



Estimation of Location and Extent of Labral Tear Based on Preoperative Range of Motion in Patients Undergoing Arthroscopic Stabilization for Anterior Shoulder Instability

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Purpose: To determine whether range of motion (ROM) varies with the location and extent of labral tear seen in patients undergoing arthroscopic anterior shoulder stabilization. **Methods:** Consecutive patients undergoing arthroscopic anterior shoulder stabilization who were enrolled in the Multicenter Orthopaedic Outcomes Network Shoulder Instability database underwent a preoperative physical examination and intraoperative examination under anesthesia in which ROM was recorded. Intraoperatively, the location and extent of the labral tear was recorded using conventional clock-face coordinates. Patients were grouped by combinations of quadrants involved in the labral tear (G1-G7): G1 = anterior only, G2 = anterior + inferior, G3 = anterior + inferior + posterior, G4 = all quadrants, G5 = superior + anterior, G6 = superior + anterior + inferior, and G7 = posterior + superior + anterior. Statistical analyses were performed with the Kruskal–Wallis rank-sum test. When $P < .05$, a post-hoc Dunn's test was performed. For categorical variables, the χ^2 test was performed. We performed a series of bivariate negative binomial regression models testing pairwise combinations of ROM parameters predicting the count of labral tear locations (possible: 0-5) within each quadrant. **Results:** A total of 467 patients were included, with 13 (2.8%) in G1, 221 (47.3%) in G2, 40 (8.6%) in G3, 51 (10.9%) in G4, 18 (3.9%) in G5, 121 (25.9%) in G6, and 3 (0.6%) in G7. Multiple statistically significant differences were noted in ROM, specifically active internal rotation at side (IRS) ($P = .005$), active abduction ($P = .02$), passive IRS ($P = .02$), and passive external rotation in abduction ($P = .0007$). Regression modeling revealed a positive correlation between passive abduction and predicted count of labral tear locations in the superior quadrant and between passive IRS and predicted count of labral tear location in the inferior quadrant. **Conclusions:** In patients undergoing arthroscopic shoulder stabilization for anterior instability, ROM varies with location and extent of labral tear. However, the clinical relevance of such small ROM differences remains undetermined. **Level of evidence:** II, prospective comparative study.

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The authors report the following potential conflicts of interest or sources of funding: Outside funding and grants received that assisted in this study are listed below along with the source of funding and grant number: An Orthopaedic Research Education Foundation Grant was received for financial assistance with this study. The grant number is: 14-003. Research reported in this publication was supported by the National Center for Advancing Translational Sciences of the National Institutes of Health under Award Number UL1TR002537. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The study is supported by the National Institute of Health (NIH) Clinical and Translational Science Awards (CTSA) grant U54TR001356. Full ICMJE author disclosure forms are available for this article online, as [supplementary material](#).

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Received February 4, 2020; accepted May 23, 2020.

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<https://doi.org/10.1016/j.asmr.2020.05.014>

Recurrent glenohumeral instability remains among the most common of shoulder pathologies in young, athletic, and/or working patient populations. For appropriately indicated patients, surgical management is beneficial due to the high incidence of recurrent anterior shoulder instability with nonoperative treatment.¹⁻⁵ Evaluation of patients with shoulder instability typically begins with history, physical examination, and clinical association of imaging findings.⁶ There are numerous physical examination tests useful for anterior shoulder instability, including the apprehension test,⁷ the relocation test,⁸ the anterior release test,^{9,10} the anterior drawer test,¹¹⁻¹³ the load and shift test,¹⁴ and the hyperabduction test.^{15,16} Previous studies¹⁶⁻²¹ have assessed the diagnostic value of these clinical tests for shoulder instability. Notably, Eisner et al.¹⁷ concluded that anterior instability diagnosis in adolescents is usually clear based on the history, physical examination, and magnetic resonance imaging (MRI); however, the extent of the intra-articular pathology often is underestimated.¹⁷

After the diagnosis of anterior instability has been made, the strategy for surgical intervention is guided by the underlying pathology. Most commonly, this involves repairing the avulsed anteroinferior capsulolabral complex (Bankart lesion) to the glenoid rim. However, if the capsulolabral pathology extends into other regions of the labrum, it can be difficult to address from a standard anterior working portal.^{22,23} If the surgeon could confidently predict the extent and location of labral pathology based on preoperative physical examination findings, then theoretically, the surgeon might be able to better prepare for the operative intervention in regards to patient positioning and approach, need for accessory portals, specific portal locations, and need for specialized instruments (curved guides/anchors, etc.).¹⁷ For example, a positive hyperabduction test¹⁵ would indicate increased lengthening and laxity of the inferior glenohumeral ligament. The correlation between the finding of a positive hyperabduction test and damage to the inferior glenohumeral ligament can provide valuable diagnostic information to the orthopaedic surgeon before surgery. Thus, in patients with anterior shoulder instability, there may be additional variations in shoulder motion that may correlate with the location and extent of the labral tear encountered at the time of arthroscopy.

The purpose of the present study was to determine whether range of motion (ROM) varies with the location and extent of labral tear seen in patients undergoing arthroscopic anterior shoulder stabilization. The authors hypothesized that, in the setting of anterior shoulder instability, ROM varies predictably with the location and extent of labral tear seen at arthroscopy.

Methods

Study Design and Setting

An analysis was performed using data collected prospectively from the Multicenter Orthopaedic Outcomes Network (MOON) Shoulder Instability Database for patients undergoing arthroscopic shoulder surgery for the treatment of anterior instability. The study data collection methods by this group have been previously reported.^{24,25} Study data were collected and managed using the Research Electronic Data Capture database (REDCap; Vanderbilt University in Nashville, TN),²⁶ a secure, web-based application designed to support data capture for research studies, providing (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages; and (4) procedures for importing data from external sources. MOON is a multicenter, prospective study group involving 11 academic and private groups with 26 sports medicine or shoulder fellowship-trained surgeons that tracks patients undergoing surgery for symptomatic shoulder instability. Institutional review board approval (ID #: 201208835; approval date: January 31, 2013) was obtained at participating institutions.

