Archives of Orthopaedic and Trauma Surgery (2019) 139:181–187
https://doi.org/10.1007/s00402-018-3054-2

TRAUMA SURGERY

Glenoid and rotator interval dimension in patients older than 40 years after traumatic anterior shoulder dislocation

Darius M Thiesen[1] · Marielle Ernst[1] · Jennifer Meyer[1] · Alexander S Spiro[2] · Jin Yamamura[1] · Till O Klatte[1]

Received: 22 May 2018 / Published online: 26 October 2018

Abstract

Introduction The number of patients above 40 years suffering an anterior shoulder dislocation for the first time has recently increased. This study investigated the role of glenoid version, inclination and rotator interval dimension in patients older than 40 years with an anterior shoulder dislocation. We hypothesize that the rotator interval plays a more important role than the osseus alignment in older patients.

Materials and methods Patients aged older than 40 years with a traumatic shoulder dislocation were compared with patients who had undergone magnetic resonance imaging (MRI) for a different reason. The MRIs of 61 dislocation group patients were compared with MRIs of 73 comparison group patients. Two shoulder surgeons measured glenoid version, inclination, height and width, rotator interval (RI) height, base (width) and area. The study and comparison group consisted of 61 patients with a mean age of 59 ± 9 years and 73 patients with a mean age of 57 ± 12, respectively.

Results The mean glenoid version of the dislocation group was $-4.9° \pm 4.4°$ (retroversion) and mean inclination was $9.8° \pm 8°$ (reclination). Mean rotator interval base, height and the rotator interval area was 46 ± 6 mm, 14 ± 5 mm and 33 ± 14 mm^2, respectively. The comparison group had a mean glenoid version of $-5.4° \pm 5.4°$ and a mean inclination of $10.8° \pm 6.2°$. The rotator interval base was 41 ± 6 mm, the height was 16 ± 4 mm and the area was 34 ± 11 mm^2. The between-group differences were statistically significant for rotator interval height and base ($p < 0.0001$). A significant difference was revealed for the height–width ratio of the glenoid ($p = 0.0001$).

Conclusions In patients older than 40 years who have suffered anterior shoulder dislocation, the shape of the glenoid rather than its spatial position is of significance. A wide and high rotator interval promotes anterior shoulder dislocation in these patients.

Keyword Anterior shoulder dislocation · Rotator interval · Glenoid dimension · Patients older than 40 years · MRI measurement · Shoulder anatomy

✉ Darius M Thiesen
d.thiesen@uke.de

Marielle Ernst
m.ernst@uke.de

Jennifer Meyer
jenmeyer@uke.de

Alexander S Spiro
alexander.spiro@kinderkrankenhaus.net

Jin Yamamura
j.yamamura@uke.de

Till O Klatte
t.klatte@uke.de

[1] Department of Trauma, Hand, and Reconstructive Surgery, University Medical Centre Hamburg-Eppendorf, Martinistr. 52, 20246 Hamburg, Germany

[2] Department of Paediatric Orthopaedics, Children's Hospital Altona, University Medical Centre Hamburg, Bleickenallee 38, 22763 Hamburg, Germany

Introduction

The shoulder joint is the most frequent joint to dislocate with a incidence rate of about 23 in 100,000 person-years in industrial countries [18, 30]. Anterior shoulder dislocation is a common reason for patients to seek help in an emergency department. The patients are mostly young, active individuals with a peak around the age of 25 years. However, patients above 40 years have recently caught up [10]. Current studies showed a rising number of dislocation events in older patients [7, 20, 25]. Although demographic change has been progressing, there has been no study so far examining the shoulder morphology in magnetic resonance imaging (MRI) scans of patients above 40 years who suffered a traumatic anterior shoulder dislocation.

There have been several publications dealing with risk factors of younger individuals or athletes who suffered from a traumatic anterior shoulder dislocation, describing the capsuloligamentous structures and dynamic muscle equilibrium [2, 3, 15, 21, 24]. However, only few have taken a closer look to the osseus anatomy of the glenoid and its angulation [9, 14, 21]. It was shown that a high and slim glenoid, a negative inclination and a lesser retroversion of the glenoid increase the likeliness of an anterior shoulder dislocation in younger patients [9]. The degenerative depletion of the rotator cuff [27] in older people and the role of the rotator interval concerning a dislocation event are not fully understood.

