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By Xiaofeng Jia, MD, PhD, Jong Hun Ji, MD, Steve A. Petersen, MD, Michael T. Freehill, MD, and Edward G. McFarland, MD

Investigation performed at the Division of Shoulder Surgery, Department of Orthopaedic Surgery, The Johns Hopkins University/Johns Hopkins Bayview Medical Center, Baltimore, Maryland

Background: It has been recognized that there is a distinction between shoulder laxity and shoulder instability and that there is a wide range of normal shoulder laxities. Our goals were (1) to evaluate if the ability to subluxate the shoulder over the glenoid rim in patients under anesthesia would be more prevalent than the inability to do so, (2) to determine if patients with a diagnosis of instability would have significantly more shoulder laxity in the operatively treated shoulder than in the contralateral shoulder, and (3) to evaluate the observation that higher grades of shoulder laxity would be related to a diagnosis of shoulder instability. We hypothesized that, on examination with the patient under anesthesia, most shoulders could be subluxated over the glenoid rim and that the degree of shoulder laxity would be related to diagnosis.

Methods: In the present study of 1206 patients undergoing shoulder surgery, we evaluated the symptomatic and contralateral shoulders with use of a modified anterior and posterior drawer test and a sulcus sign test, with the patients under anesthesia. The anterior and posterior translations were graded as no subluxation (Grade I), subluxation over the glenoid rim with spontaneous reduction (Grade II), or subluxation without spontaneous reduction (Grade III). The sulcus sign was graded as <1.0 cm (Grade I), 1.0 to 2.0 cm (Grade II), or >2.0 cm (Grade III).

Results: When the patients were evaluated while under anesthesia, the humeral head could be subluxated over the rim anteriorly in 81.6% (984 of 1206) of the patients and posteriorly in 57.5% (693 of 1206) of the patients. When the patients were evaluated while under anesthesia, there was an increase in the laxity grade anteriorly, posteriorly, and inferiorly in 50.8%, 36.3%, and 15.8% of the patients, respectively, as compared with the preoperative assessment. For all laxity testing, the higher the grade of laxity in an anterior, posterior, or inferior direction, the greater the chance that the patient had a diagnosis of instability. Compared with Grade-I laxity, Grade-III laxity increased the odds of a diagnosis of instability in the anterior (odds ratio, 170), posterior (odds ratio, 32), and inferior (odds ratio, 10.3) directions. Compared with Grade-I laxity, Grade-II laxity increased the odds of a diagnosis of instability in the anterior (odds ratio, 9.8), posterior (odds ratio, 4.6), and inferior (odds ratio, 4.4) directions.

Conclusions: The ability to subluxate the humeral head over the glenoid rim in the patient who is undergoing shoulder surgery under anesthesia is common regardless of the diagnosis. Higher grades of shoulder laxity are associated with shoulder instability.

Many physicians have recommended laxity testing of the shoulder as a component of the physical examination of patients with shoulder conditions and as a screening test during routine physical examinations of other patients[1-6]. The evaluation of shoulder laxity has been particularly recommended for two sets of patients in the clinical setting: those with symptomatic traumatic shoulder instability (to confirm the diagnosis)[1,2] and those with occult instability associated with shoulder pain[3]. This laxity evaluation has been used especially for patients who are involved in overhead sports to determine if shoulder stabilization should be performed[4,7].

However, clinicians have increasingly recognized that the range of normal shoulder laxity is wide, that high grades of shoulder laxity may not be pathologic, and that laxity and instability of the shoulder joint are not the same[8-10]. Laxity is a measure of the joint movement within normal limits, whereas instability is a pathologic condition that results in symptoms because of excessive movement of the humeral head on the

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glenoid[5,6,11]. Several studies have shown that the ability to subluxate the shoulder on examination is common, especially in athletic individuals[12-15]. However, to our knowledge, there have been no studies of shoulder laxity in large populations of patients with a variety of diagnoses.

Similarly, the performance of laxity testing of the shoulder during the examination of the shoulder with the patient under anesthesia has been widely advocated[8,11,16]. Although an increase in shoulder laxity with the patient under anesthesia has been documented[11], the role of laxity testing, particularly for patients with a diagnosis of shoulder instability, has not been thoroughly explored.