Data collected included baseline patient demographics, patient-reported outcomes, preoperative imaging data, preoperative physical examination results, intraoperative examination under anesthesia (EUA) results, findings during diagnostic arthroscopy, and surgical procedure performed. Participants provided written, informed consent using institutional review board–approved consent forms and procedures. Most preoperative data were collected at a single intake at the first evaluation, with additional data such as preoperative imaging collected as it was completed and evaluated. At the time of enrollment, plain radiographs were obtained for each patient and reviewed as standard of care. If MRI or computed tomography imaging was available, they were also reviewed but were not required as part of the standard protocol. For each patient, the MOON group investigator performed the physical examination. Patients completed the questionnaires either via a paper form or online.

Participants

Patients were enrolled at 1 of the 11 participating sites. Patients diagnosed with anterior shoulder instability who underwent unilateral surgical primary arthroscopic labral repair between November 5, 2012, and August 14, 2017, were included. For the MOON study, exclusion criteria included participants younger than 12 years of age; patients with evidence of an isolated SLAP tear;

workers compensation patients or wards of the state (prisoners); patients unable to speak or read English; patients with a psychiatric illness precluding informed consent; patients unable to return for clinical follow-up; patients with large, massive, or irreparable associated rotator cuff tears extending into the subscapularis or teres minor; patients with a history of shoulder arthroplasty; and/or patients with evidence of shoulder fracture. Additional exclusion criteria for the present study included patients in whom data regarding preoperative ROM or location of labral tear was incomplete; patients in whom no labral tear was documented at time of surgery; patients undergoing revision surgery; patients undergoing surgery to address pathology other than anterior instability, including isolated posterior Bankart +/- capsular repairs, isolated debridement, isolated suture plication, isolated open posterior capsulorrhaphy, and isolated open inferior capsular shift.

Physical Examination

A preoperative physical examination was performed on each patient and documented by the operating surgeon. During the preoperative examination, participants were evaluated for active ROM in forward elevation (FE), abduction (ABD), internal rotation with arm at side (IRS) and in abduction (IRA), external rotation with arm at side (ERS) and in abduction (ERA). The anterior and posterior apprehension tests were performed and graded as pain, fear, both pain and fear, or neither for each test.²⁷ The Beighton Hypermobility Score²⁸ was also assessed. At the time of surgery, a complete EUA was performed, including passive ROM (in the planes listed above) and a load-and-shift test. Laxity on EUA was graded as follows: grade 0 was defined as normal glenohumeral translation, grade 1+ was defined as humeral head translation up to the glenoid rim with no dislocation, grade 2+ was defined as humeral head translation over the glenoid rim with spontaneous reduction once force withdrawn, and grade 3+ was defined as humeral head translation over the glenoid rim with locking. No specific device was used for strength or ROM.

Arthroscopic Evaluation

After EUA, each subject underwent diagnostic arthroscopy during which the location and extent of the labral tear was noted using conventional clock-face coordinates (cephalad = 12:00, anterior = 3:00, caudad = 6:00, and posterior = 9:00, with left shoulders mirroring right). The surgeon recorded either the presence or absence of the labral tear at each of 20 locations around the glenoid (Fig 1).

Data Organization

For the purpose of the present study, the clock face was then divided into quadrants: superior

(10:30-1:30), anterior (right side, 2:00-4:00; left side, 8:00-10:00), inferior (4:30-7:00) and posterior (right side, 8:00-10:00; left side, 2:00-4:00) (Fig 1). Each of these quadrants included 5 locations at which a labral tear was recorded as either present or absent. Patients with anterior labral tears were then divided into 7 groups according to the extent of labral tear seen at arthroscopy (Table 1). Group 1 (G1) = anterior only, group 2 (G2) = anterior + inferior, group 3 (G3) = anterior + inferior + posterior, group 4 (G4) = all quadrants, group 5 (G5) = superior + anterior, group 6 (G6) = superior + anterior + inferior, and group 7 (G7) = posterior + superior + anterior.

Statistical Analysis

Groups were then compared based on demographics, preoperative examination findings and EUA. All data analyses were performed using R Studio.^{29,30} We used nonparametric statistics, specifically the Kruskal-Wallis rank-sum test, to compare the 7 groups. In cases in which $P < .05$, a multiple comparison using Dunn's post-hoc test was performed. For categorical variables, a χ^2 test was performed. We performed a series of bivariate negative binomial regression models testing pairwise combinations of ROM parameters predicting the count of labral tear locations (possible: 0-5) within each quadrant.

Results

Patient Demographics

In total, 467 patients (387 male, 82.87%; 80 female, 17.13%) were included in this study (Table 2). There were 13 (2.8%) patients in G1, 221 (47.3%) patients in G2, 40 (8.6%) patients in G3, 51 (10.9%) patients in G4, 18 (3.9%) patients in G5, 121 (25.9%) patients in G6, and 3 (0.6%) patients in G7 (Fig 2). The mean age at the time of surgery was 24.3 ± 9.2 years. There were no statistically significant differences in any demographic between groups ($P > .05$ for all).

A heat map of the glenoid that highlights the rate of labral tear by location is presented in Figure 3.³¹

Outcome Measures

Laxity

There were no significant differences in the degree of laxity or Beighton Hypermobility Score between groups (Table 3). In addition, no significant differences were seen with the anterior or posterior apprehension tests between groups ($P > .05$ for all).

