Diagnostic Accuracy of Contrast and Noncontrast Magnetic Resonance Imaging in Superior Labrum Anterior-Posterior Tears in an Academic Setting

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Level of Evidence: Diagnostic Study Level II
Abstract:

**Background:** Superior labral anterior posterior (SLAP) lesions are infrequent injuries, and diagnosis by magnetic resonance imaging (MRI) is difficult and controversial.

**Hypothesis:** Based on our clinical experience, the accuracy of the MRI to diagnose a SLAP lesion is less than previously reported.

**Study Design:** Diagnostic Retrospective Study

**Methods:** Between January 2006 and December 2008, 444 patients who had both shoulder arthroscopy and an MRI (non-contrast or MR arthrography) at our institution prior to surgery were identified and were included in the study. The radiologic diagnosis and surgical evaluation were compared to determine the accuracy of diagnosing a SLAP lesion by MRI. Using arthroscopy as the standard; sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) were calculated for all MRIs, the non-intra-articular contrast MRI group, and the MR arthrography group.

**Results:** Of the 444 patients, 121 had a SLAP diagnosis by MRI and 44 had a SLAP diagnosis by arthroscopy. Overall, MRI had an accuracy of 76%, a PPV of 24%, and a NPV of 95%. Sensitivity was 66%, and specificity was 77%. MR arthrography had an accuracy of 69%, sensitivity of 80%, and a PPV of 29%. Noncontrast MRI had an accuracy of 85%, sensitivity of 36%, and a PPV of 13%.

**Conclusions:** In our retrospective study of 444 patients, sensitivity, specificity, and accuracy were all lower than previously reported in the literature for diagnosing SLAP lesions. Our data suggests that while MRI could exclude a SLAP lesion (NPV=95%), MRI alone was not an accurate clinical tool. MR arthrography had a large number of false positive readings in this study. We conclude that even with intra-articular contrast, MRI has limitations in the ability to diagnose surgically proven SLAP lesions.

Introduction:

Since first described by Andrews in 1985 and further classified by Snyder et al., superior labral anterior-posterior (SLAP) lesions represent an ongoing diagnostic challenge for orthopedic surgeons [3,20]. Between 2004 and 2009 there were 25,574 cases of arthroscopic SLAP repairs reported in the United States with the number of repairs doubling between 2004 and 2009 (2654 and 5419, respectively).[25] The etiology of this increase is ultimately unknown as no consensus exists on the proper diagnosis and treatment of this injury. However, as the economic impact of orthopedic procedures is evaluated, the importance of developing accurate diagnostic tests as a component of creating high quality, efficient, accessible, and economically sustainable healthcare cannot be under emphasized.

The superior glenoid and labrum serves as an attachment for the long head of the biceps and is a highly innervated structure supporting its role as a pain generator [22,1,8]. Injuries to the bicipitalabral complex are thought to present clinically as pain, clicking, and instability [3]. Cadaveric studies support a “peel back” mechanism where torsional loads across the superior labrum from the more posteriorly oriented bicep tendon displace the labrum and biceps tendon over the glenoid rim [10]. Snyder classified these injuries into four types (types I-IV), based on arthroscopic findings [20].

Clinical examination of SLAP lesions has relatively poor diagnostic value in isolation [7]. Therefore, conventional magnetic resonance imaging (MRI) and magnetic resonance arthrography (MRA) are commonly used tools during the clinical workup of
shoulder pain [11]. Despite heavy reliance on these imaging tests by orthopaedic surgeons, the validity of MRI/MRA has wide variability reported in the literature. For example, a recent Level 1 prospective study by Phillips et al. found a specificity of 13% when comparing conventional MRI to arthroscopic findings.[17] This is in contrast to multiple previous publications, including a landmark study by Connell et al showing a specificity of 89.5%.[5] The addition of arthrography is widely believed to enhance the validity of MRI when evaluating SLAP lesions. Waldt et al. reported a specificity of 98% in the detection of SLAP lesions while, in contrast, Amin et al. found a specificity of 50% when evaluating MRA.[23,2] The range of accuracies is reported is between 27%-95% [18,12,6,21,4]. These discrepancies serve to illustrate the ongoing debate of the value of both MRI and MRA as a diagnostic tool.

The purpose of this study was to evaluate the accuracy of MRI and MRA in diagnosing SLAP lesions in an academic setting. While not the first study of its kind, we believe a large retrospective evaluation in a university setting is of benefit when evaluating highly variable and often conflicting literature. We hypothesize that the accuracy of MRI, with or without arthrography, is lower than previously reported.