It has been our observation that the ability to subluxate the shoulder over the glenoid rim is essentially a normal finding on examination of the shoulder, especially with the patient under anesthesia[13]. The purpose of the present study was threefold: (1) to evaluate if the ability to subluxate the shoulder over the glenoid rim in patients under anesthesia would be more prevalent than the inability to do so, (2) to determine if patients with a diagnosis of instability would have significantly more shoulder laxity in the operatively treated shoulder than in the contralateral shoulder, and (3) to evaluate the observation that higher grades of shoulder laxity would be related to a diagnosis of shoulder instability.

Materials and Methods

The present study was approved by our institutional review board. This retrospective cohort study analyzed information from our institution's shoulder surgery database, which includes patients managed with shoulder surgery by only the senior author (E.G.M.) from 1992 through 2007[17-26]. Of the 1836 patients who were initially identified, 630 were excluded because no examination was performed with the patient under anesthesia because of a fracture (n = 51), shoulder arthroplasty (n = 330), or infection (n = 20); because of a frozen shoulder (n = 40); or because no arthroscopic evaluation was performed (n = 189). Therefore, the study group consisted of 1206 patients who had physical examination of the symptomatic and asymptomatic shoulders, both while awake and while under anesthesia, followed by diagnostic arthroscopy of the shoulder. The study group included 716 male patients and 490 female patients with an average age of forty-five years (range, twelve to eighty-six years). The diagnoses included rotator cuff tendinitis or tear (697 patients), shoulder instability (322 patients), isolated acromioclavicular arthritis (102 patients), superior labrum anterior-posterior (SLAP) lesions (thirty-nine patients), glenohumeral joint arthritis (twenty-one patients), and other diagnoses (twenty-five patients).

All patients underwent a preoperative assessment, including a thorough physical examination, and filled out detailed questionnaires, as previously reported[17-19,21,22,24,25,27,28]. The shoulder examination included an assessment of range of motion, an evaluation of strength with use of manual muscle testing, a complete neurologic evaluation of the upper extremities, and shoulder laxity testing. The physical examination was performed by, or under the direct supervision of, the senior author. There was no attempt to standardize the examination for the amount of force used to translate the humeral head over the glenoid rim. Laxity testing of the shoulder included a modified anterior and posterior drawer test, which was adapted[6,23] from the technique described by Gerber and Ganz[29]. The tests were performed with the arm in approximately 60° to 80° of abduction and 10° to 15° of forward flexion[23].

Laxity was measured with use of a modified Hawkins scale[13] in which the humeral head was judged not to subluxate over the glenoid rim (Grade I), to subluxate over the glenoid rim but to spontaneously reduce (Grade II), or to remain dislocated even when the subluxation force exerted by the examiner's hands was withdrawn (Grade III). As previously reported[1], a note was made in the examination record if the patient was judged to be unable to relax for the examination in the office because of pain or apprehension.

All patients underwent an evaluation of inferior laxity by testing for a sulcus sign. As previously reported[6], with the patient in a sitting position, an inferiorly directed force was applied to the arm and the translation was graded as <1.0 cm (Grade I), 1.0 to 2.0 cm (Grade II), or >2.0 cm (Grade III)[2,6,8,18,23,30,31].

Laxity testing was performed with the patient under general anesthesia with or without regional anesthesia with use of a scalene block. The anterior and posterior drawer tests were performed and graded with use of the modified Hawkins scale described above. Testing for the sulcus sign was performed with the patient supine, and the result was also graded with the system described above. All examinations with the patient under anesthesia were performed by the senior author. All patients underwent diagnostic arthroscopy in the lateral decubitus position, and all intra-articular findings were recorded on a datasheet[14,17-19,21-25,32].

The final diagnosis was based on the preoperative history, physical examination, radiographs, and the findings at the time of diagnostic arthroscopy[18,19,21,22,24,25]. Patients with rotator cuff disease were subdivided into three categories: those with impingement symptoms with no rotator cuff tear, those with partial rotator cuff tears, and those with full-thickness or massive rotator cuff tears (defined as those measuring >5 cm)[33]. Shoulder instability was classified as anterior, posterior, or multidirectional[1,23].

Statistical Methods

The first objective of the current study was to estimate the prevalence of shoulder laxity among individuals presenting for shoulder surgery for the treatment of a variety of diagnoses. To test the hypothesis that the ability to subluxate the shoulder over the glenoid rim was more prevalent than the inability to subluxate the humeral head over the glenoid rim, we estimated the prevalence of instability as the ratio of the number of patients with a diagnosis consistent with shoulder instability to the total number of patients presenting for shoulder surgery. A 95% confidence interval was constructed around our estimate of prevalence with use of Clopper-Pearson exact methods.