Range of Motion

There were no significant differences in active ROM in FE, IRA, ERS, and in ERA ($P > .05$ for all). In addition, there were no significant differences in passive

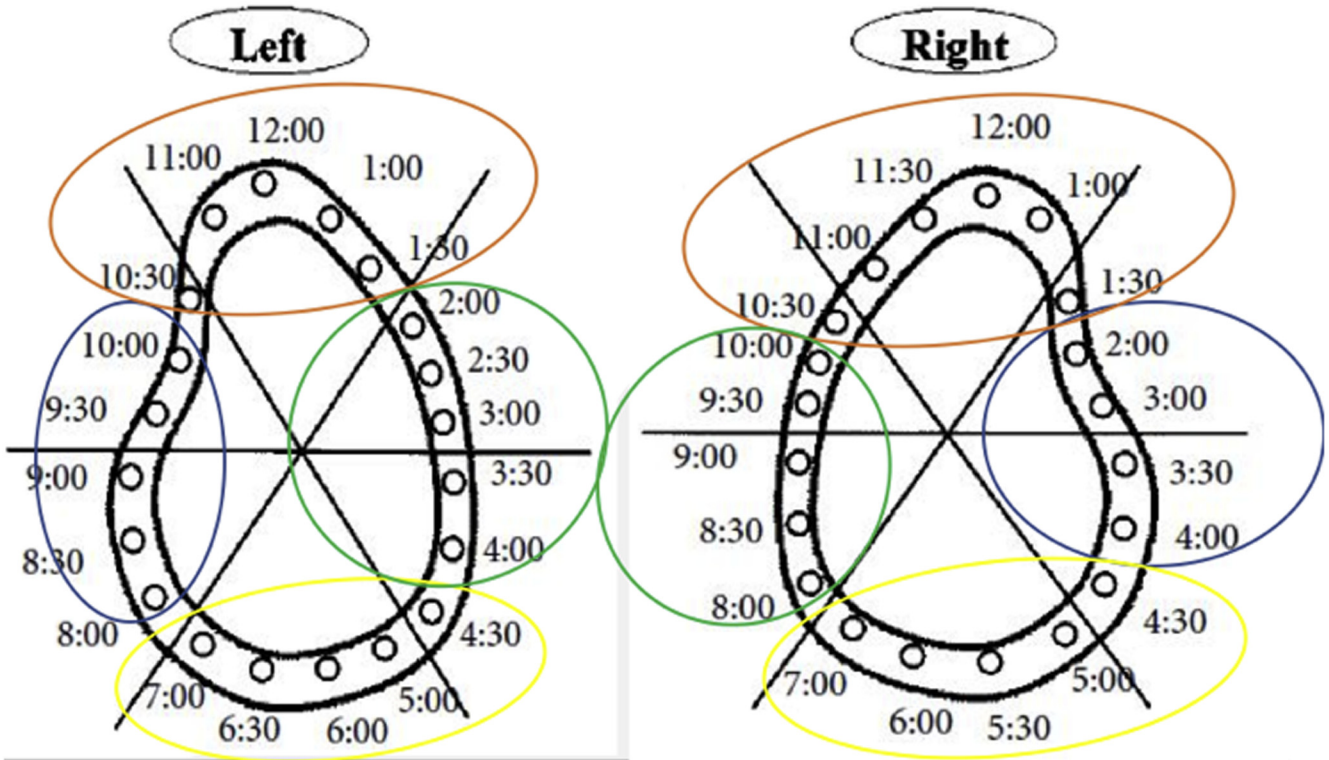


Fig 1. Diagram of glenoid labrum divided into quadrants. Blue = anterior quadrant, green = posterior quadrant, yellow = inferior quadrant, orange = superior quadrant.

ROM in FE, ABD, IRA, and in ERS ($P > .05$ for all) (Table 4).

There were multiple statistically significant differences among groups with regards to ROM. The most dramatic differences were observed in preoperative active IRS and active ABD, as well as passive IRS and passive ERA on EUA (Table 5).

Post-hoc analyses results are presented in Table 5. On post-hoc analysis between individual groups, preoperative active ABD was significantly greater in G5 than all other groups ($P < .05$ for all), except G1 ($P = .57$). The active ABD of G1 was significantly greater than G3, the group with the least active ABD ($P = .04$). Active IRS was significantly lower in G7 than all other groups ($P < .05$ for all). Similarly, passive IRS during the EUA was significantly lower in G7 than all other groups ($P < .05$ for all). There were several significant differences among groups with regards to passive ERA during EUA. The lowest passive ERA was seen in G7, which was significantly less than all other groups ($P < .05$ for all) except G1 ($P = .52$). Group 1 demonstrated the second lowest passive ERA, which was significantly less than all other groups ($P < .05$ for all) except G7 ($P = .52$).

Bivariate negative binomial regression demonstrated that ROM did not significantly predict the count of labral tear locations within the anterior and posterior quadrants. However, among patients with at least one tear within the anterior quadrant, passive ABD

predicted a significant increase in the number of labral tear locations in the superior quadrant. This included a 153.4% increase in the predicted number of labral tear locations in the superior quadrant from 120° (0.5 tear locations) to 180° (1.3 tear locations) of passive ABD, and a 59.2% increase in predicted number of labral tear locations in the superior quadrant from 150° (0.8 tear locations) to 180° (1.3 tear locations) of passive ABD. Predicted counts of this model are shown in panel A of Figure 4. Similarly, among patients with at least one tear within the anterior quadrant, passive IRS predicted a significant increase in the number of labral tear

Table 1. Quadrants Involved Per Group

Quadrant Group	Superior	Anterior	Inferior	Posterior
	10:30-1:30 320-30°	2:00-4:00 50-120°	4:30-7:00 140-210°	8:00-10:00 230-300°
G1	-	+	-	-
G2	-	+	+	-
G3	-	+	+	+
G4	+	+	+	+
G5	+	+	-	-
G6	+	+	+	-
G7	+	+	-	+

NOTE. “+/-” indicates that the labral tear was/was not located in the respective quadrant.

G1, anterior only; G2, anterior + inferior; G3, anterior + inferior + posterior; G4, all quadrants; G5, superior + anterior; G6, superior + anterior + inferior; G7, posterior + superior + anterior.

