Predictability of Early Postoperative Ultrasonography After Arthroscopic Rotator Cuff Repair

Joo Han Oh, MD, PhD; Joon Yub Kim, MD, PhD; Sae Hoon Kim, MD, PhD; Nam Yun Chung, MD

abstract

The predictability of early postoperative ultrasonography (USG) for evaluating the structural integrity of repaired rotator cuffs is still unclear. The aim of this study was to compare the predictability of early USG performed 3 and 6 months postoperatively with magnetic resonance imaging (MRI) performed 1 year after arthroscopic cuff repair for structural failure. Among 213 patients who had arthroscopic rotator cuff surgery in 2013, one hundred thirty-eight patients who underwent USG between 3 and 6 months postoperatively and MRI at 1 year postoperatively were enrolled; the postoperative MRI findings were the reference standard used for the comparison. One hundred one patients who were examined using USG at 3 months postoperatively were allocated to group A, and 108 patients who had USG at 6 months postoperatively were allocated to group B. All diagnostic values, including positive and negative predictabilities, were calculated by 2-way tables. To compare the sensitivity and specificity between groups A and B, the area under the curve was calculated from the receiver operator characteristic curve for each group. The positive predictability values were 86.36% and 93.51% for USG at 3 and 6 months postoperatively, respectively. The negative values were 84.21% and 95.83%, respectively. The areas under the receiver operator characteristic curves for groups A and B were 0.853 and 0.947, respectively (P=0.048). Although the predictability of a single USG at 3 months postoperatively reached approximately 85%, USG evaluation at 6 months postoperatively might be relevant for predicting structural failure after arthroscopic rotator cuff repair. [Orthopedics. 201x; xx(x):xx-xx.]

Despite the technical development of arthroscopic rotator cuff repair and the efforts to potentiate healing during or after arthroscopic rotator cuff repair surgery, the structural failure of repaired cuffs may be inevitable in some cases.1-10 These failures may be related to poorer functional outcomes, especially in patients with large to massive rotator cuff tears with long-term follow-up.1,4,11-14 Several previous studies regarding structural failure after rotator cuff repair have indicated that these failures are more likely during the early postoperative period than 1 year postoperatively.7,15 Identifying the relevant time for the early detection of structural failures after arthroscopic rotator cuff repair would be helpful for physicians to establish rehabilitation and additional treatment plans earlier.

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Established radiologic evaluation tools after arthroscopic rotator cuff repair are ultrasonography (USG), computed tomographic arthrography, and magnetic resonance imaging (MRI). Magnetic resonance imaging is one of the most sensitive and specific imaging tools. However, it might have limited use for follow-up evaluations due to its high cost and interference from the suture and anchor materials used for rotator cuff repairs. Ultrasonography might be the most cost-effective and easily accessible tool for evaluating rotator cuffs among outpatients. Furthermore, USG has merit for repaired cuffs because it can minimize the interference of suture materials, anchors, and tissue debris in interpretation. Therefore, USG could be an effective tool for follow-up evaluation during the early postoperative period, at 3 or 6 months, which might be the critical period for structural failure after arthroscopic rotator cuff repair. The diagnostic values of early USGs between 3 and 6 months postoperatively were already established by several authors. However, the predictability of USG during the early postoperative follow-up period after arthroscopic rotator cuff repair has not been statistically demonstrated.

The aims of this study were to (1) evaluate the predictability of USG in the early postoperative period for structural failure after arthroscopic rotator cuff repair and (2) recommend the appropriate single postoperative USG follow-up period for predicting structural integrity by comparing the diagnostic values of USGs at 3 and 6 months postoperatively to MRI at 1 year postoperatively as the reference standard.

**Materials and Methods**

**Cohort**

After institutional review board approval, the authors conducted a retrospective assessment of 213 patients who received arthroscopic rotator cuff repair by a single surgeon (J.H.O.) between March and December 2013 for eligibility. The routine radiologic follow-ups at the institution after these repairs included serial USG evaluations at 3 and 6 months postoperatively and MRI evaluations at 1 year postoperatively. Among these, the authors enrolled 138 patients who received USG at 3 and/or 6 months postoperatively and MRI at 1 year postoperatively; the authors assigned 101 patients who received USGs at 3 months postoperatively to group A and 108 patients who received USG at 6 months postoperatively (71 patients were examined using USG at both 3 and 6 months postoperatively) to group B. The authors evaluated the diagnostic value of each postoperative USG (Figure 1). To minimize bias, the authors excluded open or mini-open rotator cuff surgery (n=1), isolated subscapularis tears (n=3), and patients without postoperative 1-year MRI (n=71). The demographic characteristics of the 138 enrolled patients—age, sex, tear size, and repair techniques—are summarized in Table 1.

