Original Research

Ultrasound Assessment of Anterior Humeral Head Translation in Patients With Anterior Shoulder Instability

Correlation With Demographic, Radiographic, and Clinical Data

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Background: Ultrasonography can be used to quantitatively assess anterior humeral head translation (AHHT) at different degrees of shoulder abduction. Risk factors for recurrent shoulder instability have been identified.

Hypothesis: It was hypothesized that the number of dislocations or glenoid or humeral bone loss would be associated with more AHHT as measured using ultrasound.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 39 patients who underwent surgery for anterior shoulder instability were prospectively studied. Ultrasound assessment of AHHT was performed immediately after general anesthesia was induced. The upper arm was placed at 0°, 45°, and 90° of abduction, and a 40-N anterior force was applied to the proximal third of the arm. The distance from the posterior edge of the glenoid to that of the humeral head was measured at each abduction angle using ultrasound with and without a 40-N anterior force, and the AHHT was calculated. The differences in translation at each shoulder angle were compared. Additionally, the authors investigated the association between AHHT and demographic, radiographic, and clinical data.

Results: Compared with the AHHT at 0° of abduction (5.29 mm), translation was significantly larger at 45° of abduction (8.90 mm; $P < .01$) and 90° of abduction (9.46 mm; $P < .01$). The mean translation was significantly larger in female patients than in male patients at all degrees of abduction ($P \leq .036$ for all). There was no correlation between AHHT at any abduction angle and number of dislocations, clinical data, or radiographic data (including bone loss).

Conclusion: Ultrasound assessment of AHHT showed larger amounts of laxity at 45° and 90° than at 0° of abduction. Anterior glenohumeral laxity was greater in female than male patients. Glenoid or humeral bone loss did not correlate with AHHT, thereby clarifying that bone loss has no direct effect on measurements of capsular laxity in neutral rotation.

Keywords: translation; glenohumeral joint; instability; dislocation; ultrasonography

Anterior shoulder instability is a common problem among collision and contact sports athletes, especially when using their upper limbs. According to the National Collegiate Athletic Association Injury Surveillance System, shoulder injury is the third most common injury after knee and ankle injuries, and glenohumeral instability accounts for 23% of total shoulder injuries.[23] Persistent shoulder instability limits the participation of athletes in their regular sports and physical activities[21,36] and is treated nonoperatively or surgically.[2] To objectively assess anterior humeral translation, the load and shift test or the anterior drawer test is used in clinical settings. Although these tests are important to distinguish between intact and pathological translations, the difference in the translation between individuals is still unknown since the tests are nonquantitative and show insufficient reproducibility.[9,18] However, the relationship between translation of the humeral head and characteristics of the patients (number of dislocations, demographics,

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presence of capsular tear and glenoid or humeral bone loss) needs to be clarified. Hence, to investigate this relationship, objective assessment methods are warranted.

Stress radiography, motion capture, navigation systems, and ultrasonography have been used in earlier reports to dynamically evaluate the joint.[4,13,16,25,33] In particular, ultrasonography enables the assessment of patients repeatedly and dynamically, without any invasion or radiation exposure. Even ultrasonography-based quantitative analysis has been used for evaluating the translation of humeral head with a high reproducibility in a cadaveric study.[33] Previous studies using stress radiograph or ultrasound showed that patients with anterior shoulder instability had larger translation than a healthy shoulder when the humeral head was pushed anteriorly.[12,25] However, the difference in the translation between the positions of the shoulder or the factors affecting the translation remains unknown. Especially in the clinical setting, knowledge of the effect of an increasing number of dislocations or bone loss on the increase in pathological translation of the humeral head would be helpful for making treatment decisions.

The purpose of this study was (1) to quantitatively assess the translation of the anterior humeral head by ultrasound measurements at various shoulder abduction angles and (2) to investigate the demographic, radiological, or clinical factors associated with the extent of anterior humeral head translation (AHHT). We hypothesized that quantitative assessment using ultrasound would show differences in the amount of anterior translation depending on shoulder abduction angle, as well as demonstrate the factors associated with the increased translation for patients with anterior shoulder instability. We hypothesized that an increasing number of dislocations, bone defects, and capsular tears would increase the magnitude of the translation.