Table 2. Patient Demographics

Demographics	Total	Quadrant Group							P Value
		G1	G2	G3	G4	G5	G6	G7	
Patients, n (%)	467 (100.00)	13 (2.78)	221 (47.32)	40 (8.57)	51 (10.92)	18 (3.85)	121 (25.91)	3 (0.64)	
Male, n (%)	387 (82.87)	11 (84.62)	180 (81.45)	32 (80.00)	48 (94.12)	14 (77.78)	99 (81.82)	3 (100.00)	.41
Female, n (%)	80 (17.13)	2 (15.38)	41 (18.55)	8 (20.00)	3 (5.88)	4 (22.22)	22 (18.18)	0 (0.00)	
Right surgical side, n (%)	253 (54.18)	7 (58.85)	130 (58.82)	16 (40.00)	28 (54.90)	6 (33.33)	65 (53.72)	1 (33.33)	.18
Left surgical side, n (%)	214 (45.82)	6 (46.15)	91 (41.18)	24 (60.00)	23 (45.10)	12 (66.67)	56 (46.28)	2 (66.67)	
Age, y	24.26 ± 9.17	21.15 ± 7.73	23.89 ± 9.36	24.60 ± 7.49	24.57 ± 9.17	23.28 ± 7.68	25.18 ± 9.66	23.67 ± 12.42	.43
BMI	25.43 ± 4.43	24.45 ± 5.67	25.29 ± 4.69	25.18 ± 2.77	26.35 ± 4.25	26.21 ± 4.38	25.20 ± 4.13	32.40 ± 7.58	.08

Age and BMI are reported as a mean ± standard deviation.

BMI, body mass index; G1, anterior only; G2, anterior + inferior; G3, anterior + inferior + posterior; G4, all quadrants; G5, superior + anterior; G6, superior + anterior + inferior; G7, posterior + superior + anterior.

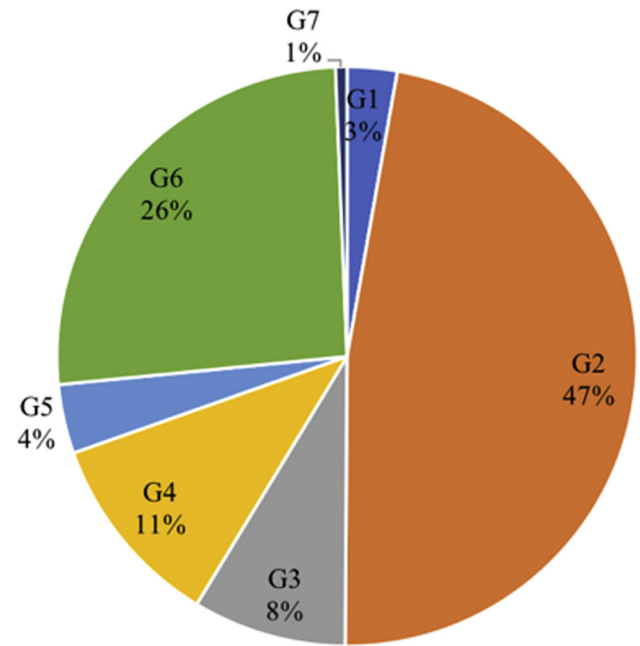


Fig 2. Quadrant group breakdown. (G1, anterior only; G2, anterior + inferior; G3, anterior + inferior + posterior; G4, all quadrants; G5, superior + anterior; G6, superior + anterior + inferior; G7, posterior + superior + anterior.)

locations in the inferior quadrant. This included a 78.7% increase in the predicted number of tear locations in the inferior quadrant between 30° (1.2 tear locations) and 60° (2.2 tear locations) of passive IRS, and a 47.2% increase in predicted number of tear locations between 40° (1.5 tear locations) and 60° (2.2 tear locations) of passive IRS. Predicted counts of this model are shown in panel B of Figure 4.

Discussion

The principle findings of this study are as follows: Among patients with at least one tear in the anterior quadrant, there was a significant increase of 153.4% in the predicted number of labral tear locations in the superior quadrant from 120° (0.5 tear locations) to 180° (1.3 tear locations) of passive ABD. Likewise, among patients with at least one tear in the anterior quadrant, there was a significant increase of 78.7% in the predicted number of labral tear locations in the inferior quadrant between 30° (1.2 tear locations) and 60° (2.2 tear locations) of passive IRS. Although there were multiple statistically significant differences in ROM among groups, specifically in preoperative active IRS and active ABD, and intraoperative passive IRS, and passive ERA, the clinical relevance of these small differences in ROM remains uncertain. Such small differences in ROM do not provide clear thresholds to accurately predict the exact location and extent of the labral tear seen during diagnostic arthroscopy. Similarly, preoperative MRI has been shown to underestimate the extent of labral tear. Our results underscore

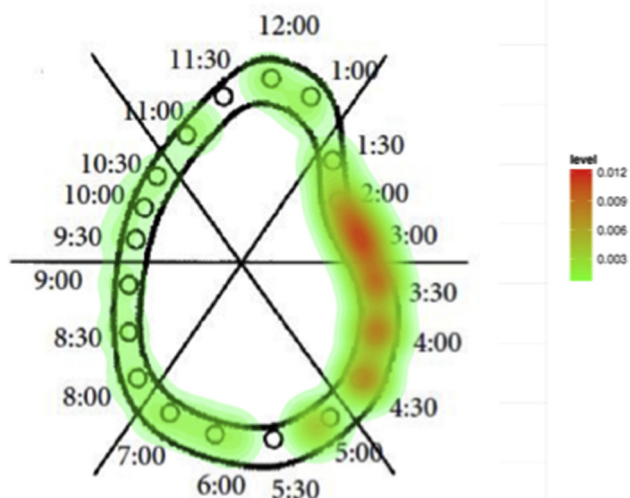


Fig 3. Heat map of the glenoid showing the rate of labral tear by location. Highest location of labral tear = red, lowest location of labral tear = green. Heat map was created using Heatmapper.³¹

the importance of a thorough diagnostic arthroscopy and suggest that the surgeon should be prepared to address all labral pathology encountered in the setting of known shoulder instability.

In the present study, preoperative active ROM and intraoperative passive ROM on EUA were very similar among patients with tears involving different quadrants of the glenoid labrum. However, there was notable heterogeneity. First, there was significant variation among groups with regards to active ABD, with greater degrees of abduction seen in patients whose labral tears were isolated to either the anterior quadrant (G1) or the superior + anterior quadrants (G5) than in patients whose tears involved the inferior or posterior quadrants (G2-4, G6-7). As well, patients with labral tears involving the posterior + superior + anterior quadrants (G7) demonstrated significantly less IRS—both actively and passively on EUA—compared with all other patients. These patients (G7), along with those patients with tears isolated to the anterior quadrant (G1), also demonstrated significantly less passive ERA during EUA compared with all other patients.