The purpose of this study was to measure the glenoid version, inclination, coracohumeral distance, rotator interval and glenoid surface of patients above 40 years of age who suffered a traumatic anterior shoulder dislocation. Comparing these patients with the same age group without a history of shoulder dislocation, we hypothesized that a high and thin glenoid, more anterior version and increased inferior inclination contribute to a higher risk of shoulder joint dislocation in older patients.

Materials and methods

This study was designed as a retrospective comparative study.

Patient population

Our retrospective case–control study included patients who underwent MRI imaging at our radiology department after suffering a traumatic shoulder dislocation for the first time at the age of 40 years or older between 2009 and 2017. One hundred and fourteen MRIs were performed for patients older than 40 years who were treated with a traumatic anterior shoulder dislocation at our trauma center. Fifty-three patients were excluded due to evidence of injuries as stated below or insufficient MRI quality compromising our measurements. Subsequently, the dislocation group consisted of 61 patients (25 female, 36 male) with a mean age of 59 ± 9 years and a median age of 57 years.

The MRI was performed in an outpatient setting. The inclusion criteria were: anterior shoulder dislocation treated at our emergency room, a history of trauma such as fall or low energy bicycle trauma, a documented dislocation by the referring medical practitioner or with a dislocation documented on an available radiograph, an MRI conducted at our radiology department and an age of 40 years and older at the time of injury. Patients were excluded if there were previous fracture dislocations, bony Bankart lesions, high energy trauma, previous surgery to the glenoid or proximal humerus and a history of atraumatic and habitual dislocations. The comparison group consisted of 73 patients (33 female, 40 male) with an age of above 40 years. The main inclusion criteria were the availability of a shoulder MRI with no prior history of shoulder joint dislocation. The indications for the MRIs in the comparison group were rotator cuff tears 28, impingement syndrome 15, calcific tendinitis 4, frozen shoulder 6, biceps tendon injury 3 and unspecific shoulder pain 17.

Imaging

Unilateral noncontrast MRI scans were obtained 6 ± 4 days after the initial trauma using a 3 T system. The scans were performed according to a pre-established protocol consisting of four sequences (PDw SPIR axial and coronal oblique, T1w TSE coronal oblique and T2w TSE sagittal oblique) with a slice thickness of 2.5 mm and a reconstructed voxel size of $X = 0.3$ mm, $Y = 0.3$ mm, $Z = 12$ mm. The results in millimeters have been rounded to the first decimal place. Patient position was supine and the arm held on the side of the body, forearm in supinated position, and the hand under the os ilium to keep the humeral position during the examination. The scans contained oblique coronal, axial and sagittal planes. The coronal oblique images were acquired in a plane parallel to the supraspinatus tendon.

Two trauma surgeons specialized in shoulder surgery reviewed these images separately and independently and measured the glenoid version, glenoid height, glenoid width, coracohumeral distance and rotator interval.

Measurement of the glenoid version

Measurement of the glenoid version was conducted as shown in the study of Hohmann or Tétreault et al. [9, 26]. The axial image directly inferior to the supraspinatus muscle where the posterior border of the scapular neck was first time clearly visible was analyzed. A line was drawn along the axis of the glenoid surface. The scapular axis was defined as another line joining the posterior glenoid neck and junction of the scapular body medially. The glenoid version was defined as the measured angle minus 90. Anteversion was defined as a positive angle and retroversion as a negative angle; see Fig. 1.

Measurement of glenoid inclination

To quantify the glenoid inclination or reclination, the method described by Maurer et al. [19] was used. Therefore, the deepest point of the supraspinatus fossa in the coronal oblique plain was identified, and the scapular body line was drawn through this utmost deepest point. Another line, namely the glenoid fossa line, was defined reaching from the uppermost to the lowest point of the glenoid. Again, by subtracting 90 from the angle formed by the scapular body line and glenoid fossa line, the inclination was calculated. A positive angle indicated caudal (reclination) and a negative angle cranial inclination. See Fig. 2.

