Original Article

Patients With Intact Shoulder Superior Capsular Reconstruction Grafts on Ultrasound Show Significant Improvement in Functional Outcomes at Minimum 2-Year Follow-up

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Purpose: To assess the utility of using dynamic ultrasound for postoperative evaluation after superior capsular reconstruction (SCR) by evaluating graft integrity and its correlation with clinical outcomes at a minimum 2-year follow-up. **Methods:** A retrospective chart review was conducted to identify patients who underwent SCR between July 2015 and July 2020 with a minimum 2-year clinical and ultrasound follow-up. Clinical outcome measures included Simple Shoulder (SS) and American Shoulder and Elbow Surgeon (ASES) scores. Integrity of the SCR graft was evaluated by dynamic ultrasound. **Results:** We evaluated 22 shoulders in 21 patients with a mean follow-up of 44.8 months (range, 24-71 months). The graft was found to be intact by ultrasound evaluation in 82% (18/22). Patients with intact grafts had higher mean SS (11.6 vs 7.8, $P = .00079$) and ASES (91.2 vs 64.1, $P = .0296$) scores at latest follow-up compared to those with failed grafts. Those with intact grafts also had significant improvement in SS (3.7 vs 11.6, $P < .00001$) and ASES (23.2 vs 91.2, $P < .00001$) scores at latest follow-up compared to their preoperative scores. In contrast, patients with graft failure had no significant improvement in SS (6.3 vs 9.0, $P = .123$) and ASES (40.4 vs 58.3, $P = .05469$) scores at latest follow-up compared to their preoperative scores. There was no difference between clinical outcomes at 6 to 12 months vs latest follow-up for both SS ($P = .11$, $P = .5$) and ASES ($P = .27$, $P = .21$) scores. **Conclusions:** SCR grafts were found by ultrasound to be intact in 82% of cases. Patients with intact grafts on ultrasound had significant improvement in functional outcome scores while those with graft failure did not. Functional outcome scores suggest that maximal recovery from this procedure occurs by 6 to 12 months. **Level of Evidence:** Level IV, therapeutic case series.

Degenerative and traumatic rotator cuff tears (RCTs) remain a significant source of dysfunction among the aging population in the United States, with an increasing reported incidence of full-thickness rotator cuff tears ranging from 25% by age 65, 50% for those 70 or older, and 80% in those over 80 years old.[1-3] Furthermore, up to 50% of asymptomatic RCTs may become symptomatic at a mean of 2.8 years after diagnosis, often with increases in tear size, muscular atrophy, and occasionally, fatty infiltration.[4]

RCTs are considered massive when the defect measures >5 cm or involves 2 or more tendons.[5,6] Treatment options for massive RCTs include biceps tenotomy/tenodesis, arthroscopic debridement, primary repair tendon transfers, superior capsular reconstruction (SCR), interpositional balloon arthroplasty, and reverse total shoulder arthroplasty.[7-10] When primary repair is not possible, SCR has been reported to be an effective treatment option using various allografts such as acellular porcine dermal allograft,[11-14] Achilles allograft,[15] autograft tensor fascia,[16,17] and long head of biceps tendon.[18,19] These various graft options have shown varying retear rates and outcome scores.[20,21] Biomechanical studies comparing SCR to shoulders with intact rotator cuffs have shown similar range of motion, subacromial contact pressures, and superior humeral migration.[16,22] Short-term outcomes studies

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have demonstrated excellent results, including decreased pain, improvement in active flexion, and improvement in outcomes scores.[11,12,23,24] The typically preferred method for evaluating SCR postoperatively is magnetic resonance imaging (MRI).[25] However, ultrasound can be a less expensive and more readily available imaging modality to assess graft integrity after SCR.

The purpose of this study was to assess the utility of using dynamic ultrasound for postoperative evaluation after SCR by evaluating graft integrity and its correlation with clinical outcomes at a minimum 2-year follow-up. Our hypothesis was that graft integrity, as determined by dynamic ultrasound, would be predictive of better clinical outcomes and that ultrasound is a convenient and feasible imaging modality for postoperative evaluation of SCR.

Methods

A retrospective review of consecutive patients undergoing SCR from July 2015 to March 2020 was performed. Inclusion criteria included all patients undergoing an SCR procedure during the studied time period who had at least a 2-year follow-up and a Hamada stage $\leq$2 at time of surgery.[26] Exclusion criteria included any patient undergoing revision SCR surgery. Thirty-four patients underwent SCR during the study period, and all had an appropriate preoperative Hamada classification of $\leq$2; however, 13 were lost to follow-up prior to the 2-year interval. Overall, 22 shoulders in 21 patients met inclusion criteria and were included in the study. Each shoulder was treated with SCR by the senior author (H.M.S.) with the use of a dermal allograft (n = 19) or Achilles allograft (n = 3) and had a minimum 2-year clinical and ultrasound follow-up. All 21 patients were male with 16 right and 6 left shoulders. The average age was 66.4 years (range, 40.0-80 years).