TABLE I Prevalence of Positive Laxity Tests According to Diagnosis in 1206 Patients Under Anesthesia Undergoing Shoulder Arthroscopy*

Primary Diagnosis	No. of Patients	Involvement of Dominant Arm	Anterior Drawer Test*		
			Grade I	Grade II	Grade III
Tendinitis	121	57.9%	29 (24.0%)	92 (76.0%)	0
Partial cuff tear	140	65.0%	35 (25.0%)	105 (75.0%)	0
Full-thickness cuff tear	369	63.0%	106 (28.7%)	261 (70.7%)	2 (0.5%)
Massive cuff tear	67	57.6%	13 (19.4%)	53 (79.1%)	1 (1.5%)
SLAP†	39	74.4%	4 (10.3%)	34 (87.2%)	1 (2.6%)
Glenohumeral instability	322	61.5%	9 (2.8%)	277 (86.0%)	36 (11.2%)
Anterior instability	231	58.9%	6 (2.6%)	191 (82.7%)	34 (14.7%)
Posterior instability	31	54.8%	0	31 (100%)	0
Multidirectional instability	26	57.7%	1 (3.8%)	23 (88.5%)	2 (7.7%)
Other glenohumeral instability	34	88.2%	2 (5.9%)	32 (94.1%)	0
Glenohumeral arthritis	21	66.7%	3 (14.3%)	18 (85.7%)	0
Acromioclavicular joint arthritis	102	50.0%	21 (20.6%)	80 (78.4%)	1 (1.0%)
Other	25	48.0%	2 (8.0%)	23 (92.0%)	0
Total	1206	61.0%	222 (18.4%)	943 (78.2%)	41 (3.4%)

*The values are given as the number of symptomatic shoulders with the diagnosis. †Superior labrum anterior-posterior lesion.

To test the second hypothesis, that there would be significant increases in laxity of the operatively treated as compared with the contralateral shoulder in patients with a final diagnosis of shoulder instability, we performed nonparametric tests (Wilcoxon tests) between the operatively treated and contralateral shoulders.

To test the third hypothesis, that increasing shoulder laxity was associated with instability, we performed a logistic regression analysis modeling the outcome of shoulder instability as a function of shoulder laxity. Odds ratios (and 95% confidence intervals) were computed for Grade-II and III laxity relative to Grade-I laxity for each of the rating scales. The level of significance was set at $p < 0.05$.

Source of Funding
There was no external funding source for this study.

Results

The findings regarding laxity with the patient under anesthesia are summarized according to diagnosis in Table I. When all patients were considered as a group, the ability to subluxate the humeral head over the glenoid rim anteriorly (81.6%; 984 of 1206) and posteriorly (57.5%; 693 of 1206) was more common than the inability to subluxate the humeral head over the rim. When the patients with a diagnosis of instability were excluded and the analysis was restricted to patients with other diagnoses (n = 884) who were examined under anesthesia, the ability to subluxate the humeral head over the glenoid rim was more common anteriorly (75.9%; 671 of 884) but was less common posteriorly (48.4%; 428 of 884) than the inability to subluxate the humeral head over the glenoid rim.

When all patients were considered as a group, significantly more laxity was documented when the patients were under anesthesia at the time of the operation than was documented when the patients were awake at the time of the preoperative office evaluation in terms of anterior translation, posterior translation, and the sulcus sign in the symptomatic (Table II) and asymptomatic shoulders. When all patients were considered as a group, the examination with the patients under anesthesia showed greater asymmetry between the symptomatic and contralateral shoulders in terms of anterior laxity (13.1%; 158 of 1205; $p < 0.001$), posterior laxity (17.5%; 211 of 1205; $p < 0.001$), and the sulcus sign (3.7%; forty-five of 1206; $p < 0.05$) (Table III).

Three hundred and twenty-two (26.7%) of the 1206 participants had instability (95% confidence interval, 24.2% to 29.3%). At the time of the preoperative office examination of the patients with a diagnosis of shoulder instability, there was significantly more laxity in the symptomatic shoulder than in the contralateral shoulder in terms of anterior translation ($p = 0.009$), posterior translation ($p = 0.041$), and inferior translation ($p < 0.001$). Similarly, with the patients under anesthesia, there was significantly more laxity in the operatively treated shoulder than in the contralateral shoulder in patients with instability in terms of anterior translation ($p < 0.001$), posterior translation ($p = 0.018$), and inferior translation ($p < 0.001$) (Table III).