**Evaluating and Interpreting Cuff Integrity**

Two musculoskeletal radiologists with more than 10 years of experience evaluated the cuff integrity and agreed on the findings from the USG done at 3 and 6 months postoperatively (high-resolution HDI 5000 USG apparatus; Philips Medical Systems, Bothell, Washington) and from the MRI taken 1 year postoperatively (Magnetom Avanto 1.5-T MRI system, Siemens, Erlangen, Germany; Gyroscan Intera 1.5-T system, Philips Medical Systems; or Achieva 3.0-T system; Philips Medical Systems). When they evaluated the MRIs, the 2 radiologists were completely blind to the results of the USG done at 3 and 6 month postoperatively.

The criteria for structural failure of the repaired rotator cuffs during the USG evaluations were non-visualization of the cuffs and focal defects or gaps (hypoechoic or mixed hypoechoic and hyperechoic) within repaired tendons with consecutive loss of the normal arc of the subdeltoid bursa (Figure 2A). The authors adapted the criteria for structural failure on MRI from the classification of Sugaya et al, and the current authors regarded types IV and V as failure (Figure 2B). The radiologists used the 1 year postoperative findings to assess the structural integrity of the repaired rotator cuffs using MRI, which was the reference standard in the current study.
Surgical Procedure and Postoperative Care

The senior author (J.H.O.) performed all arthroscopic rotator cuff repairs. Single-row repairs were usually performed in cases of massive cuff tears with severe retraction, and the remaining cases were usually transosseous-equivalent double-row repairs. For the high-grade partial tears, the surgeon converted them to full-thickness tears and repaired small tears under 1 cm using the modified Mason–Allen technique. Immobilization was maintained with an abduction brace, and the brace weaning was determined by initial tear size: 4 weeks for partial to small tears, 5 weeks for medium tears, and 6 weeks for large to massive cuff tears. After brace weaning, patients performed active assisted range of motion (ROM) exercises for 4 to 6 weeks. After patients achieved near-full ROM, they began muscle-strengthening exercises and maintained them for 6 months postoperatively.

Assessing the Predictability and Other Diagnostic Value of USG

The authors defined the healing status of the repaired rotator cuffs on MRI at 1 year postoperatively as the reference standard, and the authors calculated the positive predictive value (PPV), negative predictive value (NPV), sensitivity, specificity, and accuracy of USG at 3 and 6 months postoperatively from the 2-way tables (Table 2).

Statistical Analyses

The authors calculated all diagnostic values—PPV, NPV, sensitivity, specificity, and accuracy—using 2-way tables and calculated the 95% confidence intervals (CI) for each diagnostic value. To compare the sensitivity and specificity between groups A and B, the authors drew receiver operator characteristic (ROC) curves and calculated and compared the areas under the curves (AUCs). The authors used DBSTAT version 4.1 software (DBSTAT Co, Seoul, Korea) and SPSS version 18.0 software (SPSS Inc, Chicago, Illinois) and considered \( P<.05 \) to be statistically significant.

RESULTS

Demographic features, such as age, sex, tear size, and repair techniques, were not statistically different between the 2 groups. Table 3 presents all of the diagnostic values the authors calculated for the study. There were 28 (20.3%) cases of structural failures indicated in the MRI at 1 year postoperatively (initial cuff tear; partial-thickness tear, 1; small full-thickness tears, 7; medium full-thickness tears, 3; and large to massive full-thickness tears, 17), and 24 (86%) cases that were evaluated by USG occurred before 6-month follow-up.

| Table 1 Demographic Characteristics of Group A and Group B* |
|-----------------|-----------------|-----------------|
| Characteristic  | Group A \( \text{n}=101 \) | Group B \( \text{n}=108 \) | \( P \) |
| Age, mean±SD, y | 59.5±8.1        | 61.1±8.0        | .130  |
| Sex, No.        |                 |                 | .667  |
| Male            | 35              | 41              |       |
| Female          | 66              | 67              |       |
| Tear size, No.  |                 |                 | .977  |
| Partial         | 7               | 7               |       |
| Small           | 50              | 50              |       |
| Medium          | 5               | 6               |       |
| Large           | 20              | 22              |       |
| Massive         | 19              | 23              |       |
| Repair technique, No. |       |                 | .658  |
| Single row      | 41              | 42              |       |
| Double row      | 60              | 66              |       |

*Seventy-one of 138 patients enrolled in this study were examined using ultrasonography at both 3 and 6 months postoperatively

Ultrasonography follow-up at 3 months postoperatively.