Furthermore, bivariate negative binomial regression modeling demonstrated 2 interesting positive correlations between ROM during EUA and the predicted number of labral tear locations within each quadrant involved in the tear. First, among patients with at least 1 tear within the anterior quadrant, passive ABD during EUA predicted a significant increase in the number of labral tear locations in the superior quadrant involved in the tear. Although the increases in the predicted number of labral tear locations within the superior quadrant seem small, there was a 153.4% increase in

the predicted number of labral tear locations in the superior quadrant from 120° (0.5 tear locations) to 180° (1.3 tear locations) of passive ABD, and a 59.2% increase in predicted number of labral tear locations in the superior quadrant from 150° (0.8 tear locations) to 180° (1.3 tear locations) of passive ABD. Second, among patients with at least one tear within the anterior quadrant, there was also a positive correlation between passive IRS during EUA and the predicted number of labral tear locations in the inferior quadrant involved in the tear. Again, although the increases seem small, there was a 78.7% increase in the predicted number of tear locations in the inferior quadrant between 30° (1.2 tear locations) and 60° (2.2 tear locations) of passive IRS, and a 47.2% increase in predicted number of tear locations between 40° (1.5 tear locations) and 60° (2.2 tear locations) of passive IRS.

When interpreting the results of our study, it is important to note that although several of the differences in preoperative physical examination parameters were statistically significantly different, their clinical significance is uncertain at best. This is likely attributable to a variety of factors. First, the overall magnitudes of the differences among groups are small, ranging from 1.67° (passive IRS G1 vs G7) to 21.66° (passive ERA G5 vs G7). It is likely that this magnitude of difference would likely go undetected during a preoperative clinical examination or EUA, especially if the surgeon is not using a goniometer for precise measurement. According to one previous study,³² the minimal clinically important difference in glenohumeral ROM for detection and agreement among multiple observers is 24°. The differences seen in our study fall below this minimal clinically important difference. Despite this, it has been previously demonstrated that patient-reported measurements of shoulder ROM are in moderate-to-high level of agreement with the physician's measurements.³³ This highlights the importance of estimation of shoulder ROM and suggest that the lack of goniometer use may not significantly influence these results. Furthermore, for a continuous variable such as ROM to be of clinical utility in predicting labral tear location, a diagnostic threshold must be set, much like Gagey and Gagey¹⁵ established with their hyperabduction test for inferior shoulder instability (>105°). In the present study, the differences in ROM among groups were slight—and the 95% confidence intervals wide enough—that the authors were unable to establish such threshold values.

The strengths of this study include a comprehensive analysis including 467 patients treated by 26 surgeons at 11 different institutions. It incorporates an extensive data set pertaining with complete preoperative physical examination and intraoperative EUA as well as findings regarding intraarticular pathology at time of surgery.

Table 3. Comparison of the Degree of Laxity and Beighton Hypermobility Scores Between Quadrant Groups

Outcome	Quadrant Group (n = 467)							P Value	χ^2
	G1 (n = 13)	G2 (n = 221)	G3 (n = 40)	G4 (n = 51)	G5 (n = 18)	G6 (n = 121)	G7 (n = 3)		
BHS	0.69 [-0.66 to 2.05]	0.83 [0.60-1.06]	0.85 [0.30-1.40]	1.20 [0.62-1.77]	1.17 [-0.17 to 2.50]	0.75 [0.48-1.02]	0 [0-0]	.51	5.29
AL on EUA: 0, n (%)	0 (0)	5 (2.26)	0 (0)	1 (1.96)	1 (5.56)	2 (1.65)	0 (0)	.17	23.49
AL on EUA: 1, n (%)	2 (15.38)	52 (23.53)	11 (27.50)	7 (13.73)	0 (0)	19 (15.70)	2 (66.67)		
AL on EUA: 2, n (%)	6 (46.15)	123 (55.66)	17 (42.50)	33 (64.71)	12 (66.67)	74 (61.16)	1 (33.33)		
AL on EUA: 3, n (%)	5 (38.46)	33 (14.93)	9 (22.50)	10 (19.61)	5 (27.78)	19 (15.70)	0 (0)		
IL on EUA: 0, n (%)	5 (38.46)	116 (52.49)	22 (55.00)	22 (43.14)	13 (72.22)	55 (45.45)	2 (66.67)	.13	24.98
IL on EUA: 1, n (%)	6 (46.15)	78 (35.29)	13 (32.50)	22 (43.14)	5 (27.78)	51 (42.15)	1 (33.33)		
IL on EUA: 2, n (%)	2 (15.38)	18 (8.14)	2 (5.00)	5 (9.80)	0 (0)	8 (6.61)	0 (0)		
IL on EUA: 3, n (%)	0 (0)	0 (0)	0 (0)	2 (3.92)	0 (0)	0 (0)	0 (0)		
PL on EUA: 0, n (%)	9 (69.23)	124 (56.11)	16 (40.00)	18 (35.29)	11 (61.11)	74 (61.16)	2 (66.67)	.05	28.92
PL on EUA: 1, n (%)	3 (23.08)	64 (28.96)	12 (30.00)	19 (37.25)	5 (27.78)	32 (26.45)	1 (33.33)		
PL on EUA: 2, n (%)	1 (7.69)	22 (9.95)	8 (20.00)	12 (23.53)	2 (11.11)	8 (6.61)	0 (0)		
PL on EUA: 3, n (%)	0 (0)	1 (0.45)	1 (2.50)	2 (3.92)	0 (0)	0 (0)	0 (0)		

NOTE. BHS is reported as a mean [95% confidence interval].

AL, anterior laxity; BHS, Beighton Hypermobility Score; EUA, examination under anesthesia; G1, anterior only; G2, anterior + inferior; G3, anterior + inferior + posterior; G4, all quadrants; G5, superior + anterior; G6, superior + anterior + inferior; G7, posterior + superior + anterior; IL, inferior laxity; PL, posterior laxity.