Rotator interval

The rotator interval was defined by an imaginary triangle [22, 29]; its base was marked along the superior border of the subscapularis muscle to the anterior border of the supraspinatus muscle and consistently ended at the lateral ridge of the sulcus bicipitalis at the superior margin of the transverse humeral ligament. Based on the imaginary triangle mentioned above, the width of the rotator interval is referred to as the "base" in this study. The triangle's height

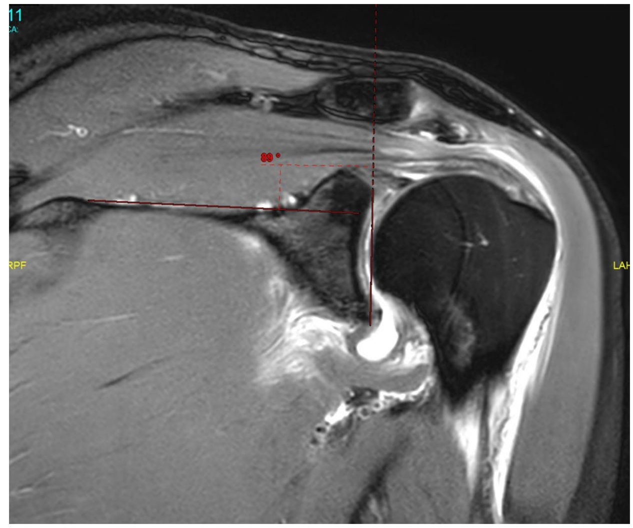

Fig. 2 The measurement of glenoid inclination (reclination) in coronal MRI slides

reached from the superior edge of the subscapularis tendon directly at the lateral base of the coracoid process to the anterior border of the supraspinatus tendon, where it intersected a line orthogonally to the superior edge of the subscapularis tendon at the lateral base of the coracoid. This triangular space contained the biceps tendon, the superior glenohumeral ligament, the glenohumeral capsule, and the coracohumeral ligament.

The measurement of the rotator interval and its area was performed in the same manner as Kim et al., by comparing MRI with MR arthrography [14]. The height was measured on the sagittal image, and the rotator interval base was

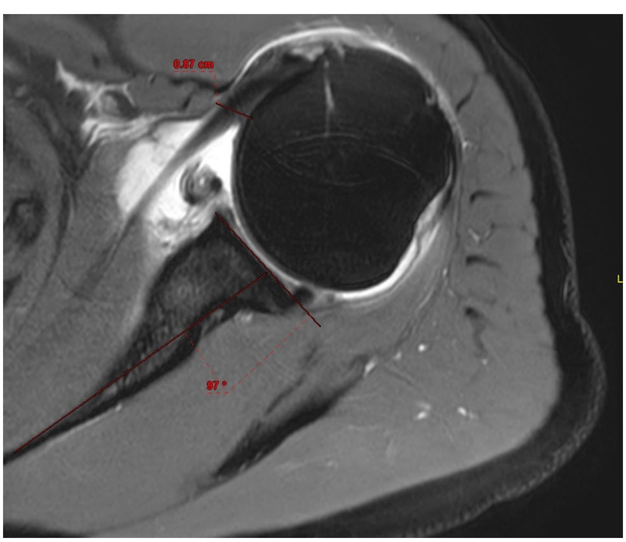

Fig. 1 The measurement of the glenoid version (retroversion) and the coracohumeral distance in axial MRI slides

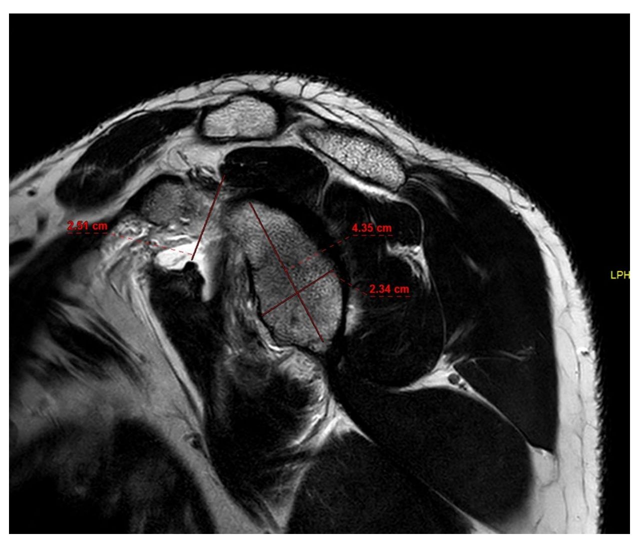

Fig. 3 The measurement of the glenoid width, height and the rotator interval height in the sagittal plane