METHODS

Patients

The protocol for this prospective case series was approved by the institutional review board of our institution, and all participants provided informed consent. We retrieved the data of 39 patients (39 shoulders) who underwent ultrasound measurements to evaluate the preoperative glenohumeral instability of patients who underwent surgery for traumatic anterior shoulder instability. The measurements were obtained between March 2020 and April 2021. Our institution specializes in arthroscopy and sports medicine. Although 78 patients underwent surgery for traumatic anterior shoulder instability during the study period, we performed the ultrasound measurements only when surgery was undertaken by a particular surgeon (A.T.) with more than 20 years of experience in arthroscopic surgery and ultrasound examination, who was assisted by another colleague (N.O.) having more than 7 years of experience. None of the 39 patients had multidirectional instability or unstable painful shoulders, which was confirmed by the preoperative physical examination of all patients (including those who were unaware of the apparent dislocation).

Ultrasound Measurement

Ultrasound measurements were performed immediately after general anesthesia was induced, and an interscalene block was performed with 10 mL of 0.25% levobupivacaine to reduce postoperative pain in all patients. The forearm was fixed in a neutral rotation position with an arm holder (TRIMANO FORTIS; Arthrex), the elbow was fixed at 90° using a goniometer, and the shoulder was fixed in the neutral rotation in the beach-chair position with the back of the bed flexed at 45° under general anesthesia. We used a 3- to 11-MHz linear matrix array ultrasound transducer (SONIMAGE HS1; Konica Minolta). The depth was set to 45 mm. An ultrasound probe was set parallel to the scapular spine, from the posterior part of the shoulder. The probe location was set at the level of the inferior edge of the infraspinatus tendon. The proximal third of the upper arm was drawn anteriorly with 40-N forces using a dynamometer (Ergo FET; Nihon Medix) at 0°, 45°, and 90° of shoulder abduction (Figure 1).

When changing the abduction angle, a compression force was applied to reduce the anterior shift of the distracted humeral head.[33] The shoulders were maintained at the neutral rotation position after changing the abduction angle that was confirmed by the long axis of the forearm directed parallel to the anterior-posterior axis of the body. The preserved sonographic images were transferred to the picture archiving and communication system (RapideyeCore; Canon Medical Systems) and analyzed by another orthopaedic surgeon (J.I.) who was blinded to these measurements during the operation. To measure the anterior translation, 2 parallel lines were drawn through the

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Ethical approval for this study was obtained from Meitetsu Hospital (study No. 238).

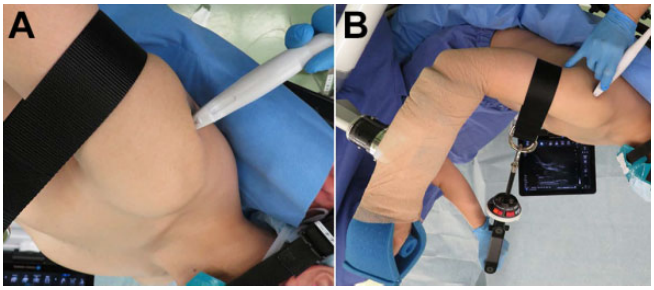

Figure 1. Positions of the arm and ultrasound probe during ultrasound measurements. (A) Anterior shoulder translation was measured with the forearm fixed and elbow positioned at 90° of flexion in the beach-chair position with the back of the bed flexed at 45° under general anesthesia. Another third proximal humeral line was drawn anteriorly with 40-N forces using a dynamometer at 0°, 45°, and 90° of shoulder abduction. (B) An ultrasound probe was set parallel to the scapular spine from the posterior part of the shoulder.

