Ultrasound Assessment of the Superior Capsular Reconstruction With Dermal Allograft: An Evaluation of Graft Thickness and Vascularity

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Purpose: To assess postoperative changes in the thickness of the dermal allograft of the superior capsular reconstruction (SCR) and to evaluate the graft for the presence of intrasubstance pulsatile vessels. **Methods:** A retrospective chart review was conducted to identify SCR patients who had ultrasound evaluations between May 2014 and February 2019. Data were collected and stratified based on time from surgery into 2 groups: 0 to 12 months and past the 12-month follow-up. The primary outcome measure was graft thickness at the articular margin−greater tuberosity interface (tuberosity measurement). Secondary measures included midsubstance graft thicknesses 0.5, 1.0, and 1.5 cm medial to the tuberosity measurement; status of lateral graft fixation; presence of pulsatile vessels; and American Shoulder and Elbow Society and visual analog scale scores. **Results:** Eighteen patients were included for analysis. The tuberosity measurement at final follow-up (mean 25 months, range 12-40 months) was (mean ± standard error [95% confidence interval (CI)]) 4.4 ± 0.2 mm (95% CI 4.0-4.8). This differed significantly from the midsubstance measurements: 0.5 cm: 3.6 ± 0.2 mm (95% CI 3.3-4.0, $P = .008$); 1.0 cm: 3.1 ± 0.2 mm (95% CI 2.7-3.4, $P < .001$); and 1.5 cm: 2.9 ± 0.2 mm (95% CI 2.6-3.2, $P < .001$). Ten constructs (56%) showed signs of pulsatile vessels in the first 12 months and all constructs were intact. ASES scores improved from 49.3 ± 4.0 (95% CI 41.6-57.1) preoperatively to 85.1 ± 2.9 (95% CI 79.4-90.8) ($P < .001$), and VAS scores decreased from 5.3 ± 0.6 (95% CI 4.2-6.5) preoperatively to 0.9 ± 0.3 (95% CI 0.3-1.5) at final follow-up ($P < .001$). **Conclusions:** The SCR dermal allograft significantly thickens at its lateral aspect, presents with evidence of vasculature in most patients in the first year of implantation, and is not resorbed by the body. **Level of Evidence:** Level IV − therapeutic case series.

See commentary on page 3203

Introduction

The superior capsular reconstruction (SCR) was originally developed as a surgical alternative to reverse total shoulder arthroplasty for patients with massive, irreparable rotator cuff tears using a tensor fascia latae autograft.[1] The indications for SCR have since expanded to reversing pseudoparalysis and functioning as an internal brace to support rotator cuff repairs.[2-5] Hirahara and Adams[6] altered the fascia lata autograft techniques[1,7] to use a decellularized dermal allograft to restore the superior restraint to the humerus. The clinical outcomes studies published on SCR with dermal allograft have shown promising results.[2,8-11]

Ultrasound offers clinicians the ability to gather different information than that obtained with radiography, magnetic resonance imaging (MRI), or computed tomography at less cost, greater frequency, and less inconvenience to the patient. It has been described as a useful tool for evaluating the rotator cuff[12-15] and is an effective device to monitor SCR patients throughout the postoperative period.[9] Our clinical outcomes study touched on findings on ultrasound that indicated integration of the allograft and highlighted the necessity for further exploration of ultrasound examinations of the SCR.[9]

The purpose of this study was to assess postoperative changes in the thickness of the dermal allograft of the SCR and to evaluate the graft for the presence of intrasubstance pulsatile vessels. We hypothesized the