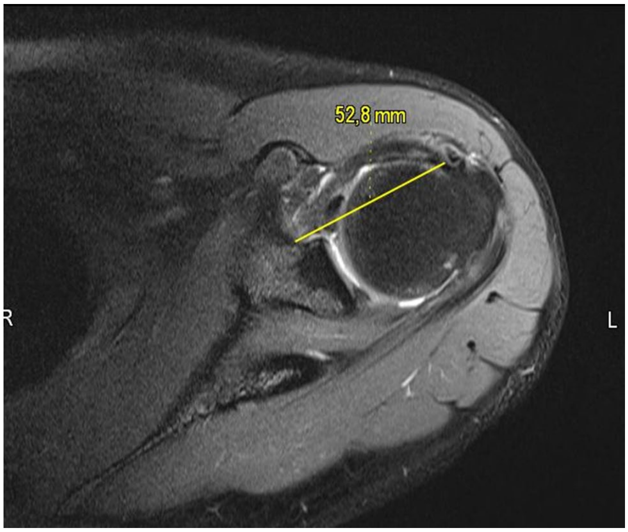

Fig. 4 The measurement of the rotator interval base in axial MRI plane

measured on the axial image as described above; see Figs. 3 and 4. The area was calculated as 0.5 × base × height.

Glenoid measurements

The glenoid height and width were measured using the sagittal plane in which the humeral head disappeared the first time and the rotator cuff was clearly visible. See Fig. 3. The glenoid index was calculated by dividing the height by the width, i.e., height in mm/width in mm = glenoid index.

Statistics

Means and standard deviations were calculated for age, glenoid version, glenoid inclination, base, height, glenoid diameter, rotator interval area and rotator interval index. Independent samples *t* test and Mann–Whitney tests were used to compare the results.

As a measure of interrater reliability, intraclass correlation coefficients (ICCs) were calculated by the two observers for all the measured variables. Based on the 95% confidence interval of the ICC estimate, values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 were indicative for poor, moderate, good, and excellent reliability, respectively [1].

All statistical analyses were performed with SPSS statistical software version 25.0 (SPSS, Chicago, IL). *P* values < 0.05 (2-sided) were considered statistically significant.

Results

The mean version in the dislocation group was −4.9° ± 4.4° (retroversion) and the mean inclination was 9.8° ± 8.3° (reclination); see Table 1. The mean rotator interval height, base and the mean calculated area (rotator interval area) were 14 ± 5 mm, 46 ± 6 mm and 33 ± 11 mm^2, respectively. For the coracohumeral interval, a mean of 12 ± 4 mm in the dislocation group was measured. The mean dimensions of the glenoid height, width and glenoid index were 40 ± 5 mm, 24 ± 4 mm and 1.65 ± 0.2; see Table 2. The mean version in this group was −5.4° ± 5.4° and mean inclination was 10.8° ± 6.2°; see Table 1. For the rotator interval, the following values were measured: 16 ± 4 mm for height, 41 ± 6 mm for base and 34 ± 11 mm^2 for rotator interval area. The glenoid height, width and the glenoid index were 40 ± 4 mm, 26 ± 3 mm and 1.56 ± 0.14, respectively. See Table 2.

The between-group differences were statistically significant for the rotator interval height ($p = 0.0001$) and the rotator interval base ($p < 0.0001$), but not for the rotator interval area ($p = 0.247$). A significant difference too was revealed for the glenoid index between the groups ($p = 0.0001$).

Intraclass correlation coefficient (ICC) analysis gave an excellent interrater reliability for measurement of glenoid

Table 1 The patient demographics, glenoid version and inclination of the dislocation and control group illustrated for both surgeons. The *p* values for the between-group comparison and the interrater evaluation are depicted as well (ICC = intraclass correlation coefficient)

Group	Number	Age, year Mean ± SD	Version, ° Mean ± SD (range)	Inclination, ° Mean ± SD (range)
Dislocation group	61	59.07 ± 13	−4.9 ± 4.4 (−5.7 to −4.1)	9.8 ± 8 (8.3–11.1)
Surgeon 1			−4.7 ± 4.3 (−3.6 to −5.8)	10.2 ± 8.1 (8–12.2)
Surgeon 2			−5.1 ± 4.6 (−4 to −6.3)	9.4 ± 7.8 (7.3–11.4)
ICC			0.915	0.977
p value			0.23	0.3
Comparison group	74	57.31 ± 12	−5.4 ± 5.4 (−6.2 to −4.5)	10.8 ± 6 (9.9–11.8)
Surgeon 1			−5.4 ± 5.1 (−4.1 to −6.6)	10.9 ± 6.2 (9.5–12.3)
Surgeon 2			−5.3 ± 5.6 (−6.6 to −4)	10.6 ± 5.5 (9.3–12)
ICC			0.943	0.97
p value		0.4	0.7	0.2