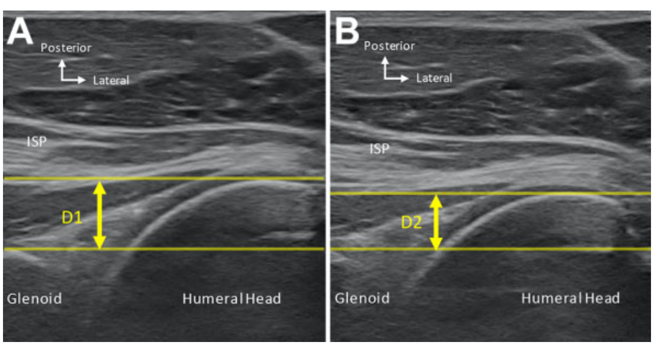

Figure 2. Ultrasound assessment of anterior translation in the glenohumeral joint. Two parallel lines (yellow straight lines) are drawn through the posterior edges of the glenoid and the humeral head shown in panels A and B. D1 and D2 are the shortest distances measured between the 2 parallel lines (vertical yellow lines with arrows) (A) without the 40-N distraction force and (B) with it toward the humeral head, respectively. The difference between D1 and D2 was calculated as the anterior translation. ISP, infraspinatus tendon.

posterior edges of the glenoid and the humeral head (Figure 2).

The shortest distance between the 2 lines was measured without the 40-N distraction force (D1) and with it (D2). When the posterior edge of the humeral head was anteriorly aligned to the posterior edge of the glenoid, D1 and D2 were assigned negative values. The AHHT was calculated by subtracting D2 from D1.

Study Variables

Potential patient characteristics associated with varying AHHT values were collected from the medical records. Specifically, we gathered data on patient age, sex, height, weight, body mass index, number of dislocations or

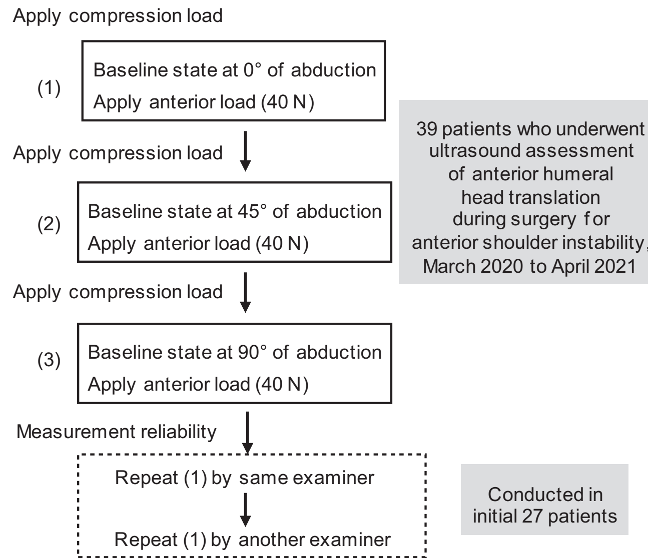

Figure 3. Flowchart of the study protocol.

subluxation, age at first dislocation or subluxation, duration of symptoms, radiographic data, capsular tears, and preoperative clinical evaluation using the Rowe score. Using 3-dimensional computed tomography (CT) reconstruction, we calculated glenoid bone loss as a percentage of the defect width against the diameter of a best-fit circle on the inferior glenoid rim.[32] We also measured the length and width of the Hill-Sachs lesions; lesion depth was obtained from an axial slice of the CT image using a previously published evaluation protocol.[24] These measurements were utilized to calculate whether the combined bone loss was on-track or off-track.[22] The existence of capsular tears and partial- or full-thickness rotator cuff tears was determined from the surgical report and preoperative magnetic resonance imaging, respectively.

Test-Retest Reliability

To determine inter- and intraobserver reliability (intraclass correlation coefficient $[ICC]_{2,1}$ and $ICC_{1,1}$, respectively), the measurement at 0° of shoulder abduction was repeated by the same 2 surgeons who conducted the ultrasound evaluation. Adequate sample size was calculated as 27 cases (tolerance limit, 0.2; ICC, 0.85); thus, ICC analysis was conducted in the first 27 patients reviewed (Figure 3). The ICC values were interpreted according to a previous study,[11] in which ICC <0.50 was considered poor reliability, 0.50 to 0.75 moderate, 0.76 to 0.90 good, and >0.90 excellent.