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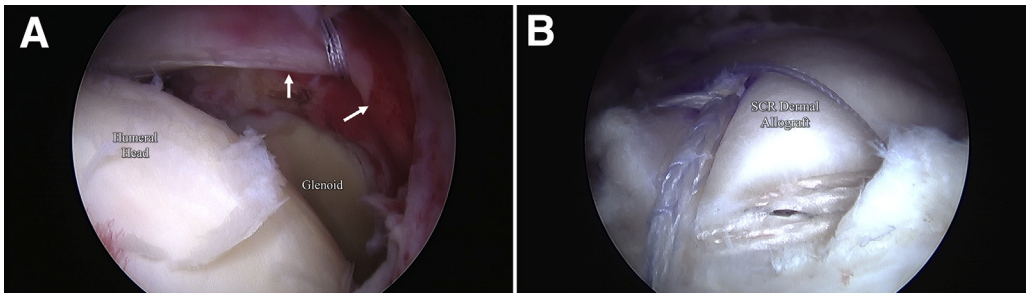

Fig 1. (A) An intraoperative view of the subacromial space through the posterolateral portal of the left arm showing a massive rotator cuff tear (white arrows) with retraction to the glenoid. (B) An intraoperative view of the subacromial space through a posterolateral portal of the left arm. An arthroscopic superior capsular reconstruction (SCR) has been completed, and the ArthroFlex dermal allograft (LifeNet Health, Virginia Beach VA) can be viewed in place.

dermal allograft would be thicker at the greater tuberosity than at the midsubstance of the graft. Additionally, we hypothesized that the graft will at least maintain its native thickness throughout the 1-year follow-up and that intrasubstance pulsatile vessels will not be observed in all patients in this series.

Methods

The study period for this retrospective review was from May 2014 to February 2019. Patients were included in this study if they were treated with the SCR by the senior author (A.M.H.) with the use of a 3.0-mm graft, had a minimum 1-year follow-up, and had at least 1 postoperative ultrasound evaluation. Patients were excluded if they did not have follow-up ultrasound examinations. All patients provided written consent for the anonymous publication of their clinical data.

Surgical Technique

Patients were indicated for treatment with SCR in the setting of massive, irreparable supraspinatus and/or infraspinatus tears, intolerable shoulder pain, unacceptable dysfunction, minimal to no arthritic changes, and a functioning or repairable subscapularis. Individuals with significant arthropathy, bone defects, passive range of motion deficits, and dysfunction of the deltoid, latissimus dorsi, or pectoralis musculature were contraindicated for the procedure.[6] The SCR procedure in this article followed the technique described by the senior author.[6] A decellularized dermal allograft of 3.0-mm thickness (ArthroFlex 301; LifeNet Health, Virginia Beach, VA) was used to center the humeral head in the glenohumeral joint. A PASTA Bridge[16] or double surgeon's knot, double-pulley configuration was used for medial fixation, and a SpeedBridge (standard or 6-way) (Arthrex, Naples, FL) was used for lateral fixation. The number of lateral anchors varied depending on the width of the rotator cuff defect, which ultimately determined the width of the lateral dermal allograft (Fig 1).

Ultrasound Assessment and Data Collection

The ultrasound assessment technique followed that of a normal rotator cuff evaluation as detailed by Panero and Hirahara.[13] All authors contributed to the ultrasound evaluations and interpretations under the guidance of the senior author (A.M.H.). All evaluations were performed by using the SonoSite Xporte (FUJIFILM SonoSite, Bothell, WA) ultrasound unit or the Synergy Ultrasound Scanner (Clarius Mobile Health, Burnaby, BC, Canada). Because ultrasound is nonirradiating, convenient for the patient, and inexpensive and provides immediate results, we use ultrasound as a tool in the clinical evaluation and to monitor changes in the dermal allograft throughout follow-up, just as other physicians measure range of motion and strength.

