumatic anterior shoulder dislocation in young patients. J Bone Joint Surg Am 88(11):2326–2336
21. Rowe CR, Patel D, Southmayd WW (1978) The Bankart procedure: a long-term end-result study. J Bone Joint Surg Am 60(1):1–16
22. Seybold D, Gekle C, Fehmer T, Pennekamp W, Muhr G, Kalicke T (2006) Immobilization in external rotation after primary shoulder dislocation. Chirurg 77(9):821–826
23. Seybold D, Schliemann B, Heyer CM, Muhr G, Gekle C (2009) Which labral lesion can be best reduced with external rotation of the shoulder after a first-time traumatic anterior shoulder dislocation? Arch Orthop Trauma Surg 129(3):299–304
24. Simonet WT, Cofield RH (1984) Prognosis in anterior shoulder dislocation. Am J Sports Med 12(1):19–24
25. Taskoparan H, Kilincoglu V, Tunay S, Bilgic S, Yurttas Y, Komurcu M (2010) Immobilization of the shoulder in external rotation for prevention of recurrence in acute anterior dislocation. Acta Orthop Traumatol Turc 44(4):278–284
26. Taylor DC, Arciero RA (1997) Pathologic changes associated with shoulder dislocations. Arthroscopic and physical examination findings in first-time, traumatic anterior dislocations. Am J Sports Med 25(3):306–311
27. Vavken P, Sadoghi P, Quidde J, Lucas R, Delaney R, Mueller AM, Rosso C, Valderrabano V (2014) Immobilization in internal or external rotation does not change recurrence rates after traumatic anterior shoulder dislocation. J Shoulder Elb Surg 23(1):13–19
28. Windolf M, Gotzen N, Morlock M (2008) Systematic accuracy and precision analysis of video motion capturing systems—exemplified on the Vicon-460 system. J Biomech 41(12):2776–2780
29. Wu G, van der Helm FC, Veeger HE, Makhsous M, Van Roy P, Anglin C, Nagels J, Karduna AR, McQuade K, Wang X, Werner FW, Buchholz B, International Society of B (2005) ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—part II: shoulder, elbow, wrist and hand. J Biomech 38(5):981–992