**Methods:**

We retrospectively reviewed 735 consecutive dictated patient operative reports between January 2006 and December 2008 who underwent arthroscopic shoulder surgery by one of two experienced sports medicine orthopaedic surgeons with the [blinded for review] Orthopedic Sports Medicine Clinic. We compared these findings with dictated imaging reports performed by one of three fellowship trained musculoskeletal radiologists. Patients were included if they underwent a preoperative MRI, with or without arthrogram. Patients were excluded who lacked a preoperative MRI within the past 6 months, had an MRI performed at a facility other than our institution, or had a history of a previous SLAP repair. Ten patients with the radiologic reading of “equivocal SLAP” were excluded due to lack of a definitive diagnosis. The Institutional Review Board (IRB) of [blinded for review] approved this study.

**MRI Protocols**

Conventional MRI of the shoulder was performed utilizing the following sequences: coronal proton density and proton density, fat-saturated sequences in sagittal, axial and oblique coronal planes. For MR arthrography, fluoroscopically-guided injection of 12 cc dilute gadolinium (approximately 1:200 dilution) into the glenohumeral joint via an anterior approach. Subsequent MRI included coronal T1-weighted fat-saturated, coronal proton density fat-saturated, coronal proton density, sagittal T1-weighted fat-saturated, and axial T1-weighted fat-saturated sequences. Additional T1-weighted fat-saturated radial sequence with axis of rotation centered on the center of the glenohumeral joint as depicted on a sagittal image through the joint was also routinely obtained. A 1.5-Tesla scanner was utilized for both arthrogram and non-arthrogram MRIs.

MRI images were interpreted using standard MR criteria for diagnosing a SLAP lesion. Briefly, a tear was diagnosed if any of the following observations were made: a linear high-signal contrast cleft in the superior labrum oriented laterally, directed away from the glenoid; a linear high signal cleft that extended posterior to the biceps tendon anchor; or an irregular or globular high-signal focus within the superior labrum [4,23,13].
Multiple contrast clefts within the superior labrum, as well as frankly displaced labral fragments, were interpreted as SLAP III or IV lesions, depending on whether a high signal contrast cleft extending into the biceps tendon (denoting a SLAP IV lesion) was present or not [4,23,19]. Fraying of the superior labrum without a discernible tear cleft was interpreted as a SLAP I lesion and such studies were reported as showing no discrete tear [23].

Linear high-signal clefts that were smooth, oriented directly superiorly or medially towards the glenoid, and did not extend posterior to the biceps tendon anchor were considered characteristic for a sublabral cleft rather than SLAP lesion [4,23]. With conventional MRI, SLAP tears were detected by assessing foci of high signal on fluid-sensitive sequences (proton-density fat-saturated or T2-weighted fat-saturated) using the same criteria as described for MR arthrography above.

The above observations were made predominantly on the oblique coronal T1 fat-saturated sequence (in the case of MR arthrography), or the oblique coronal proton density fat-saturated/T2 fat-saturated sequence (in the case of conventional MRI), with images from other planes reviewed to add diagnostic confidence.

Arthroscopic SLAP Diagnosis

Type I, III, and IV SLAP lesions were clearly seen during arthroscopic exam due to the evidence of fraying and/or splitting of the labrum. To distinguish a type II lesion one or more of the following intraoperative findings were used to demonstrate abnormal laxity in the biceps anchor and labral attachment: a positive peel-back sign, a bare sublabral footprint, a displaceable biceps root, a positive drive through sign with or without a large sublabral recess. This was most important in a type II lesion as it may not be apparent on simple arthroscopic exam. Normal anatomic variants such as a sublabral foramen or “Buford complex” were excluded from the SLAP cohort.

Statistical analysis

We used arthroscopy as the reference standard for diagnosing SLAP lesions. Overall accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive values (NPV) were calculated. For those estimates of diagnostic accuracy, the precision of the estimates were reported as 95% confidence intervals [11]. Approximate confidence intervals were calculated by using the standard error of a proportion which is based on a binomial approximation to the normal distribution. As a general rule, this normal approximation can be used whenever np and n(1-p) are at least 10, where p represents either sensitivity or specificity and n is the sample size [11]. However, when the proportion is small, the 95% confidence interval for proportion were calculated according to the efficient-score method (corrected for continuity) described by Robert Newcombe [16].

Results:

The study group consisted of 444 patients, 271 men and 173 women, with an average age of 49 years old. We created contingency tables (1-3) and calculated accuracy, sensitivity, specificity, PPV, and NPV along with their 95% confidence intervals (Table 4).