Graft thickness was measured in 4 locations in the long axis of the dermal allograft (Fig 2), like one would image the supraspinatus in long axis. The allograft runs in an arc, and measurements were taken perpendicular to the allograft at that measurement location. The articular margin–greater tuberosity interface was

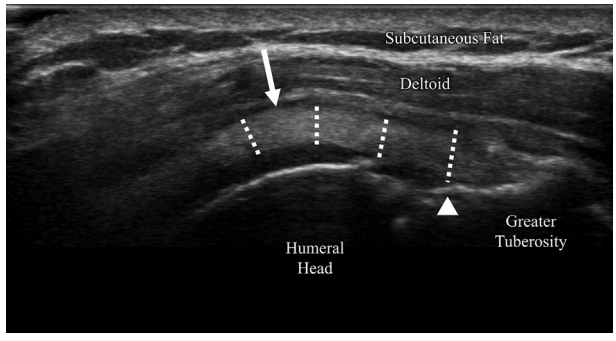

Fig 2. A long axis view of an intact dermal allograft of the superior capsular reconstruction (SCR) (solid white arrow) on the right shoulder at three months postoperatively. The articular margin-greater tuberosity interface is identified (white arrowhead). Demonstration of the tuberosity and midsubstance measurement locations are shown (dashed white lines). This image was captured on the Sonosite Xporte (FUJIFILM Sonosite, Bothell, WA).

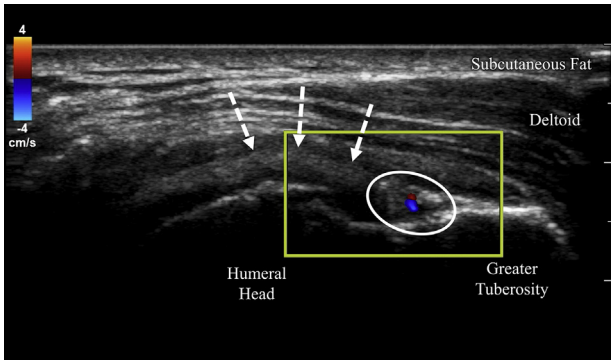

Fig 3. A long axis view of the dermal allograft of the superior capsular reconstruction on the right shoulder at six months postoperatively. The ultrasound unit is in Color Doppler mode, which detects pulsatile vessels within a specific portion of the image (yellow square). The pulsatile vessels (white circle) can be seen to be within the dermal allograft (dashed white arrows) at its attachment on the greater tuberosity. The red and blue colors are indicative of the direction of blood flow. This image was captured on the Sonosite Xporte (FUJIFILM Sonosite, Bothell, WA).

identified, and the graft thickness at this location was measured. This was termed the *tuberosity measurement*. On the same image, measurements were taken at 0.5, 1.0, and 1.5 cm medial to the location of the tuberosity measurement. The graft thicknesses at these locations were measured in the same manner and termed the *midsubstance measurements*. Due to the limitations of ultrasound, more medial portions of the graft and its attachment at the glenoid were unable to be reliably and consistently assessed on every patient. The presence of blood flow in the graft has been previously reported.[9] Pulsatile vessels were identified by using the color Doppler setting (Fig 3), and the investigation was performed in the short and long axes of the dermal allograft.

Measurements were recorded at 2 time-points: 0 to 12 months and past the 12-month postoperative follow-up. For individuals who received >1 ultrasound evaluation within the given time periods, the earliest examination was used for the 0- to 12-month timeframe and the latest examination was used for those after the 1-year follow-up. The primary outcome measure was graft thickness at the tuberosity measurement. Secondary measures included graft thicknesses at the midsubstance measurement locations, status of lateral graft fixation, and the presence of pulsatile vessels within the graft. American Shoulder and Elbow Society (ASES) and visual analog scale (VAS) scores were recorded and reported corresponding to the date of the patient's ultrasound assessment.

Statistical Analysis

Graft measurements were reported as mean ± standard error of the mean (95% confidence interval [CI]). Analysis of variance (ANOVA) was conducted to determine if a significant difference was present between the means of graft thickness measurements at the various graft locations. ANOVA was also used to determine if a significant difference existed between the ASES and VAS scores preoperatively and the follow-up periods. If a significant difference was found with the ANOVA, *t* tests were subsequently performed to test for statistically significant differences between the individual groups. A 2-tailed level of significance was set at $P < .05$ for all analyses.