Statistical Analysis

The AHHTs at each angle of abduction were compared with the paired *t* test. To determine the association between each explanatory variable and AHHT at each angle of abduction, we performed bivariate analyses using the Pearson correlation coefficient (r) for continuous variables and the Mann-

TABLE 1
Patient Characteristics (N = 39)[a]

Variable	Value
Age, y	24.1 ± 10.2 (15-51)
Sex, male/female	35 (89.7)/4 (10.3)
Height, cm	168.9 ± 6.7
Body weight, kg	67.5 ± 9.2
Body mass index	23.6 ± 2.3
No. of dislocations/subluxation	12.7 ± 19.7 (1-100)
Age of first dislocation/subluxation, y	18.3 ± 6.8
Duration of symptoms, y	5.8 ± 7.1 (2 mo–30 y)
Glenoid bone loss, %	14.7 ± 7.8 (0-38.6)
Hill-Sachs lesion size, mm	
Length	19.2 ± 9.0 (0-29.8)
Width	11.4 ± 6.8 (0-31.3)
Depth	4.1 ± 2.2 (0-8.4)
On-track/off-track	28 (71.8)/11 (28.2)
Capsular tear	5 (12.8)
Partial- or full-thickness rotator cuff tear	0 (0)
Rowe score (n = 38)	32.1 ± 20.0

[a]Data are reported as mean ± SD (range) in the case of continuous variables or No. of shoulders (%) in the case of dichotomous variables.

Whitney *U* test for dichotomous variables. Statistical analyses were performed using SPSS Version 21.0 software (IBM). Statistical significance was set at $P < .05$.

The statistical power was calculated with a priori analysis using G*Power Version 3.1.9 (Heinrich Heine University) to determine the required sample size for identifying the changes between pre- and postoperative translation distance. At least 26 cases were needed to achieve a power of 0.8 with the effect size set at 0.5 and significance (α) set at .05.

RESULTS

Table 1 presents the baseline characteristics of the 39 study patients. The preoperative Rowe score was unavailable in 1 patient.

With regard to the reliability of the AHHT measurements, $ICC_{1,1}$ and $ICC_{2,1}$ were 0.810 (95% CI, 0.628-0.908) and 0.724 (95% CI, 0.481-0.864), respectively, indicating moderate to good reliability. The mean AHHT was 5.29 ± 3.12 mm at 0° of abduction, 8.90 ± 5.16 mm at 45° of abduction, and 9.46 ± 4.40 mm at 90° of abduction. The mean AHHTs at both 45° and 90° of abduction were larger than that at 0° of abduction ($P < .01$ for both) (Figure 4). No significant association was observed between each explanatory variable and the AHHT at each angle of abduction (Table 2).

Capsular tear and glenoid track did not affect AHHT at any shoulder abduction angle (Table 3).

DISCUSSION

This study is the first to show that in patients with traumatic anterior shoulder instability, AHHT was larger at 45° and 90° of shoulder abduction than at 0°. Moreover,

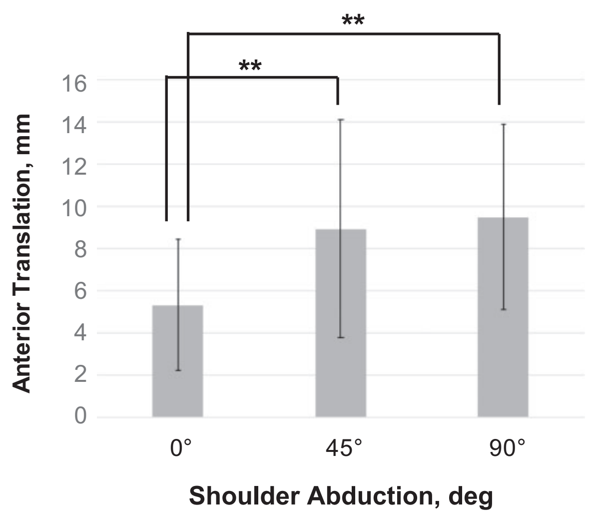

Figure 4. Anterior humeral head translation at each angle of shoulder abduction. **Significant difference ($P < .01$).

increased AHHT was associated with female sex regardless of any abduction angle; other factors, including the increasing number of dislocations or bone loss, were not associated with increased AHHT.