The accuracy of noncontrast MRIs was superior to that when contrast was used (82% [77%-87%] vs. 69% [63%-75%]). The addition of arthrogram resulted in an increase in sensitivity (contrast 80% [61%-92%] vs. noncontrast 36% [14%-64%]).
poor sensitivity of noncontrast MRI is a reflection of a proportionately large number of false negatives (9 of 14 patients); it should be noted this is the smallest of the sample groups. An arthrogram resulted in worse specificity (contrast 67% [60%-74%] vs. noncontrast 85% [79%-89%]) than the non-arthrogram group. This statistic is influenced by a large number of false positives in the arthrogram group, where 59 patients were read as positive on MRI and subsequently found to be negative on arthroscopy.

Positive predictive value was poor in both groups (contrast 29% [20%-40%] vs. noncontrast 13% [5%-29%]) while negative predictive value was equivalently good in both groups (95% for both). The combined performance of MRI, with or without contrast, was 76% (72%-80%) accurate, 66% (50%-79%) sensitive and 77% (73%-81%) specific with a PPV of 24% (17%-33%) and NPV of 95% (92%-97%).

**Discussion:**

The purpose of this study was to assess the accuracy of MRI and MRA in diagnosing SLAP lesions. Our data represents a typical patient population presenting to an academic orthopedic sports practice. To reduce bias, we did not select for overhead athletes, a population where SLAP lesions are particularly common[24]. Additionally, our subgroup analysis did not include a distinction between Snyder classification groups.

We believe that reporting the presence of SLAP tears as either present or absent strengthens the use of arthroscopy as a reference standard while maintaining broad applicability. Previous studies indicate that intraobserver reliability has only moderate agreement and thus analysis based on Snyder subgroups may lead to misleading results [9]. The results of our study suggest that MRI and MRA underperformed in this population with regards to our reference standard.

In the presence of an arthroscopically diagnosed SLAP lesion, MRI was more specific (85%, 79%-89%) while MRA was more sensitive (80%, 61%-92%). Neither test performed well in both sensitivity and specificity. The sensitivity of MRI was particularly poor, 36% (14%-64%), while the specificity of MRA was a modest 67% (60%-745). These results are in contrast to a recently published study by Phillips et al. who prospectively examined 77 patients using conventional MRI and found a sensitivity of 86% (83%-91%) and specificity of 12% (4%-22%) in patients with or without concomitant findings. One potential explanation is the difference in MRI reading protocols, which were not specifically stated in the study by Phillips et al. We suspect that without intraarticular contrast subtle details, such as fraying at the biceps anchor in type I lesions, were overlooked but found intraoperatively. This would result in an increased specificity but worse sensitivity. A recently published study by Connolly et al. found similar results in MRIs read by musculoskeletal radiologists with a sensitivity of 46% and specificity of 93% in type II SLAP lesions [6]. This finding is further supported by a study by Amin et al., where patients with a negative MRI subsequently underwent MRA. Of 34 patients with normal MRI, 22 patients were diagnosed with SLAP tears on MRA. MRA in their study was sensitive but not specific (90% and 50%, respectively) with relatively more false positive results, findings similar to our findings. Arthrography is believed to inflate the glenohumeral joint and could undermine SLAP lesions that would otherwise not be seen in a standard MRI. This inflation of the joint with contrast could also mimic the fluid distention present with arthroscopy [15,23]. Magee compared noncontrast MRI with MRI arthrography and showed a statistical improvement in
sensitivity for the detection of SLAP lesions with MRI arthrography[5]. Our data is consistent with his findings in that MRA was more sensitive than conventional MRI.

Overall, our results for sensitivity and specificity were lower than that reported in the literature for both MRI and MRA. Legan et al. found a sensitivity of 75% and a specificity of 99% with noncontrast MRI [14]. The largest series is by Connell et al. who identified 102 SLAP lesions from a large database and prospectively analyzed them arthroscopically. Their results show a 98% sensitivity and 89% specificity. However, the identification of SLAP positive MRIs introduces an inherent selection bias by eliminating the presence of false negative MRIs and thus increasing sensitivity. Magee et al. [15] reported a 98% sensitivity and 99% specificity in the diagnosis of a SLAP lesion with MRI arthrography. Bencardino et al [4] reported a 91% sensitivity, 93% specificity, and 90% accuracy with MRI arthrography for the diagnosis of SLAP lesions. These studies were limited by small patient populations. Several authors have hypothesized that higher Tesla scanners are more accurate; this hypothesis was not supported in a recent study by Connolly et al [6].