Results

Thirty-eight SCRs were performed in the study period, and 29 patients had a minimum 1-year follow-up. Twenty-two patients met the initial inclusion criteria of having the 1-year follow-up, ≥1 ultrasound evaluation, and SCR with the 3.0-mm graft. One patient did not have an ultrasound examination within the first 12 months, and 3 other patients had an initial ultrasound evaluation but were lost to follow-up and did not have an examination after 12 months. These patients were excluded, yielding 18 patients who had an ultrasound evaluation before and after the 1-year follow-up and who ultimately were included in the data analysis. This resulted in a follow-up rate of 82% (18/22). Demographics of the included patients are given in Table 1. For initial evaluations of all patients conducted within the first 12 months, the average time from surgery was 4.9 months (range 1-8.5 months). For examinations conducted after 12 months, the average time from surgery was 25 months (range 12-40 months). Eighteen patients had SCR with Arthro-Flex 301 (3.0-mm thickness).

One patient in this series had failure as a result of an accidental fall at 18 months postoperatively. This patient fell and tore the graft 1 week after an ultrasound examination that had shown the SCR to be intact. The patient went on to have a reverse total shoulder arthroplasty.

Graft Thickness

For initial evaluations, the average graft thickness of the tuberosity measurement was 4.2 ± 0.2 mm (95%

Table 1. Patient Demographics

Age, yr	63 ± 2.0
Male/female	14/4
Right/left	11/8
Dominant arm	11 (58)
Previous rotator cuff repair	7 (37)
Graft size, anterior, cm	5.1 ± 0.1
Graft size, posterior, cm	5.1 ± 0.1
Graft size, medial, cm	2.6 ± 0.1
Graft size, lateral, cm	3.3 ± 0.1

NOTE. Data reported as mean ± standard error, n/N, or n (%).

CI 3.9-4.6). The average midsubstance measurements were as follows: 0.5 cm medial to the tuberosity measurement, 3.5 ± 0.2 mm (95% CI 3.2-3.8); 1.0 cm medial to the tuberosity measurement, 3.0 ± 0.1 mm (95% CI 2.7-3.3); and 1.5 cm medial to the tuberosity measurement, 2.8 ± 0.1 mm (95% CI 2.5-3.1). All constructs were intact. The ANOVA found a significant difference between the groups ($P < .001$). The tuberosity measurement was significantly different from all midsubstance measurements (0.5 cm, $P = .006$; 1.0 cm, $P < .001$; 1.5 cm, $P < .001$). There were significant differences between the 0.5-cm and 1.0-cm midsubstance measurements ($P = .015$) and between the 0.5-cm and 1.5-cm midsubstance measurements ($P = .002$). There was no significant difference between the 1.0-cm and 1.5-cm midsubstance measurements.

For the examinations conducted after 12 months postoperatively, the average tuberosity measurement was 4.4 ± 0.2 mm (95% CI 4.0-4.8). The average midsubstance measurements were as follows: 0.5 cm medial to the tuberosity measurement, 3.6 ± 0.2 mm (95% CI 3.3-4.0); 1.0 cm medial to the tuberosity measurement, 3.1 ± 0.2 mm (95% CI 2.7-3.4); and 1.5 cm medial to the tuberosity measurement, 2.9 ± 0.2 mm (95% CI 2.6-3.2). All constructs in this group were intact at the time of ultrasound. The ANOVA found a significant difference between groups ($P < .001$). There were significant differences between the tuberosity measurement and the midsubstance measurements (0.5 cm, $P = .008$; 1.0 cm; $P < .001$; 1.5 cm, $P < .001$). There was a significant difference between the 0.5-cm midsubstance measurement and the 1.0-cm and 1.5-cm measurements ($P = .05$ and $P = .006$, respectively). There was no difference between the 1.0-cm and 1.5-cm measurements. There were no significant differences when comparing the initial measurements with the final follow-up measurements at any graft location.