Simple Shoulder (SS) and American Shoulder and Elbow Surgeon (ASES) scores were collected at various time points, including preoperatively, 6 to 12 months postoperatively, and most recent follow-up.[27,28] The patient acceptable symptom state (PASS) and minimal clinically important difference (MCID) for all patients were assessed in relation to ASES scores. Previously validated PASS and MCID values for ASES scores of 81.0 and 19.0 were used.[29] At final follow-up, in addition to clinical outcome measure scores, a dynamic ultrasound was performed as described below.

Indications

Indications for the SCR procedure in this patient group included irreparable posterior RCT, cuff tear arthropathy Hamada classification type 1 or 2 with intact or repairable subscapularis. Concomitant procedures included subpectoral biceps tenodesis in 12 shoulders and upper subscapularis repair in 13 shoulders. In 10 shoulders, the intra-articular biceps was not present.

Surgical Technique

A diagnostic arthroscopy was performed to confirm massive and irreparable posterior RCT. The superior labrum was completely debrided. Three knotless anchors were placed along the superior glenoid rim medially and the lateral edge was then secured to the greater tuberosity using a knotless double-row suture anchor technique. Side-by-side sutures were then placed to converge the remaining intact posterior cuff with the posterior border of the SCR graft. The upper subscapular tears were repaired with a single anchor. All biceps tendons with intact origin were tenotomized and a later subpectoralis tenodesis was performed.

Dynamic Ultrasound Evaluation

Patients were evaluated using dynamic ultrasound imaging at a minimum of 2 years (range, 24-71 months) after their index surgery.

The SCR graft was imaged from both an anterior and a posterior view using a high-frequency linear probe. The shoulder was placed in a modified crass position with the palm of the hand placed on the ipsilateral back pocket region with the elbow pointed posteriorly for the anterior view (Fig 1). The shoulder was then placed in the forward flexed, adducted, and internally rotated position for the posterior view. The long- and short-axis views were used to confirm SCR graft insertion at the articular margin−greater tuberosity interface. Grafts were considered intact if they had complete continuity from medial to the insertion on both the anterior and posterior views. For all intact grafts, a graft thickness was then measured at the graft midsubstance just medial to the articular margin−greater tuberosity interface. The thickness measurements ranged from 4 to 8 mm.

All ultrasound examinations were performed by a single contributor orthopaedic surgery PGY-5 resident (J.S.K.) with dynamic shoulder ultrasound training and >50 prior shoulder ultrasound examinations performed.

Statistical Analysis

Analysis of variance was used to determine if a significant difference existed between SS and ASES scores from preoperatively to various postoperative time points.

Results

We evaluated 22 shoulders in 21 patients with a mean follow-up of 44.8 months (range, 24-71 months). The graft was found to be intact by dynamic ultrasound evaluation in 82% (18/22). Of the 18 shoulders with

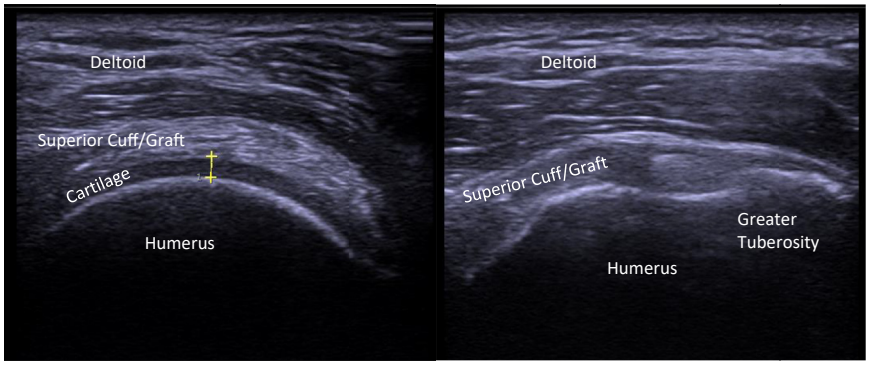

Fig 1. Right shoulder, 2 ultrasound long-axis views of the superior cuff/graft demonstrating intact graft and surrounding anatomic structures.

intact grafts, 15 had decellularized dermal allograft and 3 had Achilles allograft.

