The Bony Apprehension Test for Instability of the Shoulder: A Prospective Pilot Analysis

Brandon D. Bushnell, M.D., R. Alex Creighton, M.D., and Marion M. Herring, M.D.

Purpose: We performed a prospective pilot study of the “bony apprehension test,” in which apprehension is experienced at or below 45° of abduction and 45° of external rotation, as a means of screening for a significant bony lesion causing instability of the shoulder. Methods: Over a 1-year period, 29 consecutive cases of symptomatic shoulder instability were examined with the bony apprehension test and treated with surgery. Findings at arthroscopy were used as the definitive diagnostic data point. This information was compared with the results of the test and with the results of the preoperative plain radiographs. Results: There were 8 cases involving significant bony lesions and 21 cases involving only soft-tissue lesions. The bony apprehension test was positive in all 8 patients in the bony lesion group and in 3 of 21 patients in the soft-tissue lesion group, representing a sensitivity of 100%, specificity of 86%, positive predictive value of 73%, and negative predictive value of 100%. Preoperative radiographs were positive in 4 patients in the bony lesion group only, representing a sensitivity of 50%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 84%. Conclusions: The bony apprehension test can reliably screen for significant osseous lesions. In this study it was more sensitive than plain radiographs, as shown by a higher sensitivity for the test (100%) than for preoperative plain radiographs (50%). Level of Evidence: Level II, development of diagnostic criteria based on consecutive patients with universally applied gold standard. Key Words: Apprehension test—Shoulder instability—Bony instability—Bankart lesion—Hill-Sachs lesion—Glenoid insufficiency.
diagnose without advanced imaging modalities such as computed tomography (CT) or magnetic resonance imaging (MRI). Instability due to such bony defects—"bony instability"—constitutes an important cause of failure of primary reconstruction because of failure to properly address the bony lesion. A simple, inexpensive, reliable tool for screening for bony instability would thus prove quite valuable in the workup of a patient with shoulder stability complaints.

In 2004 Miniaci and Gish called attention to the fact that significant apprehension could be present well below the standard position of 90° of abduction/90° of external rotation in cases of anterior glenohumeral instability associated with large Hill-Sachs defects. To our knowledge, no previously published study has involved a clinical series to validate this observation. At our institution, we have treated several cases of anterior instability related to osseous lesions, and we have witnessed similar findings on physical examination. A retrospective analysis of our cases found a correlation of the "bony apprehension test," performed at the position of 45° of abduction/45° of external rotation, with significant bony lesions of the shoulder (Fig 4). The purpose of this pilot study was

![Figure 1](image1.png)

**Figure 1.** Standard apprehension test. (A) The examiner attempts to elicit a sensation from the patient that the shoulder "feels like it is about to come out of joint" by stabilizing the scapula and placing the arm slowly into a position of 90° of abduction and 90° of external rotation. (B) Anteriorly directed pressure on the posterior humerus is then applied as needed in a further attempt to elicit this sensation, illustrated here as the examiner pulls the proximal humerus forward. Pain alone is generally not considered a positive result.

![Figure 2](image2.png)

**Figure 2.** Bony Bankart lesion. Oblique sagittal (A) and coronal (B) MRI cuts of a large bony Bankart lesion. The red line indicates the approximate missing area of the glenoid. The yellow line highlights the bony fragment found in the inferior recess.
to prospectively investigate the bony apprehension test as a screening examination for a bony defect causing symptomatic anterior instability of the shoulder. Our hypothesis was that the test could identify a significant bony lesion.

METHODS

For purposes of this study, a positive bony apprehension test (Fig 4) was defined a priori as a patient’s sensation of apprehension of an episode of glenohumeral instability when the examiner placed the arm in a position of 45° of abduction or less and 45° of external rotation or less. The presence of pain without apprehension of instability was not considered a positive test.2

Between February 2007 and February 2008, we followed up all the patients presenting with shoulder instability symptoms to the practices of the 2 senior authors (R.A.C. and M.M.H.) at our institution. Inclusion criteria were subjective complaints of instability and the decision for surgical treatment. Findings at surgery were used as the definitive diagnostic data point of the study, and thus nonoperatively treated patients were excluded from the study. There were no other exclusion criteria.

All patients underwent a complete history and physical examination performed by the attending surgeon.

A plain radiographic “instability series” was obtained, consisting of a true anteroposterior (Grashey) view, internal and external rotation views, scapular-Y view, axillary lateral view, Stryker notch view, West Point view, and apical oblique (Garth) view (Fig 5).25,26 Readings were performed by an attending radiologist and the attending surgeon. Results of these plain radiographs were used as a comparative data point. CT and MRI studies were obtained in some cases at the discretion of the treating surgeon, and several patients had already undergone these studies before their presentation to our institution. These data were not used as part of the study analysis or in final operative decision making because of lack of uniformity across the study population.