Table 2 The rotator interval height, base and area, the coracohumeral distance and the glenoid dimensions of the dislocation and comparison group are shown as means

Group	*n*	Age, year	Rotator interval height, mm	Rotator interval base, mm	Rotator interval area, mm^2	Coracohumeral interval, mm	Glenoid height, mm	Glenoid width, mm	Glenoid-index
		Mean ± SD	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)	Mean ± SD (95% CI)
Dislocation group	61	59.07 ± 13	14 ± 5 (13–15)	46 ± 6 (45–47)	33 ± 14 (30–35)	12 ± 4 (11–13)	40 ± 5 (39–41)	24 ± 4 (24–25)	1.65 ± 0.21 (1.6–1.7)
Surgeon 1			18 ± 4 (17–19)	45 ± 7 (44–47)	41 ± 12 (37–44)	13 ± 3 (12–14)	40 ± 5 (39–41)	24 ± 4 (23–25)	1.67 ± 0.19 (1.61–1.71)
Surgeon 2			11 ± 3 (10–12)	47 ± 6 (46–49)	24 ± 10 (21–27)	11 ± 3 (10–11)	41 ± 5 (39–42)	25 ± 4 (24–26)	1.63 ± 2.3 (1.57–1.69)
ICC			0.101	0.786	–	0.607	0.792	0.77	–
Comparison group	74	57.31 ± 12	16 ± 4 (16–17)	41 ± 6 (40–42)	34 ± 11 (32–36)	13 ± 3 (12–13)	40 ± 4 (39–41)	26 ± 3 (25–26)	1.56 ± 0.14 (1.54–1.58)
Surgeon 1			15 ± 3 (15–16)	40 ± 6 (39–42)	31 ± 9 (30–33)	12 ± 3 (11–13)	40 ± 5 (39–41)	25 ± 3 (25–26)	1.57 ± 0.14 (1.52–1.61)
Surgeon 2			17 ± 5 (16–19)	42 ± 6 (41–44)	37 ± 13 (34–40)	13 ± 4 (12–14)	40 ± 5 (39–41)	26 ± 3 (25–27)	1.56 ± 0.13 (1.53–1.59)
ICC			0.478	0.747	–	0.43	0.975	0.984	–
p value (means)		0.4	*0.0001*	*< 0.0001*	*0.247*	0.12	0.3	0.07	*0.0001*

The results of each surgeon are shown as means. *p* values and ICC (intraclass correlation coefficient) are also depicted. The *p*-values were measured between the comparison and dislocation group as means of both measured values of Surgeon 1 and 2

SD standard deviation, *CI* confidence interval

inclination (0.977) and glenoid version (0.915) in the dislocation group and an excellent ICC for inclination (0.943) version (0.97), glenoid height (0.975) and glenoid width (0.984) in the comparison group. For rotator interval height, the ICC was poor in the dislocation group with 0.101, and in the comparison group the ICC was 0.478. For the other ICC values, see Tables 1 and 2.

Discussion

The main finding of this study was the significant difference in rotator interval height, base and area in patients older than 40 years of age who suffered from an anterior shoulder dislocation in comparison to the patients in the comparison group. The second key aspect was the determination of a significantly more slender and higher glenoid in the dislocation group, as shown before in younger athletes [21]. To our knowledge, this is the first study which evaluated the anatomic morphology of the shoulder in case of patients with traumatic shoulder dislocation and an age above 40 years.

The role of the rotator interval in case of anterior shoulder instability is still a controversially discussed field in shoulder surgery. Evaluating its anatomic dimensions and its traumatic lesions is best performed in combination with clinical findings, arthroscopy and MRI or MR arthrography [5, 14, 16]. The rotator interval describes the anatomic space bounded by the coracoid, the subscapularis and supraspinatus. It contains the glenohumeral and coracohumeral ligament, the biceps tendon and the anterior joint capsule. In biomechanical studies, the anatomic structures of the rotator interval have been researched thoroughly and shown to contribute to the stability of the glenohumeral joint to maintain negative intra-articular pressure [13] and to decrease inferior glenohumeral translation [8, 12, 23].