TABLE I (*continued*)

Posterior Drawer Test*			Sulcus Sign*		
Grade I	Grade II	Grade III	Grade I	Grade II	Grade III
60 (49.6%)	60 (49.6%)	1 (0.8%)	98 (81.0%)	22 (18.2%)	1 (0.8%)
79 (56.4%)	60 (42.9%)	1 (0.7%)	112 (80.0%)	26 (18.6%)	2 (1.4%)
198 (53.7%)	170 (46.1%)	1 (0.3%)	316 (85.6%)	52 (14.1%)	1 (0.3%)
37 (55.2%)	30 (44.8%)	0	58 (86.6%)	9 (13.4%)	0
17 (43.6%)	20 (51.3%)	2 (5.1%)	33 (84.6%)	6 (15.4%)	0
57 (17.7%)	245 (76.1%)	20 (6.2%)	163 (50.6%)	143 (44.4%)	16 (5.0%)
41 (17.7%)	187 (81.0%)	3 (1.3%)	128 (55.4%)	94 (40.7%)	9 (3.9%)
2 (6.5%)	16 (51.6%)	13 (41.9%)	15 (48.4%)	15 (48.1%)	1 (3.2%)
4 (15.4%)	18 (69.2%)	4 (15.4%)	7 (26.9%)	15 (57.7%)	4 (15.4%)
10 (29.4%)	24 (70.6%)	0	13 (38.2%)	19 (55.9%)	2 (5.9%)
10 (47.6%)	11 (52.4%)	0	14 (66.7%)	5 (23.8%)	2 (9.5%)
45 (44.1%)	57 (55.9%)	0	84 (82.4%)	18 (17.6%)	0
10 (40.0%)	15 (60.0%)	0	17 (68.0%)	7 (28.0%)	1 (4.0%)
513 (42.5%)	668 (55.4%)	25 (2.1%)	895 (74.2%)	288 (23.9%)	23 (1.9%)

When only the shoulders that underwent arthroscopic evaluation were considered, the anterior drawer test for laxity was classified as Grade I for 222 patients, Grade II for 943 patients, and Grade III for forty-one patients. An examination of cross-frequency revealed that individuals with Grade-III laxity were more likely also to experience instability (87.8%; thirty-six of forty-one) than those with Grade-I laxity (4.1%; nine of 222) or Grade-II laxity (29.4%; 277 of 943). Individuals with Grade-II anterior laxity were more likely also to experience instability than those with Grade-I anterior laxity ($p < 0.001$ for all comparisons).

When only the shoulders that underwent arthroscopy were considered, laxity on the posterior drawer test was classified as Grade I for 513 patients, Grade II for 668 patients, and Grade III for twenty-five patients. An examination of cross-frequency revealed that individuals with Grade-III laxity were more likely also to experience instability (80.0%; twenty of twenty-five) than those with Grade-I laxity (11.1%; fifty-seven of 513) or Grade-II laxity (36.7%; 245 of 668). Individuals with Grade-II posterior laxity were more likely also to experience instability than those with Grade-I posterior laxity ($p < 0.001$ for all comparisons).

TABLE II Percentage of Patients with Increased Laxity of the Symptomatic Shoulder While Under Anesthesia as Compared with the Preoperative Assessment

Primary Diagnosis	No. of Patients	Anterior Drawer Test	Posterior Drawer Test	Sulcus Sign
Tendinitis	121	51.7% (31 of 60)	32.8% (20 of 61)	13.1% (11 of 84)
Partial cuff tear	140	52.4% (44 of 84)	27.9% (19 of 68)	11.4% (10 of 88)
Full-thickness cuff tear	369	51.9% (112 of 216)	37.5% (69 of 184)	11.7% (31 of 266)
Massive cuff tear	67	72.1% (31 of 43)	35.5% (11 of 31)	14.9% (7 of 47)
SLAP*	39	56.0% (14 of 25)	47.1% (8 of 17)	17.9% (5 of 28)
Glenohumeral instability	322	40.7% (87 of 214)	37.0% (70 of 189)	25.3% (64 of 253)
Glenohumeral arthritis	21	45.5% (5 of 11)	30.0% (3 of 10)	11.1% (2 of 18)
Acromioclavicular joint arthritis	102	59.3% (35 of 59)	42.6% (23 of 54)	10.6% (7 of 66)
Other	25	72.7% (8 of 11)	33.3% (3 of 9)	0% (0 of 16)
Total	1206	50.8% (367 of 723)	36.3% (226 of 623)	15.8% (137 of 866)

*Superior labrum anterior-posterior lesion.