On the basis of positive findings of the instability workup, all patients were offered diagnostic arthroscopy.27 Arthroscopic or open treatment of the pathology was then performed as indicated based on arthroscopic findings. The primary data point was the presence or absence of a significant bony lesion, defined as an osseous glenoid deficiency (bony Bankart lesion) of at least 25% of the glenoid,28 and/or an engaging Hill-Sachs lesion of at least 2 cm in engagement length.5,25 Measurements were made arthroscopically in the manner described by Burkhart et al.13-15 If possible, bony defects were measured on CT and/or MRI as well. All additional lesions were also identified and recorded, as was their surgical treatment.29

During the study period, 29 patients underwent surgery for symptomatic instability of the shoulder. The mean age at the time of surgery was 24 years 8 months (range, 16 years 3 months to 52 years 4 months). There were 22 male patients (76%) and 7 female patients (24%). In 5 cases previous surgery had been performed for shoulder instability.

Analysis focused on the correlation of the preoperative bony apprehension test and the plain radiographs with the ultimate pathologic findings at surgery. A true-positive finding was defined as a positive bony apprehension test in a case involving a significant bony lesion, whereas a false-positive finding was defined as a positive bony apprehension test in a case without a significant bony lesion. A true-negative finding was defined as a negative bony apprehension test in a case without a significant bony lesion, and a false-negative finding was defined as a negative bony apprehension test in a case with a significant bony lesion. These data were used to calculate the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the bony apprehension test. Findings of the preoperative plain radio-
graphs were also compared with the findings at surgery in a similar fashion.

RESULTS

At surgery, 8 patients were found to have a significant bony lesion (Table 1). Within this group, there were 6 cases involving at least 25% bone loss from the anterior glenoid. Of these patients, 3 underwent autogenous iliac crest bone grafting of the anterior glenoid21 and 3 underwent a modified Latarjet procedure.16 There were 2 cases involving an engaging Hill-Sachs lesion with an engagement length of at least 2 cm, both treated with arthroscopic capsulorrhaphy and grafting of the Hill-Sachs lesion with either an autogenous iliac crest bone graft25 or a HemiCAP prosthesis (Arthrosurface, Franklin, MA).30 Twenty-one patients were found to have soft-tissue pathology without significant bony involvement, with various arthroscopic soft-tissue procedures being performed (Table 2).

The standard apprehension test was positive preoperatively in all 29 patients. The bony apprehension test was positive in all 8 patients in the bony lesion group and in 3 of 21 patients in the soft-tissue lesion group. This represents a sensitivity of 100%, specificity of 86%, PPV of 73%, and NPV of 100%. Preoperative radiographs were positive for the operative bony lesion in 4 patients in the bony lesion group and did not show any suspicion for a bony lesion in the soft-tissue lesion group. This represents a sensitivity of 50%, specificity of 100%, PPV

Figure 4. Bony apprehension test.24 This test is identical to the standard apprehension test except that the arm is brought to only 45° of abduction and 45° of external rotation. A positive result should alert the examiner to the possibility of a bony lesion as the cause of symptomatic shoulder instability. These images illustrate the position of the arm for the standard apprehension test (A) compared with the bony apprehension test (B, C), as well as the performance of the bony apprehension test (D).
of 100%, and NPV of 84%. Prior surgery for instability of the same shoulder has been performed in 3 patients in the bony lesion group (38%) and 2 patients in the soft-tissue lesion group (10%).

**DISCUSSION**

In a landmark article in 2000, Burkhart and De Beer\(^\text{15}\) showed that two thirds of patients in whom arthroscopic Bankart repair failed had a significant bone defect that caused residual instability. They recommended open treatment to address the osseous lesion instead of an isolated arthroscopic soft-tissue stabilization procedure. Open treatment options for bony instability have included bone grafting of glenoid or humeral defects, transfer of the coracoid to the glenoid, humeral rotational osteotomy, humeral head plasty, and other procedures\(^\text{8,9,12,13,15-23,25,31-46}\).