In our cohort, in patients who had an anterior dislocation event the height, base and consequently the rotator interval area were significantly larger than in the comparison group. The fact that this anatomic complex is injured after a dislocation event in 38–49% of patients older than 60 years [25, 28] and our finding of a wider and higher rotator interval in patients who suffered from a shoulder dislocation underline the importance of its extension. Biomechanical studies also show that a dislocation event is more likely if a previous rotator cuff tear is present, which causes imbalance of muscle tension and consequently anterior instability [6, 11].

Kim et al. [14] reported similar findings of significantly different rotator interval dimension in patients who suffered from chronic anterior instability after recurrent shoulder dislocations. They reviewed 120 shoulder MR arthrographies split into two groups, one with shoulder instability ($n = 50$) and the other with no instability

($n = 70$). Despite the same significant results between the cohorts, their estimated values were of larger scale. In contrast to our study, the patients in their dislocation group already suffered from a chronic state of anterior shoulder instability and the mean age was 32 years. The differences in the absolute values may arise from a varying age distribution in our population. This might raise the question whether one event of dislocation in patients older than 40 years already injures the rotator interval to a similar level like in younger patients with a chronic instability. It too may indicate that patients with a wider and higher rotator interval are of higher risk to suffer from a dislocation event in the first place, which at least for the younger patients was not confirmed regarding the rotator base and area by Owens et al. [21] in a large cohort of 714 patients.

The role of the bony alignment of the shoulder joint was investigated by Hohmann et al. [9] for patients younger than 40 years of age who underwent arthroscopic stabilization after a dislocation event. They performed measurements of the glenoid version and inclination in 258 MRI scans divided into a dislocation group ($n = 128$) and a comparison group ($n = 130$). It was demonstrated that patients who had suffered an anterior dislocation event showed a significantly different glenoid version and inclination. They did not measure the bony dimension of the glenoid regarding height, width and area. In a biomechanical cadaveric study [4], a high glenoid inclination led to linear instability on specimen with an average age of 59 ± 4.3 years, consistent with our population. However, this biomechanical connection does not seem to be transferable to everyday clinical practice, as no differences in inclination emerged from our measurements.

One might argue that patients with a less retroverted and inferior oriented glenoid went through a dislocation event earlier in their lives anyway, based on a higher activity level and the given less stable bony alignment of their shoulder joint. In that case, these patients would not have been included in our study due to the inclusion criteria of first time dislocation event.

Our data of glenoid dimension and the ratio of height and width matched former findings in younger patients [17, 21]. While neither height nor width alone but only the ratio—the glenoid index—was significantly different between the groups, this was not surprising, as a thin and high glenoid is susceptible to anterior instability. It was confirmed for patients older than 40 years for the first time.

A previous study investigating the risk of anterior shoulder dislocation in 714 US army members reported a significantly higher dislocation risk in people with a larger coracohumeral interval [21]. In our cohort, we could not find a statistically significant difference, but a slightly larger coracohumeral distance which might indicate an association in people older than 40 years also.

This study has its limitations. The low number of MRI scans in the dislocation group may have limited statistical power for our comparisons between groups. Though the height of the rotator interval was significantly associated with shoulder dislocation in our study, the accuracy of its measurement was poor. This inaccuracy might have been caused by an advanced degeneration of the shoulder joint in elderly patients or due to a fresh injury with still existing joint haematoma; both might have influenced the measurement.

Furthermore, the comparison group did not represent a normal “shoulder-healthy” population in the same age group, but patients with other pathological characteristics which could potentially introduce bias.

Conclusion

Our study is the first to show that in patients above 40 years of age who suffered from an anterior shoulder dislocation, the shape of the glenoid, namely a slim and high glenoid, is significantly different from a non-dislocation comparison group. Furthermore, we could show that the version and reclination or inclination are not significantly different from the normal population.

The role of the musculo-tendinous and ligamentous structures called the rotator interval is of higher importance in patients older than 40 year and should be the subject of future research.

Funding There is no funding source.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights This article does not contain any studies with human participants or animals performed by any of the authors.