Table 4. Comparison of Range of Motion Between Quadrant Groups

Outcome	Quadrant Group (n = 467)							P Value	χ^2
	G1 (n = 13)	G2 (n = 221)	G3 (n = 40)	G4 (n = 51)	G5 (n = 18)	G6 (n = 121)	G7 (n = 3)		
Active FE°	177.69 [175.30-180.08]	171.58 [169.55-173.61]	172.00 [167.78-176.22]	167.06 [160.65-173.47]	174.44 [171.18-177.70]	168.76 [165.10-172.42]	166.66 [160.13-173.19]	.25	7.89
Active ABD°	175.38 [171.79-178.97]	162.49 [159.04-165.94]	156.50 [146.39-166.61]	163.72 [157.20-170.24]	177.22 [174.57-179.87]	164.13 [159.62-168.64]	160.00 [148.68-171.32]	.02	14.96
Active IRS°	54.17 [48.28-60.06]	58.19 [57.47-58.91]	56.97 [54.71-59.23]	56.81 [54.59-59.03]	57.50 [53.92-61.08]	58.12 [57.12-59.12]	50.00 [50.00-50.00]	.005	18.61
Active IRA°	63.85 [51.99-75.70]	60.05 [57.60-62.50]	59.72 [54.01-65.44]	57.45 [52.86-62.04]	59.44 [48.53-70.36]	59.58 [56.12-63.04]	60.00 [48.68-71.32]	.76	3.37
Active ERS°	74.62 [66.13-83.11]	66.52 [64.03-69.01]	71.25 [65.58-76.92]	62.75 [57.09-68.40]	68.33 [59.76-76.90]	64.71 [61.22-68.20]	76.67 [59.38-93.95]	.24	7.93
Active ERA°	90.00 [83.34-96.66]	86.27 [84.18-88.36]	88.97 [85.09-92.86]	80.98 [75.79-86.17]	88.33 [82.79-93.88]	84.21 [81.26-87.17]	76.67 [70.13-83.20]	.06	12.32
Passive FE°	176.92 [174.31-179.53]	177.19 [176.42-177.97]	177.00 [174.76-179.24]	178.24 [176.71-179.76]	178.89 [177.39-180.38]	176.69 [175.39-178.00]	173.33 [166.80-179.87]	.25	7.80
Passive ABD°	176.1538 [173.40-178.91]	168.01 [165.40-170.62]	164.00 [156.48-171.52]	171.76 [168.35-175.18]	178.33 [176.56-180.10]	170.99 [168.26-173.73]	166.67 [160.13-173.20]	.11	10.50
Passive IRS°	55.00 [48.65-61.35]	58.51 [57.83-59.19]	59.71 [59.18-60.24]	59.35 [58.45-60.25]	58.24 [55.80-60.68]	58.44 [57.47-59.41]	53.33 [48.80-59.86]	.02	15.20
Passive IRA°	73.85 [64.29-83.40]	65.92 [63.49-68.34]	70.53 [64.90-76.15]	65.69 [60.50-70.87]	66.11 [56.33-75.90]	64.58 [61.19-67.97]	73.33 [66.80-79.87]	.54	5.04
Passive ERS°	75.38 [66.07-84.70]	71.59 [69.17-74.01]	78.00 [71.83-84.17]	73.92 [68.22-79.63]	77.78 [71.33-84.23]	71.74 [68.16-75.31]	73.33 [66.80-79.87]	.53	5.13
Passive ERA°	79.23 [72.40-86.06]	92.65 [90.72-94.58]	97.00 [93.21-100.79]	91.57 [87.23-95.91]	98.33 [89.91-106.75]	90.42 [87.45-93.39]	76.67 [70.14-83.20]	.0007	23.48

NOTE. Data are reported as a mean [95% confidence interval]. Active range of motion was performed preoperatively; passive range of motion was performed intraoperatively during examination during anesthesia.

ABD, abduction; ERA, external rotation in abduction; ERS, external rotation at side; FE, forward elevation; G1, anterior only; G2, anterior + inferior; G3, anterior + inferior + posterior; G4, all quadrants; G5, superior + anterior; G6, superior + anterior + inferior; G7, posterior + superior + anterior; IRA, internal rotation in abduction; IRS, internal rotation at side,

Table 5. Comparison of Range of Motion Between Quadrant Groups: Post-hoc Analyses Results

Outcome	Quadrant Group (n = 467)							P Value	χ^2
	G1 (n = 13)	G2 (n = 221)	G3 (n = 40)	G4 (n = 51)	G5 (n = 18)	G6 (n = 121)	G7 (n = 3)		
Active ABD°	175.38 [171.79-178.97]	162.49 [159.04-165.94]	156.50 [146.39-166.61]	163.72 [157.20-170.24]	177.22 [174.57-179.87]	164.13 [159.62-168.64]	160.00 [148.68-171.32]	.02	14.96
Post-hoc P value	G1-G3: p = 0.04; G2-G5: p = 0.002; G3-G5: p = 0.003; G4-G5: p = 0.009; G5-G6: p = 0.009; G5-G7: p = 0.02								
Active IRS°	54.17 [48.28-60.06]	58.19 [57.47-58.91]	56.97 [54.71-59.23]	56.81 [54.59-59.03]	57.50 [53.92-61.08]	58.12 [57.12-59.12]	50.00 [50.00-50.00]	.005	18.61
Post-hoc P value	G1-G7: p = 0.003; G2-G7: p = 0.00007; G3-G7: p = 0.0004; G4-G7: p = 0.0002; G5-G7: 0.0003; G6-G7 p = 0.00007								
Passive IRS°	55.00 [48.65-61.35]	58.51 [57.83-59.19]	59.71 [59.18-60.24]	59.35 [58.45-60.25]	58.24 [55.80-60.68]	58.44 [57.47-59.41]	53.33 [46.80-59.86]	.02	15.20
Post-hoc P value	G1-G7: p = 0.01; G2-G7: p = 0.001; G3-G7: p = 0.0004; G4-G7: p = 0.0005; G5-G7: p = 0.004; G6-G7: p = 0.001								
Passive ERA°	79.23 [72.40-86.06]	92.65 [90.72-94.58]	97.00 [93.21-100.79]	91.57 [87.23-95.91]	98.33 [89.91-106.75]	90.42 [87.45-93.39]	76.67 [70.14-83.20]	.0007	23.48
Post-hoc P value	G1-G2: P = .0008; G1-G3: P = .00008; G1-G4: P = .002; G1-G5: P = .0005; G1-G6: P = .002; G3-G6: P = .04; G2-G7: P = .02; G3-G7: P = .005; G4-G7: P = .02; G5-G7: P = 0.007; G6-G7: P = .03								

NOTE. Data are reported as a mean [95% confidence interval]. Active range of motion was performed preoperatively; passive range of motion was performed intraoperatively during examination during anesthesia.