TABLE III Percentage of Patients with Asymmetrical Laxity Under Anesthesia

Primary Diagnosis	No. of Patients	Anterior Drawer Test	Posterior Drawer Test	Sulcus Sign
Tendinitis	121	9.9% (12 of 121)	16.5% (20 of 121)	3.3% (4 of 121)
Partial cuff tear*	140	6.5% (9 of 139)	15.1% (21 of 139)	2.9% (4 of 140)
Full-thickness cuff tear	369	15.4% (57 of 369)	17.3% (64 of 369)	2.2% (8 of 369)
Massive cuff tear	67	16.4% (11 of 67)	29.9% (20 of 67)	7.5% (5 of 67)
SLAP†	39	7.7% (3 of 39)	10.3% (4 of 39)	0% (0 of 39)
Glenohumeral instability	322	15.5% (50 of 322)	18.0% (58 of 322)	6.2% (20 of 322)
Glenohumeral arthritis	21	9.5% (2 of 21)	19.0% (4 of 21)	4.8% (1 of 21)
Acromioclavicular joint	102	9.8% (10 of 102)	18.6% (19 of 102)	2.9% (3 of 102)
Other	25	16.0% (4 of 25)	4.0% (1 of 25)	0% (0 of 25)
Total	1206	13.1% (158 of 1205)	17.5% (211 of 1205)	3.7% (45 of 1206)

*One patient with a partial cuff tear did not have anterior and posterior drawer test results for the contralateral shoulder. †Superior labrum anterior-posterior lesion.

When only the shoulders that underwent arthroscopy were considered, laxity as indicated by the sulcus sign was classified as Grade I in 895 patients, Grade II in 288 patients, and Grade III in twenty-three patients. An examination of cross-distribution revealed that individuals with Grade-III laxity were more likely also to experience instability (69.6%; sixteen of twenty-three) than those with Grade-I laxity (18.2%; 163 of 895) or Grade-II laxity (49.7%; 143 of 288) ($p < 0.001$ for all comparisons). Individuals with Grade-II laxity were more likely also to experience instability than those with Grade-I laxity ($p < 0.001$).

Logistic regression analysis showed that the degree of laxity was strongly related to a diagnosis of instability. When the patients were stratified according to the results of the anterior drawer test, those with Grade-III laxity had 170.3 times the odds of instability as compared with those with Grade-I laxity (95% confidence interval, 54.0 to 537.0), and those with Grade-II laxity had 9.8 times the odds of having instability as compared with those with Grade-I laxity (95% confidence interval, 5.0 to 19.4). Patients with Grade-III laxity also had increased odds of having instability as compared with those with Grade-II laxity (odds ratio, 17.2; 95% confidence interval, 6.7 to 45.5).

When the patients were stratified according to the results of the posterior drawer test, those with Grade-III laxity had 32.0 times the odds of having instability as compared with those with Grade-I laxity (95% confidence interval, 11.6 to 88.5) and those with Grade-II laxity had 4.6 times the odds of having instability as compared with those with Grade-I laxity (95% confidence interval, 3.4 to 6.4). Patients with Grade-III laxity also had increased odds of having instability as compared with those with Grade-II laxity (odds ratio, 6.9; 95% confidence interval, 2.6 to 18.5).

When the patients were stratified according to the sulcus sign grade, those with a Grade-III sulcus sign had 10.3 times the odds of having instability as compared with those with a Grade-I sulcus sign (95% confidence interval, 4.2 to 25.3) and those with a Grade-II sulcus sign had 4.4 times the odds of having instability as compared with those with a Grade-I sulcus sign (95% confidence interval, 3.3 to 5.9). There was no increase in the odds of having instability when patients with a Grade-III sulcus sign were compared with those with a Grade-II sulcus sign (odds ratio, 2.3; 95% confidence interval, 0.9 to 5.8).

Discussion

To the best of our knowledge, our study is the first to evaluate the distribution of shoulder laxity in a large cohort of patients and to compare laxity on the basis of diagnosis. The present study confirms our hypothesis that, overall, in anesthetized patients undergoing laxity testing before shoulder arthroscopy, the ability to subluxate the shoulder over the glenoid rim anteriorly or posteriorly is more common than the inability to do so. Therefore, the finding that the shoulder can be subluxated over the glenoid rim should not be presumed by clinicians to represent an abnormal degree of shoulder laxity.