References

1. Bartko JJ (1966) The intraclass correlation coefficient as a measure of reliability. Psychol Rep 19:3–11. https://doi.org/10.2466/pr0.1966.19.1.3. Accessed 16 Feb 2018
2. Brophy RH, Marx RG (2009) The treatment of traumatic anterior instability of the shoulder: nonoperative and surgical treatment. Arthrosc J Arthrosc Relat Surg 25:298–304. http://linkinghub.elsevier.com/retrieve/pii/S0749806308009432. Accessed 27 Feb 2017
3. Dodson CC, Cordasco FA (2008) Anterior glenohumeral joint dislocations. Orthop Clin N Am 39:507–518. http://linkinghub.elsevier.com/retrieve/pii/S0030589808000461. Accessed 6 Mar 2017

4. Eichinger JK, Massimini DF, Kim J, Higgins LD (2016) Biomechanical evaluation of glenoid version and dislocation direction on the influence of anterior shoulder instability and development of Hill-Sachs lesions. Am J Sports Med 44:2792–2799. http://www.ncbi.nlm.nih.gov/pubmed/27496904. Accessed 21 Aug 2018
5. Frank RM, Taylor D, Verma NN, Romeo AA, Mologne TS, Provencher MT (2015) The rotator interval of the shoulder. Orthop J Sport Med 3:232596711562149. http://www.ncbi.nlm.nih.gov/pubmed/26779554. Accessed 8 Feb 2018
6. Gomberawalla MM, Sekiya JK, Sekiya JK (2014) Rotator cuff tear and glenohumeral instability. Clin Orthop Relat Res 472:2448–2456. http://www.ncbi.nlm.nih.gov/pubmed/24043432. Accessed 21 Aug 2018
7. Gumina S, Postacchini F (1997) Anterior dislocation of the shoulder in elderly patients. J Bone Jt Surg Br 79:540–3. http://www.ncbi.nlm.nih.gov/pubmed/9250734. Accessed 2 May 2016
8. Harryman DT, Sidles JA, Harris SL, Matsen FA (1992) The role of the rotator interval capsule in passive motion and stability of the shoulder. J Bone Jt Surg Am 74:53–66. http://www.ncbi.nlm.nih.gov/pubmed/1734014. Accessed 8 Feb 2018
9. Hohmann E, Tetsworth K (2015) Glenoid version and inclination are risk factors for anterior shoulder dislocation. J Shoulder Elb Surg 24:1268–1273. http://www.ncbi.nlm.nih.gov/pubmed/25958217. Accessed 8 Dec 2016
10. Hovelius L, Rahme H (2016) Primary anterior dislocation of the shoulder: long-term prognosis at the age of 40 years or younger. Knee Surg Sports Traumatol Arthrosc 24:330–42. http://www.ncbi.nlm.nih.gov/pubmed/26754859. Accessed 7 Apr 2016
11. Hsu HC, Luo ZP, Cofield RH, An KN. Influence of rotator cuff tearing on glenohumeral stability. J Shoulder Elb Surg 6:413–22. http://www.ncbi.nlm.nih.gov/pubmed/9356929. Accessed 21 Aug 2018
12. Hunt SA, Kwon YW, Zuckerman JD (2007) The rotator interval: anatomy, pathology, and strategies for treatment. J Am Acad Orthop Surg 15:218–27. http://www.ncbi.nlm.nih.gov/pubmed/17426293. Accessed 8 Feb 2018
13. Itoi E, Berglund LJ, Grabowski JJ, Naggar L, Morrey BF, An K-N (1998) Superior-inferior stability of the shoulder: role of the coracohumeral ligament and the rotator interval capsule. Mayo Clin Proc 73:508–515. http://www.ncbi.nlm.nih.gov/pubmed/9621856. Accessed 8 Feb 2018
14. Kim K-C, Rhee K-J, Shin H-D, Kim Y-M (2007) Estimating the dimensions of the rotator interval with use of magnetic resonance arthrography. J Bone Jt Surg 89:2450. http://www.ncbi.nlm.nih.gov/pubmed/17974888. Accessed 27 Feb 2017
15. Labriola JE, Lee TQ, Debski RE, McMahon PJ (2005) Stability and instability of the glenohumeral joint: the role of shoulder muscles. J Shoulder Elb Surg 14:32S–38S. http://www.ncbi.nlm.nih.gov/pubmed/15726085. Accessed 27 Feb 2017