A drastic change in surgical plan thus can suddenly result if the surgeon fails to recognize a bony lesion until diagnostic arthroscopy. More importantly, failure to recognize functionally significant lesions before or during arthroscopy can result in failure of the reconstruction altogether. Arthroscopic diagnosis of functionally significant lesions can sometimes prove difficult,\(^\text{13}\) and plain radiographs must often be supplemented with CT or MRI studies to adequately diagnose bony lesions preoperatively.\(^\text{24,32,47}\)

Any diagnostic modality that can help the surgeon recognize and appropriately manage this entity thus represents a valuable asset to patient care. When the possibility of a bony lesion is identified, preoperative counseling of the patient will include the planned or potential need for conversion to an open procedure if and when diagnostic arthroscopy confirms the presumptive diagnosis. The surgeon can also make adequate material and technical preparation for the required open procedure, which will likely mandate special equipment, positioning, graft options, hardware, and other items.

This prospective pilot study of a small series of patients showed that the bony apprehension test had both a sensitivity of 100% and NPV of 100%—ideal for a screening test. Furthermore, the bony apprehension test costs nothing to perform and poses no increased risk to the patient—also ideal for a screening test. Although the test had a lower spec-

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**FIGURE 5.** Garth view. The Garth view is a 45° apical oblique projection of the glenohumeral joint that can greatly assist in identifying bony lesions of the glenoid.\(^\text{26}\) In this image a step-off defect of the anteroinferior glenoid is noted.

**TABLE 1. Patients in Bony Lesion Group**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Race</th>
<th>Sex</th>
<th>Age (yr)</th>
<th>Side</th>
<th>Surgery</th>
<th>Previous Surgery Performed</th>
<th>Bone Loss*</th>
<th>Bony Apprehension Test Result†</th>
<th>Preoperative Plain Radiograph Findings†</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>White</td>
<td>F</td>
<td>21</td>
<td>L</td>
<td>AC, HSICBG</td>
<td>OC</td>
<td>2-cm HS</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>White</td>
<td>M</td>
<td>22</td>
<td>L</td>
<td>AGICBG</td>
<td>No</td>
<td>50% G</td>
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<td>+</td>
</tr>
<tr>
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<td>F</td>
<td>41</td>
<td>L</td>
<td>Latarjet</td>
<td>OC</td>
<td>25% G</td>
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<td>–</td>
</tr>
<tr>
<td>4</td>
<td>White</td>
<td>M</td>
<td>21</td>
<td>L</td>
<td>AGICBG</td>
<td>No</td>
<td>25% G</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>Black</td>
<td>M</td>
<td>20</td>
<td>L</td>
<td>AGICBG</td>
<td>AC</td>
<td>50% G</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>6</td>
<td>White</td>
<td>M</td>
<td>24</td>
<td>R</td>
<td>Latarjet</td>
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<td>35% G</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>7</td>
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<td>F</td>
<td>27</td>
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<td>AC, Pros</td>
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<td>2.5-cm HS</td>
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<td>+</td>
</tr>
<tr>
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<td>White</td>
<td>F</td>
<td>22</td>
<td>R</td>
<td>Latarjet</td>
<td>No</td>
<td>30% G</td>
<td>+</td>
<td>–</td>
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</table>

Abbreviations: AC, arthroscopic capsulorrhaphy; HSICBG, Hill-Sachs lesion iliac crest bone grafting; HS, Hill-Sachs lesion; AGICBG, anterior glenoid iliac crest bone grafting; G, glenoid; Latarjet, modified Latarjet coracoid transfer; OC, open capsulorrhaphy; Pros, prosthetic resurfacing with HemiCAP implant (Arthrosisurface).

*Measured size of Hill-Sachs lesion or percentage loss from glenoid.
†A plus sign indicates a positive test result, and a minus sign indicates a negative test result.
ificity (86%) and PPV (73%), it did not miss a single case involving a significant osseous lesion. Plain radiographs, on the other hand, had a sensitivity of only 50% and NPV of only 84%, further supporting the established idea that bony lesions can be difficult to diagnose and are easily missed by current methods of screening. These data support the use of the bony apprehension test in the workup of every patient with shoulder instability complaints as a screening examination for a significant bony lesion, confirming our hypothesis.

In our study we noted a high percentage of cases with a prior history of surgical treatment in the bony lesion group (3/8, or 38%) versus the soft-tissue lesion group (2/21, or 10%). These data further support the findings of Burkhart and De Beer\textsuperscript{15} regarding the contribution of an unrecognized bony lesion to failure of surgical repair. Indeed, continued instability symptoms in a patient with a history of a prior surgical procedure should raise very high suspicion for a possible missed bony lesion.