Patients with intact grafts, as determined by ultrasound, had higher mean SS (11.6 vs 7.8, $P = .00079$) and ASES (91.2 vs 64.1, $P = .0296$) scores at latest follow-up compared to those with failed grafts. Those with intact grafts also had significant improvement in SS (3.7 vs 11.6, $P < .00001$) and ASES (23.2 vs 91.2, $P < .00001$) scores at latest follow-up compared to their preoperative scores. Sixteen of 17 with intact grafts had PASS scores above the threshold of 81.0 at latest follow-up, while all 17 had achieved an ASES increase that was above the MCID of 21.0. In contrast, patients with graft failure had no significant improvement in SS (6.3 vs 9.0, $P = .123$) and ASES (40.4 vs 58.3, $P = .05469$) scores at latest follow-up compared to their preoperative scores. Additionally, 2 of 4 patients with failed grafts met the defined PASS score threshold and 2 of 4 also maintained an ASES score increase that met the MCID at final follow-up.

We found no significant difference in outcome scores for SS ($P = .11$, $P = .5$) or ASES ($P = .27$, $P = .21$) regardless of graft integrity beyond the 6- to 12-month follow-up ,suggesting that maximal recovery from this procedure ranges from 6 to 12 months.

Discussion

This study demonstrates that dynamic ultrasound can be used to evaluate SCR graft integrity as this correlated with clinical outcome scores, which were significantly higher in intact grafts. Our hypothesis that graft integrity, as determined by dynamic ultrasound, is associated with better clinical outcomes and that ultrasound is a feasible imaging modality for postoperative evaluation of SCR was confirmed.

The findings in this current study demonstrate similar results as prior investigations evaluating the efficacy of SCR.[30,31] While the surgical technique and graft choice[19,24,32-37] are still evolving, arthroscopic SCR has become a reliable option with the appropriate indications using either autograft or allograft options.[14,38-41] Finding a reliable, cost-effective, and convenient method to evaluate and monitor clinical success in the short and long term will be advantageous.

When evaluating the rotator cuff, diagnostic modalities include MRI and US. Routine use of postoperative MRI is typically not practical due to costs. Patient convenience given the duration and location of the examination as well as potential compliance issues with positioning or claustrophobia are also deterrents. In contrast, ultrasound is portable, is increasingly available, can be readily performed in the office, and offers immediate results. Furthermore, it has shown to be cost-effective in the outpatient clinic setting.[42] These attributes of US can improve patient satisfaction and compliance. US has also demonstrated good correlation with MRI in previous studies,[43,44] and a recent meta-analysis found US to be as sensitive and specific as MRI in the diagnosis of both partial and complete tears of the native rotator cuff.[45] It should, however, be noted that US evaluation of the rotator cuff is highly dependent on its limited viewing potential. Specifically, it is difficult to use US to evaluate the glenoid graft insertion site. While it is most common for graft failure to occur at the humeral insertion,[46,47] which is well visualized using US, it can occur at the glenoid side due to suture anchor loosening.[48] A clear view of the glenoid with US can be obstructed by bony or range of motion constraints, making visualization of the glenoid fixation difficult in some patients. Ultrasound is also an operator-dependent imaging modality. Despite these limitations, the US findings in this study did correlate with clinical outcome scores, which suggests utility of this modality.

A focused ultrasound training on a limited anatomic region has been reported to reasonably be achieved with limited formal training, an apprenticeship model, and repetition.[49,50] This would suggest most clinicians do not require a comprehensive ultrasound skillset to find great utility in this imaging modality. The training of the author (J.S.K.) who performed the ultrasound

evaluations in this study included a musculoskeletal-focused ultrasound workshop, approximately 50 shoulder ultrasound examinations/procedures of prior experience, and independent-focused examination training on a limited anatomic region by an experienced ultrasonographer prior to beginning ultrasound evaluations on patients in this study. The effectiveness of this focused ultrasound learning series was further supported by the correlation of ultrasound findings and clinical outcome scores obtained in the study.

Limitations

Limitations of this study include the retrospective design and the relatively small number of patients included. The findings of 82% intact grafts at latest follow-up may not be generalizable as our study was a single-surgeon experience. The ultrasound images were not reviewed by a radiologist.

Conclusions

SCR grafts were found by ultrasound to be intact in 82% of cases. Patients with intact grafts on ultrasound had significant improvement in functional outcome scores while those with graft failure did not. Functional outcome scores suggest that maximal recovery from this procedure occurs by 6 to 12 months.

Disclosure

The authors report the following potential conflicts of interest or sources of funding: C.M.J. reports stock or stock options with Sonex outside the submitted work and is a board or committee member of the American Shoulder and Elbow Surgeons. W.P.P. is a paid consultant, speaker, or presenter for Arthrex and is a board or committee member of the American Shoulder and Elbow Surgeons. All other authors (J.S.K., D.W., M.T.G., H.M.S.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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