16. Lee JC, Guy S, Connell D, Saifuddin A, Lambert S (2007) MRI of the rotator interval of the shoulder. Clin Radiol 62:416–423. http://www.ncbi.nlm.nih.gov/pubmed/17398265. Accessed 8 Feb 2018
17. Lenart BA, Freedman R, Van Thiel GS, Dhawan A, McGill KC, Basu S, Meyer JR, Provencher CMT, Cole BJ, Romeo AA, Verma NN (2014) Magnetic resonance imaging evaluation of normal glenoid length and width: an anatomic study. Arthrosc J Arthrosc Relat Surg 30:915–920. http://www.ncbi.nlm.nih.gov/pubmed/24813321 Accessed 16 Feb 2018
18. Leroux T, Wasserstein D, Veillette C, Khoshbin A, Henry P, Chahal J, Austin P, Mahomed N, Ogilvie-Harris D (2014) Epidemiology of primary anterior shoulder dislocation requiring closed reduction in Ontario, Canada. Am J Sports Med 42:442–50. http://www.ncbi.nlm.nih.gov/pubmed/24275862. Accessed 29 July 2018
19. Maurer A, Fucentese SF, Pfirrmann CWA, Wirth SH, Djahangiri A, Jost B, Gerber C (2012) Assessment of glenoid inclination on routine clinical radiographs and computed tomography examinations of the shoulder. J Shoulder Elb Surg 21:1096–1103. http://www.ncbi.nlm.nih.gov/pubmed/22036540. Accessed 6 Mar 2017
20. Murthi AM, Ramirez MA (2012) Shoulder dislocation in the older patient. J Am Acad Orthop Surg. 20:615–622. http://www.ncbi.nlm.nih.gov/pubmed/23027691. Accessed 27 Feb 2017
21. Owens BD, Campbell SE, Cameron KL (2014) Risk factors for anterior glenohumeral instability. Am J Sports Med 42:2591–2596. https://doi.org/10.1177/0363546514551149. Accessed 27 Feb 2017
22. Petchprapa CN, Beltran LS, Jazrawi LM, Kwon YW, Babb JS, Recht MP (2010) The rotator interval: a review of anatomy, function, and normal and abnormal MRI appearance. Am J Roentgenol 195:567–576. https://doi.org/10.2214/AJR.10.4406. Accessed 27 Feb 2017
23. Pradhan RL, Itoi E (2001) Rotator interval lesions of the shoulder joint. Orthopedics 24:798–801. http://www.ncbi.nlm.nih.gov/pubmed/11518414. Accessed 8 Feb 2018 **(quiz 802–3)**
24. Rhee YG, Cho NS, Cho SH (2009) Traumatic anterior dislocation of the shoulder: factors affecting the progress of the traumatic anterior dislocation. Clin Orthop Surg 1:188. https://synapse.koreamed.org/DOIx.php?id=10.4055/cios.2009.1.4.188. Accessed 27 Feb 2017
25. Shin S-J, Yun Y-H, Kim DJ, Yoo JD (2012) Treatment of traumatic anterior shoulder dislocation in patients older than 60 years. Am J Sports Med 40:822–7. http://www.ncbi.nlm.nih.gov/pubmed/22287643. Accessed 2 May 2016
26. Tétreault P, Krueger A, Zurakowski D, Gerber C (2004) Glenoid version and rotator cuff tears. J Orthop Res 22:202–207. https://doi.org/10.1016/S0736-0266%2803%2900116-5 Accessed 6 Mar 2017
27. Teunis T, Lubberts B, Reilly BT, Ring D (2014) A systematic review and pooled analysis of the prevalence of rotator cuff disease with increasing age. J. Shoulder Elb Surg 23:1913–1921. http://www.ncbi.nlm.nih.gov/pubmed/25441568. Accessed 6 Mar 2017
28. Toolanen G, Hildingsson C, Hedlund T, Knibestöl M, Oberg L (1993) Early complications after anterior dislocation of the shoulder in patients over 40 years. An ultrasonographic and electromyographic study. Acta Orthop Scand 64:549–52. http://www.ncbi.nlm.nih.gov/pubmed/8237322. Accessed 8 Feb 2018
29. Woertler K (2015) Rotator interval. Semin Musculoskelet Radiol 19:243–253. http://www.thieme-connect.de/DOI/DOI?10.1055/s-0035-1549318. Accessed 27 Feb 2017
30. Zacchilli MA, Owens BD (2010) Epidemiology of shoulder dislocations presenting to Emergency Departments in the United States. J Bone Jt Surg Am 92:542–549. http://www.ncbi.nlm.nih.gov/pubmed/20194311. Accessed 29 July 2018