Perhaps the most striking finding was the poor positive predictive value of both MRI and MRA. In our combined results, approximately three out of every four positive MRI scans was falsely positive, without a significant advantage seen in contrast or noncontrast groups as evidenced by overlapping 95% confidence intervals. This result is similar to a recent study published by Phillips et al, who prospectively analyzed 77 sequential patients undergoing arthroscopic surgery. They found a PPV of 18% using noncontrast MRI in patients with isolated SLAP lesions [17]. This is in contrast to findings published by Amin et al, who found a PPV of 81.8% using MRA. Their study consisted of 59 patients with clinically diagnosed SLAP lesions. Their cohort, which had a suspected clinical diagnosis, introduces a sampling bias which may overstate the validity of MRI, including positive predictive value [12]. This bias was also observed in a study by Iqbal et al, who retrospectively studied 124 clinically diagnosed SLAP lesions and found a PPV of 84.6%. Our results show that an isolated positive MRI finding, regardless of the use of contrast, has poor value. This finding is of clinical importance, as orthopedists are often faced with vague physical exam findings and a positive MRI scan. Our results reinforce the need to be cautious when recommending surgery in patients with a vague clinical picture.

This study had several limitations. Surgeons were not blinded to the MRI report prior to arthroscopy and many patients had concomitant shoulder pathologies. The retrospective design of this study leaves the possibility for variables that are not well controlled or evenly distributed. The use of two surgeons and three musculoskeletal radiologists also introduces the potential for bias.

This investigation found that conventional MRI is specific but not sensitive and that conversely magnetic resonance arthrography is sensitive but not specific. The positive predictive value is poor for both MRI/MRA while the negative predictive value is acceptable for both. Both MRI and magnetic resonance arthrography are diagnostically less accurate than previously reported in an academic setting. The clinical decision on when or when not to operate must be balanced with the clinical scenario, physical exam findings and imaging results as none of these modalities in isolation provide sufficient diagnostic accuracy.


10.2214/AJR.08.1097


Table 1- Overall diagnostic accuracy of magnetic resonance imaging (MRI) in detecting SLAP lesion regardless of the use of contrast.

<table>
<thead>
<tr>
<th>MRI reading</th>
<th>+ SLAP Arthroscopy</th>
<th>- SLAP Arthroscopy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>29 (True positive)</td>
<td>92 (False positive)</td>
<td>121</td>
</tr>
<tr>
<td>Negative</td>
<td>15 (False negative)</td>
<td>308 (True negative)</td>
<td>323</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>400</td>
<td>444</td>
</tr>
</tbody>
</table>

Table 2- Diagnostic accuracy of magnetic resonance imaging (MRI) in detecting SLAP lesion when contrast was used (MRI arthrography).

<table>
<thead>
<tr>
<th>MRI reading</th>
<th>+ SLAP Arthroscopy</th>
<th>- SLAP Arthroscopy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>24 (True positive)</td>
<td>59 (False positive)</td>
<td>83</td>
</tr>
<tr>
<td>Negative</td>
<td>6 (False negative)</td>
<td>121 (True negative)</td>
<td>127</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>180</td>
<td>210</td>
</tr>
</tbody>
</table>

Table 3- Diagnostic accuracy of magnetic resonance imaging (MRI) in detecting SLAP lesion when the contrast was not used.

<table>
<thead>
<tr>
<th>MRI reading</th>
<th>+ SLAP Arthroscopy</th>
<th>- SLAP Arthroscopy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>5 (True positive)</td>
<td>33 (False positive)</td>
<td>38</td>
</tr>
<tr>
<td>Negative</td>
<td>9 (False negative)</td>
<td>187 (True negative)</td>
<td>196</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>220</td>
<td>234</td>
</tr>
</tbody>
</table>

Table 4- Diagnostic Accuracy of MRI in detecting SLAP lesion

<table>
<thead>
<tr>
<th>Contrast in MRI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used (n=210)</td>
<td>Not used (n=234) (n=444)</td>
</tr>
<tr>
<td>Overall Accuracy</td>
<td>69% (63-75) 82% (77-87) 76% (72-80)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>80% (61-92) 36% (14-64) 66% (50-79)</td>
</tr>
<tr>
<td>Specificity</td>
<td>67% (60-74) 85% (79-89) 77% (73-81)</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>29% (20-40) 13% (5-29) 24% (17-33)</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>95% (90-98) 95% (91-98) 95% (92-97)</td>
</tr>
</tbody>
</table>

Numbers in parenthesis are 95% confidence intervals
Figure 1. Flow diagram of patients who underwent shoulder surgery by the orthopedic sports faculty at UC Davis between 2006-2008.

All patients who had shoulder arthroscopy (n=734)

Patients with MRI and arthroscopy at same institution (n=454)

Included in this study (n=444)  MRI reading is equivocal Excluded (n=10)

Contrast use? Yes: (n=210)  Contrast use? No: (n=234)