ABD, abduction; ERA, external rotation in abduction; G1, anterior only; G2, anterior + inferior; G3, anterior + inferior + posterior; G4, all quadrants; G5, superior + anterior; G6, superior + anterior + inferior; G7, posterior + superior + anterior; IRS, internal rotation at side.

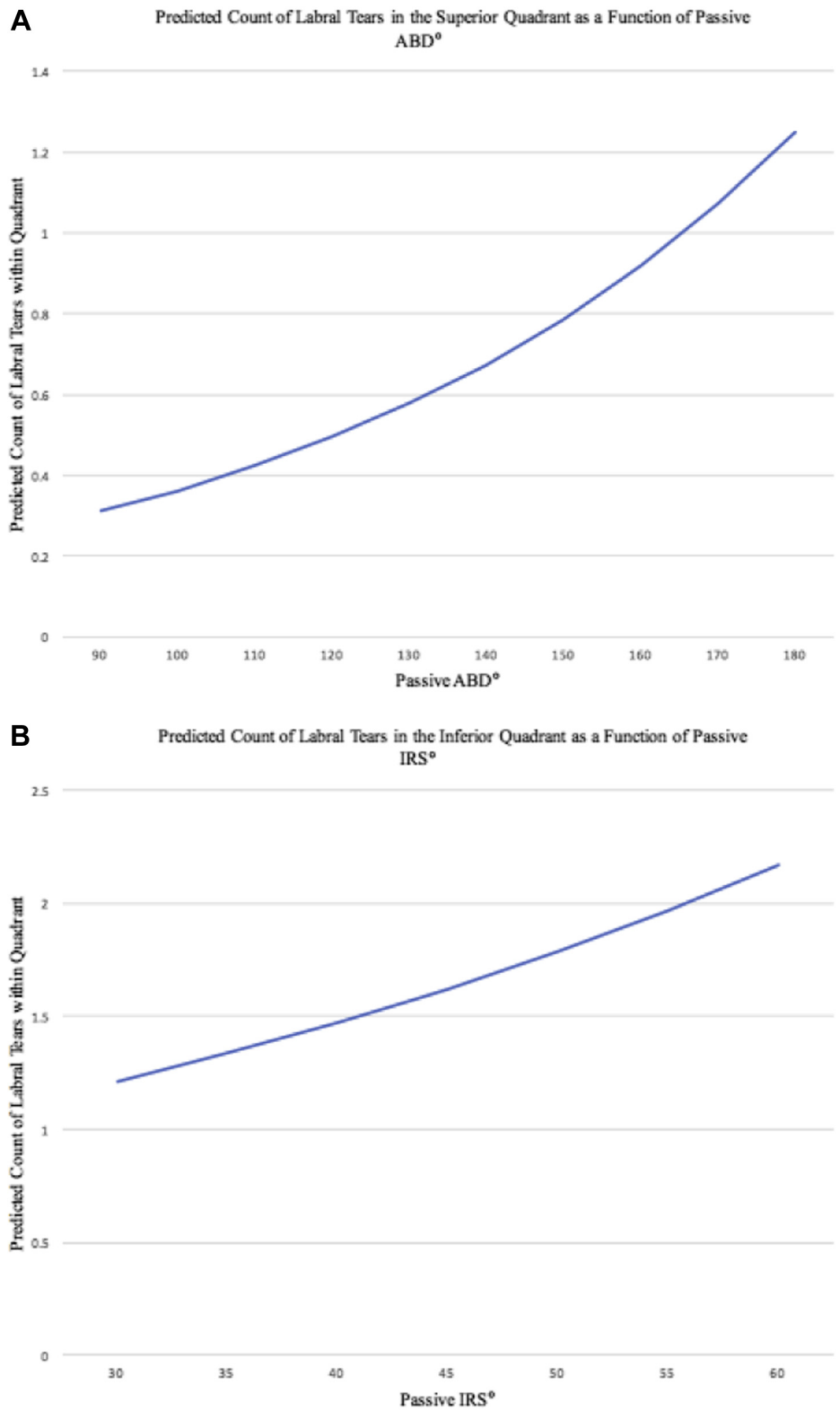


Fig 4. Predicted count of labral tears within quadrant. (ABD, abduction; IRS, internal rotation at side.)

Limitations

There are several limitations that must also be noted. The first is inherent within the MOON database. For each patient, the preoperative examination, EUA, and

diagnostic arthroscopy findings were reported by a single observer, who was likely not recording these data points immediately after each measurement nor using goniometers to measure ROM. This study relies on self-

reported data from single-observer surgeons, and the authors are unable to independently verify the findings on arthroscopy or physical examination. Finally, we were not able to assess the location of labral tears on advanced preoperative imaging, such as MRI or computed tomography, to determine whether this was different than the intraoperative results.

Conclusions

In patients undergoing arthroscopic shoulder stabilization for anterior instability, ROM varies with location and extent of labral tear. However, the clinical relevance of such small ROM differences remains undetermined.