The main limitation of the present study is that the study group consisted of patients who were undergoing shoulder surgery, not a group of normal individuals who did not have shoulder problems or who had had shoulder problems but were not undergoing surgery. However, it would not be practical or ethical to examine normal shoulders with laxity testing with patients under anesthesia to obtain a control group, so our study was necessarily limited to the shoulders of patients undergoing shoulder surgery.

The present study may have been influenced by the fact that the patients were from the practice of one surgeon and the final diagnosis was made by that surgeon. The final diagnosis was largely based on the findings at the time of arthroscopic surgery, but preoperative factors were considered. The senior author was not blinded to the preoperative examination, diagnosis, radiographs, or magnetic resonance images, and we did not evaluate the influence of preoperative variables on the final diagnosis.

Our findings may not be transferable to the evaluation of shoulder laxity in the office setting. The present study and previous studies[11,16,34] documented that laxity in the shoulder is increased with the patient under anesthesia as compared with that determined during an office examination. One study demonstrated that approximately 80% of patients relax enough for anterior drawer testing in the office[1]. In the current study, all patients were examined while under a general anesthetic with or without a regional block, so different distributions of laxity according to diagnosis may be explained by the fact that, in other studies, a general anesthetic was not used.

Any study of laxity testing of the shoulder is confounded by the lack of a gold standard measurement. In the present study, we used a scale for laxity based on what the clinician feels when performing the examination, and this measure is not currently quantifiable. As a result, statistical analysis of laxity did not allow parametric analysis of measurable distances. To our knowledge, the amount of translation necessary to create Grade-I, II, or III laxity in an anterior, posterior, or inferior direction has not been established. Similarly, it may be that subtle differences in shoulder laxity (which possibly could have influenced our findings and conclusions) are not measurable with use of existing shoulder examination methods. In addition, the amount of force used by the senior author to subluxate the shoulder was not quantified, but this shortcoming is inherent to any study involving the use of such uninstrumented examination techniques for the examination of shoulder laxity.

Despite these limitations, an important variable of our study was that one clinician performed all of the shoulder examinations of patients who were under anesthesia for the entire time period with use of the same technique and the same scale for measuring laxity. A previous study showed that the intraobserver reliability of the examination by this one examiner was 100% (twenty-eight of twenty-eight) for anterior translation and 86% (twenty-four of twenty-eight) for posterior translation[23]. Similarly, an interobserver study of this method of measuring shoulder laxity showed that the agreement between observers using this technique was 77% (thirty-four of forty-four) for anterior drawer testing and 70% (thirty-one of forty-four) for posterior drawer testing[23]. However, in the current study, the examiner was not blinded to the patient's diagnosis, and it is possible that observer bias influenced our results. It may be that the results reported here are not transferable to a wider range of examiners because the reliability of the examination for a wide range of examiners has not been studied extensively.

The technique used for measuring anterior and posterior shoulder laxity in the present study differed slightly from that originally described by Gerber and Ganz[29], and it is unknown how that factor might have affected the results.

The present study confirms our observation that the ability to subluxate the shoulder over the glenoid rim is more common than previously believed. We also found that the distribution of shoulder laxities is related to the diagnosis, with increasing grades of shoulder laxity associated with a higher likelihood of shoulder instability. Until instruments for the measurement of laxity are available, the subjective aspect of present systems to grade shoulder laxity limits the clinician's ability to use laxity testing to make a definitive diagnosis of shoulder instability. The clinical examination of shoulder laxity with the patient under anesthesia should be performed with the knowledge that the ability to subluxate the shoulder over the glenoid rim is common regardless of diagnosis and that the extent and distribution of shoulder laxities may vary according to diagnosis. ■

Xiaofeng Jia, MD, PhD
Jong Hun Ji, MD
Steve A. Petersen, MD
Michael T. Freehill, MD
Edward G. McFarland, MD
c/o Elaine P. Henze, BJ, ELS, Medical Editor,
Department of Orthopaedic Surgery,
Johns Hopkins Bayview Medical Center,
4940 Eastern Avenue, #A665, Baltimore,
MD 21224-2780.
E-mail address for E.P. Henze: ehenze1@jhmi.edu

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