Previous studies have used ultrasound, stress radiographs, and motion-tracking systems to measure humeral head translation. Ultrasound measurements are used for assessing the dynamic movement without radiographic exposure, which is used with anterior and posterior approaches based on the position of the probe. Jerosch et al[8] first reported the use of ultrasound using a posterior approach to assess glenohumeral joint instability. Borsa et al[4] reported the use of the posterior approach and validated ultrasound assessment as having good repeatability for asymptomatic shoulder translation, compared with stress radiography. Rathi et al[28] compared the anterior and posterior ultrasonographic approaches and concluded that the posterior approach had greater intra- and interrater reliability. Importantly, the posterior approach is advantageous because the scapular spine is useful as a bony landmark, which can be used to set the probe at a reproducible position. In the current study, the interobserver reliability was moderate ($ICC_{2,1}$, 0.724) and intraobserver reliability was good ($ICC_{1,1}$, 0.810), which was comparable with previous reports that used the posterior approach.[4,28] This study had the advantage of using a dynamometer to perform quantitative distraction force to the humeral head during the translation test.

Previous studies of AHHT in the healthy shoulder showed a wide range of translation distance: 7.5 to 11.3 mm of translation with a 67- to 134-N anterior force at 0° of abduction with neutral rotation according to Sauers et al[30]; 1.3 mm of translation with a 150-N distraction force at 90° of abduction with neutral rotation according to Park et al[25]; and 2 to 3 mm of translation with a 100-N distraction force at 90° of abduction with 60° of external rotation according to Borsa et al.[4] These inconsistent results may reflect either the difference

TABLE 2
Correlation Analysis Between Each Explanatory Variable and AHHT at Each Angle of Shoulder Abduction[a]

	0° of Abduction		45° of Abduction		90° of Abduction	
	r	*P*	*r*	*P*	*r*	*P*
Age	0.054	.745	–0.137	.407	–0.110	.507
Height	–0.263	.106	–0.140	.396	–0.105	.526
Body weight	–0.303	.061	–0.189	.248	–0.078	.638
Body mass index	–0.205	.210	–0.143	.387	–0.026	.874
No. of dislocations/subluxations	–0.132	.422	–0.212	.195	0.067	.687
Age of first dislocation/subluxation	–0.043	.794	–0.143	.387	–0.081	.624
Duration of symptoms	0.122	.460	–0.062	.709	–0.087	.600
Glenoid defect	–0.120	.467	–0.133	.495	0.093	.573
Hill-Sachs lesion length	–0.009	.959	0.156	.343	0.049	.768
Hill-Sachs lesion width	0.072	.662	0.084	.610	0.017	.916
Hill-Sachs lesion depth	0.052	.751	0.189	.248	0.149	.364
Rowe score	–0.201	.225	–0.108	.518	0.092	.582

[a]The mean anterior humeral head translation (AHHT) in females was significantly larger than that in males at all shoulder abduction angles ($P \leq .036$ for all).

TABLE 3
Comparison of AHHT According to Sex, Capsular Tear, and Glenoid Track[a]

	0° of Abduction	45° of Abduction	90° of Abduction
Sex			
Male	4.83 ± 2.72	8.15 ± 4.87	8.87 ± 3.98
Female	9.27 ± 3.78	15.48 ± 2.02	14.63 ± 5.05
P	**.036**	**.01**	**.01**
Capsular tear			
Positive	6.77 ± 4.92	8.41 ± 4.42	6.34 ± 3.19
Negative	5.07 ± 2.81	8.98 ± 5.31	9.92 ± 4.40
P	.356	>.999	.098
Glenoid track			
On	5.49 ± 3.44	9.02 ± 5.24	9.52 ± 4.81
Off	4.90 ± 2.20	8.47 ± 5.17	9.72 ± 3.30
P	.794	.770	.508

[a]Data are reported as mean ± SD. Boldface *P* values indicate a statistically significant difference. AHHT, anterior humeral head translation.