References

1. Aboalata M, Halawa A, Basyoni Y. The double Bankart bridge: A technique for restoration of the labral footprint in arthroscopic shoulder instability repair. *Arthrosc Tech* 2017;6:e43-e47.
2. Aboalata M, Plath JE, Seppel G, Juretzko J, Vogt S, Imhoff AB. Results of arthroscopic Bankart repair for anterior-inferior shoulder instability at 13-year follow-up. *Am J Sports Med* 2017;45:782-787.
3. Jakobsen BW, Johannsen HV, Suder P, Sojbjerg JO. Primary repair versus conservative treatment of first-time traumatic anterior dislocation of the shoulder: A randomized study with 10-year follow-up. *Arthroscopy* 2007;23:118-123.
4. Owens BD, DeBerardino TM, Nelson BJ, et al. Long-term follow-up of acute arthroscopic Bankart repair for initial anterior shoulder dislocations in young athletes. *Am J Sports Med* 2009;37:669-673.
5. Robinson CM, Howes J, Murdoch H, Will E, Graham C. Functional outcome and risk of recurrent instability after primary traumatic anterior shoulder dislocation in young patients. *J Bone Joint Surg Am* 2006;88:2326-2336.
6. Forsythe B, Frank RM, Ahmed M, et al. Identification and treatment of existing copathology in anterior shoulder instability repair. *Arthroscopy* 2015;31:154-166.
7. Rowe CR, Zarins B. Recurrent transient subluxation of the shoulder. *J Bone Joint Surg Am* 1981;63:863-872.
8. Jobe FW, Kvitne RS, Giangarra CE. Shoulder pain in the overhand or throwing athlete. The relationship of anterior instability and rotator cuff impingement. *Orthop Rev* 1989;18:963-975.
9. Gross ML, Distefano MC. Anterior release test. A new test for occult shoulder instability. *Clin Orthop Relat Res* 1997;339:105-108.
10. Silliman JF, Hawkins RJ. Classification and physical diagnosis of instability of the shoulder. *Clin Orthop Relat Res* 1993;291:7-19.
11. Gerber C, Ganz R. Clinical assessment of instability of the shoulder. With special reference to anterior and posterior drawer tests. *J Bone Joint Surg Br* 1984;66:551-556.
12. Gerber C, Hersche O, Farron A. Isolated rupture of the subscapularis tendon. *J Bone Joint Surg Am* 1996;78:1015-1023.
13. Gerber C, Krushell RJ. Isolated rupture of the tendon of the subscapularis muscle. Clinical features in 16 cases. *J Bone Joint Surg Br* 1991;73:389-394.
14. McFarland EG, Torpey BM, Curl LA. Evaluation of shoulder laxity. *Sports Med* 1996;22:264-272.
15. Gagey OJ, Gagey N. The hyperabduction test. *J Bone Joint Surg Br* 2001;83:69-74.
16. van Kampen DA, van den Berg T, van der Woude HJ, Castelein RM, Terwee CB, Willems WJ. Diagnostic value of patient characteristics, history, and six clinical tests for traumatic anterior shoulder instability. *J Shoulder Elbow Surg* 2013;22:1310-1319.
17. Eisner EA, Roocroft JH, Edmonds EW. Underestimation of labral pathology in adolescents with anterior shoulder instability. *J Pediatr Orthop* 2012;32:42-47.
18. Farber AJ, Castillo R, Clough M, Bahk M, McFarland EG. Clinical assessment of three common tests for traumatic anterior shoulder instability. *J Bone Joint Surg Am* 2006;88:1467-1474.
19. Imhoff AB, Hodler J. Correlation of MR imaging, CT arthrography, and arthroscopy of the shoulder. *Bull Hosp Jt Dis* 1996;54:146-152.
20. Liu SH, Henry MH, Nuccion S, Shapiro MS, Dorey F. Diagnosis of glenoid labral tears. A comparison between magnetic resonance imaging and clinical examinations. *Am J Sports Med* 1996;24:149-154.
21. Lo IK, Nonweiler B, Woolfrey M, Litchfield R, Kirkley A. An evaluation of the apprehension, relocation, and surprise tests for anterior shoulder instability. *Am J Sports Med* 2004;32:301-307.
22. Cvetanovich GL, Hamamoto JT, Campbell KJ, McCarthy M, Higgins JD, Verma NN. The use of accessory portals in Bankart repair with posterior extension in the lateral decubitus position. *Arthrosc Tech* 2016;5:e1121-e1128.
23. Cvetanovich GL, McCormick F, Erickson BJ, et al. The posterolateral portal: Optimizing anchor placement and labral repair at the inferior glenoid. *Arthrosc Tech* 2013;2:e201-e204.
24. Brophy RH, Hettrich CM, Ortiz S, Group MSI, Wolf BR. Patients undergoing shoulder stabilization surgery have elevated shoulder activity compared with sex- and age-matched healthy controls. *Sports Health* 2016;9:59-63.
25. Kraeutler MJ, McCarty EC, Belk JW, et al. Descriptive epidemiology of the MOON shoulder instability cohort. *Am J Sports Med* 2018;46:1064-1069.
26. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42:377-381.
27. Mahaffey BL, Smith PA. Shoulder instability in young athletes. *Am Fam Physician* 1999;59:2773-2782, 2787.
28. Beighton P, Horan F. Orthopaedic aspects of the Ehlers-Danlos syndrome. *J Bone Joint Surg Br* 1969;51:444-453.

29. Pohlert T. The Pairwise Multiple Comparison of Mean Ranks Package (PMCMR), *Package Version 4.3*. Vienna, Austria: R Foundation for Statistical Computing, 2014.
30. Venables WNR BD. *Modern Applied Statistics with S. Package Version 7.3-50*. Vienna, Austria: R Foundation for Statistical Computing, 2002.
31. Babicki S, Arndt D, Marcu A, et al. Heatmapper: Web-enabled heat mapping for all. *Nucleic Acids Res* 2016;44:W147-W153.
32. Muir SW, Corea CL, Beaupre L. Evaluating change in clinical status: Reliability and measures of agreement for the assessment of glenohumeral range of motion. *N Am J Sports Phys Ther* 2010;5:98-110.
33. Uribe B, El Bitar Y, Wolf BR, Bollier M, Kuhn JE, Hettrich CM. Agreement between patient self-assessment and physician assessment of shoulder range of motion. *J Shoulder Elbow Surg* 2016;25:1649-1654.