The small sample size of this study raises concerns on initial review. Comparison to the literature, however, shows some interesting data. Over a 3-year period, Warner et al.\textsuperscript{21} identified 11 cases of instability due to glenoid bone loss (3.7 cases per year). Burkhart and De Beer\textsuperscript{15} reported on 21 patients with significant bone defects collected over a 6-year period (3.5 cases per year). Miniaci and Gish\textsuperscript{8} reported on 18 cases of Hill-Sachs lesions requiring surgery collected over a 7-year period (2.6 cases per year). In our previous retrospective series we noted 19 cases of bony lesion–induced instability over a period of 24 months (9.5 cases per year),\textsuperscript{24} and we found 8 cases over a 1-year period in the present study. Considering these calculations, it seems that our sample size compares favorably with the literature and actually represents quite a high incidence of this problem. Indeed, we had a very high percentage of bony lesions within the overall group (8/29, or 28%). In the overall population, bony lesions do not represent such a com-

### Table 2. Patients in Soft-Tissue Lesion Group

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Race</th>
<th>Sex</th>
<th>Age (yr)</th>
<th>Side</th>
<th>Surgery Preformed</th>
<th>Bone Loss*</th>
<th>Bony Apprehension Test Result†</th>
<th>Preoperative Plain Radiograph Findings†</th>
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Abbreviations: AC, arthroscopic capsulorrhaphy; AD, arthroscopic debridement; BT, biceps tenodesis; AS, arthroscopic SLAP repair; HS, Hill-Sachs lesion; G, glenoid; AR, arthroscopic rotator cuff repair; Rev, revision of prior surgery; ODCR, open distal clavicle resection; LBR, loose body removal.

*Measured size of Hill-Sachs lesion or percentage loss from glenoid.
†A plus sign indicates a positive test result, and a minus sign indicates a negative test result.
mon cause of instability.\textsuperscript{21,35,48} Our institution, however, serves as a referral center for difficult cases and revision cases, likely explaining our high numbers of bony instability. Indeed, it is this high percentage of bony lesions that we have encountered that has led to our interest in this topic.

Another concern about this study may be the design of the bony apprehension test. The position of 45° of abduction and 45° of external rotation was admittedly chosen arbitrarily. This position has been described previously as one to test for the middle glenohumeral ligament and the subscapularis.\textsuperscript{49} Future clarification studies of the bony apprehension test may seek to perform the test at a wider range of positions and compare the results at each point. A recent study by Farber et al.\textsuperscript{2} analyzed the usefulness of 3 common tests for traumatic anterior shoulder instability: the anterior apprehension test, the relocation test, and the anterior drawer test. In this study the sensitivity, specificity, and likelihood ratios for the anterior apprehension and relocation tests were higher when apprehension, rather than pain, was used as the criterion for a positive test.\textsuperscript{2} This study confirmed the previous findings of Lo et al.,\textsuperscript{50} who also showed that apprehension was a more accurate predictor of instability than the isolated presence of pain. The collective message of these and other similar studies led us to use apprehension, rather than pain, as the core determinant of a positive bony apprehension test.

This study had several limitations. It involved a very small series of patients, which obviously limits its power. We did not perform an a priori power or sample size analysis because we intended this study to serve only as a pilot investigation for using the test as a screening examination; we did not seek to establish it as a definitive diagnostic modality. Moreover, the true incidence of bony instability is unknown, because it is often misdiagnosed and thus may be under-reported, causing further difficulty with a priori sample size calculations. A second problem with the study was that the treating surgeons performed the preoperative examinations, rather than a completely blinded examiner. Even though the final diagnosis was not confirmed in each case until arthroscopy (an effective “blinding”), there is still an element of bias introduced without true blinding.

A third drawback was the grouping of both engaging Hill-Sachs defects and large bony Bankart lesions into a common “bony lesion” designation. Although these are distinct entities with differing treatments,\textsuperscript{15} we believe that they still represent parts of a common pathologic process in which the bony anatomy (rather than just the soft tissues) contributes to the problem. Furthermore, use of the bony apprehension test as a screening examination does not require the test to distinguish between these 2 lesions—only to identify them as a potential problem requiring further attention. A fourth limitation was the lack of including our nonoperative patients in the study. There were a few patients during the study period with a positive bony apprehension test who elected, for various reasons, not to have surgery. Because we defined our ultimate data points via arthroscopic findings, we had no choice but to exclude these patients. Future study designs should consider using 3-dimensional CT scans\textsuperscript{47} as an additional definitive diagnostic data point so that nonsurgical patients could also be included in the analysis.

CONCLUSIONS

The bony apprehension test can reliably screen for significant osseous lesions. In this study it was more sensitive than plain radiographs, as shown by a higher sensitivity for the test (100%) than for preoperative plain radiographs (50%).

REFERENCES