Ultrasonography follow-up at 6 months postoperatively.
In analyzing the 71 patients who were included in both groups A and B, the authors observed moderate agreement (κ = 0.705; Table 4). The PPV was 86.36% (95% CI, 79.19-93.53) at 3 months postoperatively (group A) and 93.51% (95% CI, 88.00-99.01) at 6 months postoperatively (group B). The NPV was 84.21% (95% CI, 67.81-100.61) for group A and 95.83% (95% CI, 87.84-103.83) for group B.

Although both positive and negative predictive values at 6 months postoperatively were higher than those at 3 months postoperatively, confidence intervals overlapped between the 2 groups. Accuracy was 85.98% (95% CI, 79.40-92.56) for group A and 94.06% (95% CI, 89.45-98.67) for group B. The AUCs from the ROC curves for sensitivity and specificity were 0.853 for group A and 0.947 for group B; the values for group B were significantly superior to those for group A (P = .048, Figure 3).

**DISCUSSION**

To the authors’ knowledge, this is the first study to evaluate the predictability of early postoperative single USG compared with MRI examinations of structural integrity 1 year after arthroscopic rotator cuff repair. Single USG results at 6 months postoperatively were as effective as MRIs taken 1 year postoperatively, with a diagnostic accuracy of 94.06%. Furthermore, USG results at 6 months postoperatively could be used as clinical predictors of structural failure after arthroscopic rotator cuff repair because of the high PPV (93.51%) and NPV (95.83%) and the high specificity (82.14%).

Magnetic resonance arthrography (MRA) appeared to be more accurate, with high sensitivity and specificity, for detecting rotator cuff tears than conventional MRI and USG. However, the authors are not aware of whether MRA is superior to MRI for evaluating rotator cuff healing after repair because the postoperative changes to repaired tendons on MRI were present for 1 year postoperatively, and the authors might overestimate the healing failure of repaired cuffs on MRA compared with MRI. Therefore, the authors preferred to evaluate the repaired cuffs using MRI rather than MRA for the current study.

Magnetic resonance imaging might be effective for precisely evaluating rotator cuff pathology, but it has drawbacks for evaluating repaired cuffs that include accessibility and high cost, as well as inaccurate interpretation due to sutures.

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**Table 2**

Calculations of Diagnostic Values by 2-Way Tables

<table>
<thead>
<tr>
<th>Radiologic Evaluation</th>
<th>Intact Structural Integrity</th>
<th>Failed Structural Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>3- or 6-mo ultrasonography</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Intact structural integrity</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

*Positive predictive value = A/A+B. Negative predictive value = D/C+D. Sensitivity = A/A+C. Specificity = D/B+D. Accuracy = A+D/A+B+C+D.*

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**Table 3**

Comparison of Diagnostic Values Between Postoperative 3- and 6-Month USG

<table>
<thead>
<tr>
<th>Radiologic Evaluation</th>
<th>USG at 3 Months Postoperatively</th>
<th>USG at 6 Months Postoperatively</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intact Structural Integrity</td>
<td>Failed Structural Integrity</td>
</tr>
<tr>
<td>Postoperative 1-year MRI, No.</td>
<td>76</td>
<td>3</td>
</tr>
<tr>
<td>Intact structural integrity</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Failed structural integrity</td>
<td>88</td>
<td>19</td>
</tr>
<tr>
<td>Diagnostic value</td>
<td>96.20 (91.99-100.42)</td>
<td>98.63 (95.96-101.30)</td>
</tr>
<tr>
<td>Sensitivity (95% CI), %</td>
<td>57.14 (38.81-75.47)</td>
<td>82.14 (67.96-96.33)</td>
</tr>
<tr>
<td>Specificity (95% CI), %</td>
<td>86.36 (79.19-93.53)</td>
<td>93.51 (88.00-99.01)</td>
</tr>
<tr>
<td>Positive predictive value (95% CI), %</td>
<td>84.21 (67.81-100.61)</td>
<td>95.83 (87.84-103.83)</td>
</tr>
<tr>
<td>Negative predictive value (95% CI), %</td>
<td>85.98 (79.40-92.56)</td>
<td>94.06 (89.45-98.67)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; MRI, magnetic resonance imaging; USG, ultrasonography.
suture anchors, knots, debris, and signal changes in the early postoperative period.\textsuperscript{10} During early postoperative MRI, the high signal intensity at tendons, which could be the result of inflammation and formation of granulation tissue, might lead to misinterpretation of the structural integrity after rotator cuff repair.\textsuperscript{26,27} Furthermore, other findings, such as irregularity and thinning, might be normal until 1 year postoperatively,\textsuperscript{26} whereas evaluations of the vascularity at the peritendinous area after rotator cuff repair appear to be more accurate with USG than with MRI.\textsuperscript{28} Therefore, USG might be the preferable tool for evaluating structural integrity in the early postoperative period given its relatively high sensitivity and specificity.\textsuperscript{4,7,16,29-32} However, the predictability of early postoperative single USG after arthroscopic rotator cuff repair is unclear, and this could be the first study to verify the predictability of early postoperative USG for the structural integrity of repaired cuffs compared with MRIs taken 1 year postoperatively as the reference standard.