of distraction methods among previous studies or the difficulty of suppressing muscle contraction; the examinations were conducted in conscious patients, and contraction of rotator cuff muscles may restrict humeral head translation.[29] Previous studies on anterior shoulder instability have reported an AHHT of 3.4 mm with a 150-N distraction force at 90° of abduction with neutral rotation (Park et al) and an AHHT of 4.9 mm with a 90-N distraction force at 0° of abduction with internal rotation (Krarup et al[12]); AHHT in the current study was 5.29 mm at 0°, 8.90 mm at 45° and 9.46 mm at 90°. A smaller translation distance than that reported in this study was reported in earlier studies despite a larger distraction force, which was because we performed the examinations under general anesthesia. Faber et al[7] compared the anterior shoulder translations obtained in the awake conditions and under anesthesia for patients with traumatic anterior shoulder instability. They reported slight differences between both sides when patients were awake, while the differences became obvious when the patients were under anesthesia. In this study, to identify factors associated with increased translation, we needed to investigate the translation under anesthesia because the distances had a broader range than those awake under examination.[7]

Until now, no studies have investigated the differences between AHHTs at different abduction angles. Each glenohumeral ligament plays an important role at different angles of shoulder abduction.[1,10,20,31,34] The superior glenohumeral ligament is an important stabilizer at 0° of abduction.[1,10] The middle glenohumeral ligament is important at 45° and 90° of abduction.[20,34] Further, the anterior-inferior glenohumeral ligament is important at 90° of abduction.[31,34] The current study showed that AHHT in 0° of abduction was smaller than those at 45° or 90° of abduction. Clinically, this result suggests that the assessment for AHHT only at 0° of abduction would be insufficient since increased AHHT can become apparent at 45° or 90° of abduction.

Female sex was shown to be the only factor associated with high AHHT at all angles of shoulder abduction. The difference between the sexes associated with shoulder instability has been reported previously.[14,15,19,26,35] Female athletes participating in soccer, basketball, and rugby have been reported to have a higher risk of shoulder dislocation compared with their male counterparts.[23,27] The Multicenter Orthopaedic Outcomes Network study group reported that capsular laxity was higher in females, whereas labral pathology and bone defect were higher in males.[15] The higher frequency of capsular laxity in females would increase AHHT.

There was no correlation between AHHTs and an increasing number of dislocations, bone defects, or capsular tears, which contradicted our hypothesis. Previous studies showed that an increasing number of dislocations have been associated with the development of glenoid and humeral bone defects[6,17,32] and that glenoid and humeral bone defects have been among the most important risk factors for recurrent dislocations.[3,5] Considering our results and those of previous studies, a higher risk of recurrent dislocations in the patients with bone defect seemed to result from the Hill-Sachs lesion engaging easily with the glenoid rim, not from increasing AHHT.

Limitations

We need to acknowledge the limitations of this study. First, this study had a comparatively small sample size, and a power analysis was set to detect the strong correlations. Hence, it was possible to miss the small or moderate factors associated with AHHT. Second, our quantitative distraction technique was performed on the skin and distraction was applied to the proximal humerus and not to the humeral head. Therefore, the anterior distraction force to the glenohumeral joint could be affected by the thickness and/or stiffness of the soft tissue. Third, AHHT was not measured in shoulders of the contralateral side because the measurement for the contralateral side required another setting to fix the arm and took too much time for patients under general anesthesia. Hence, it was unknown how much of the anterior laxity resulted from anatomic injuries or generalized laxity. Fourth, although the labral tear size or type had the possibility of influencing the translation, these factors could not be included because the operating reports lacked details about labral pathology. Fifth, AHHT was assessed in neutral rotation, although the Hill-Sachs engagement on the glenoid rim occurs with combined abduction and external rotation and most anterior instability events occur with the arm externally rotated. Despite these limitations, the current study is valuable in revealing a quantitative difference in AHHT among different shoulder abduction angles and clarifies that female sex is the only risk factor for increased translation. In future studies, AHHT will be postoperatively assessed using the same protocol.

CONCLUSION

Ultrasound assessment of AHHT shows larger amounts of laxity at 45° and 90° than at 0°. Anterior glenohumeral laxity is increased in female patients. Meanwhile, glenoid or humeral bone loss did not correlate with AHHT, thereby clarifying that bone loss has no direct effect on the measurements of capsular laxity in neutral rotation.

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