In the current study, USG at 3 months postoperatively revealed 96.20% sensitivity, 57.14% specificity, and 86.36% diagnostic accuracy, whereas USG at 6 months postoperatively had 98.63% sensitivity, 82.14% specificity, and 94.06% accuracy. When the authors compared 2 independent cohorts (groups A and B), USG at 6 months postoperatively was superior in diagnostic values regarding sensitivity and specificity. There was a significant difference in the AUCs of the ROC curves between groups A (0.853) and B (0.947; \(P = .048\)). The other USG diagnostic values at 6 months postoperatively (PPV= 93.51%; NPV= 95.83%) revealed the superiority of the 6-month USG values to those from 3-month USG, which were 86.36% for PPV and 84.21% for NPV. The current data are similar to those from Prickett et al.,\textsuperscript{23} who reported that USG evaluation of repaired cuffs revealed sensitivity of 91%, specificity of 86%, and accuracy of 89%. However, these authors obtained their diagnostic USG values by evaluating re-tears in patients with painful shoulders at specific follow-up points after rotator cuff repair, not at periodic serial postoperative time points as in the current study.

The important diagnostic feature of early postoperative USG after arthroscopic rotator cuff repair might be the higher specificity rather than the higher sensitivity because additional evaluation and treatment were needed in the failed cases.\textsuperscript{20-32} However, the specificity of 57.14% with postoperative 3-month USG was unacceptable compared with the specificity of 82.14% with postoperative 6-month USG. Considering the merits of early detection of structural failure after arthroscopic rotator cuff repair for further rehabilitation and treatment, the authors could use single USG at 6 months postoperatively as a cost-effective tool for predicting the structural integrity of these repairs.
The authors also recommend that all patients undergo USG at 6 months postoperatively as a routine procedure after arthroscopic rotator cuff repair, even when patients show no symptoms, because the authors could predict future functional outcomes; different types or amounts of rehabilitation, workouts, and daily activity based on the USG findings could be recommended.

Previous studies\(^7\)\(^11\)\(^15\) have reported that failures after rotator cuff repair occur in the early postoperative period. Miller et al\(^7\) reported that most structural failures after arthroscopic rotator cuff repair occurred before 3 months postoperatively, with the remaining re-tears occurring before 6 months postoperatively, and Kluger et al\(^15\) reported that 74% of all failures occurred before 3 months postoperatively and 11% occurred between 3 and 6 months postoperatively in a MRI and USG study with long-term follow-up. In line with the previous studies, the current study revealed 86% of structural failures occurred before 6 months after arthroscopic rotator cuff repairs. Furthermore, the authors observed moderate agreement (kappa=0.705) between USG at 3 and 6 months postoperatively by analyzing 71 patients who had USG performed at both time points, because most of the structural failures occurred before 3 months postoperatively.

Several limitations exist in the current study. First, the heterogeneity of the 2 groups might have affected the USG diagnostic values at the different times, even though the baseline demographics were similar and 71 patients were in both groups. Second, USG itself is a user-dependent tool for evaluating cuff integrity, but the USG examinations in this study were performed by musculoskeletal radiologists with more than 10 years of experience, which could have been helpful for accurately evaluating cuff integrity by USG. In contrast, the current diagnostic value of USG might be difficult to apply for general radiologists who are not familiar with arthroscopic rotator cuff repair or for general orthopedic surgeons. Third, some of the diagnostic values, including PPV, NPV, and accuracy, were not statistically supported. Fourth, the authors did not include any clinical information regarding symptoms in this study; the authors might have suggested more appropriate patient management if they could have correlated their study results with patients’ symptoms. Finally, the authors did not perform MRI at 3 or 6 months postoperatively or USG at 1 year postoperatively because of cost; therefore, the authors could not compare the MRI data with the USG findings side by side.

**CONCLUSION**

Because of the significant superiority of the areas under the curve in the ROC curves for sensitivity and specificity, as well as the high predictability and accuracy, single USG evaluation at 6 months postoperatively rather than 3 months might be relevant for predicting structural failure after arthroscopic rotator cuff repair.

**REFERENCES**