Change in Thickness

The average increase in graft thickness from the initial evaluation to past the 1-year follow-up for the tuberosity measurement was 0.2 ± 0.2 mm (95% CI −02 to 0.6). The average increases in thickness for the midsubstance measurements were as follows: 0.5 cm medial to the tuberosity measurement, 0.1 ± 0.2 mm (95% CI −0.3 to 0.4); 1.0 cm medial to the tuberosity measurement, 0.1 ± 0.2 mm (95% CI −0.2 to 0.4); and 1.5 cm medial to the tuberosity measurement, 0.1 ± 0.2 mm (95% CI −0.2 to 0.4). There was no significant difference in the change from the initial examination between any of the measurement locations ($P = .99$).

Pulsatile Vessels

Ten of the 18 patients presented with signs of vasculature during the initial 12 months postoperatively (56%). The minimum time from surgery for evidence of blood flow was 4.0 months. Evidence of pulsatile vessels disappeared in this series of patients by 8.7 months except in 1 instance. This patient had persistent vasculature 25 months postoperatively. There was a significant difference in graft thickness observed between those who showed evidence of pulsatile vessels and those who did not at the 1.0-cm midsubstance measurement only ($P = .048$) for the measurements conducted within the first 12 months. When comparing means in graft thicknesses between the initial examination and past the 12-month follow-up, there were no significant differences observed. Measurement values for the patients are presented in Table 2.

Outcome Measures

Patient ASES and VAS scores are reported preoperatively and at the time-points associated with their ultrasound follow-up. ASES scores increased from 49.3 ± 4.0 (95% CI 41.6-57.1) preoperatively to 74.5 ± 3.1 (95% CI 66.5-82.5) at initial follow-up and 85.1 ± 2.9 (95% CI 79.4-90.8) at final follow-up ($P < .001$). There was a significant difference between the preoperative scores and the 2 follow-up scores (0-12 months, $P < .001$; >12 months, $P < .001$). There was also a significant difference between the 2 follow-up periods ($P = .01$). VAS scores significant decreased from 5.3 ± 0.6 (95% CI 4.2-6.5) preoperatively to 1.8 ± 0.4 (95% CI 1.0-2.7) at initial follow-up and 0.9 ± 0.3 (95% CI 0.3-1.5) at final follow-up ($P < .001$). There was a significant difference between the preoperative and follow-up scores (0-12 months, $P < .001$; >12 months, $P < .001$). There was a significant difference between the initial and final follow-up VAS scores ($P = .02$). Individual scores per patient are reported in Table 3.

Discussion

This study shows a dermal allograft in an SCR maintains its structural integrity, significantly increases in thickness at the lateral aspect compared with initial implantation thickness, presents with signs of pulsatile vessels in the first year, and is not resorbed by the body past 1 year postoperatively. The hypothesis that the dermal allograft of the SCR was thicker at the greater tuberosity than throughout the midsubstance of the graft was confirmed. During both evaluation periods, there was a significant difference between the greater tuberosity measurement and all midsubstance measurement locations, and the 0.5-cm measurement was significantly thicker than the more medial midsubstance measurements. All 18 patients had intact constructs at the time of the ultrasound and significantly improved in pain and function at final follow-up. Ten grafts showed signs of intrasubstance pulsatile

Table 2. Measurement Values of Graft Thicknesses Based on the Presence of Pulsatile Vessels

		0-12 Months				12+ Months			
			Midsubstance Measurements				Midsubstance Measurements		
	Total, %	Tuberosity	0.5 cm	1.0 cm	1.5 cm	Tuberosity	0.5 cm	1.0 cm	1.5 cm
All patients (N = 18)		4.2 ± 0.2[†‡] (3.9-4.6)	3.5 ± 0.2[*†] (3.2-3.8)	3.0 ± 0.1[*‡] (2.7-3.3)	2.8 ± 0.1[†‡] (2.5-3.1)	4.4 ± 0.2[†‡] (4.0-4.8)	3.6 ± 0.2[*†] (3.3-4.0)	3.1 ± 0.2[*‡] (2.7-3.5)	2.9 ± 0.2[†‡] (2.6-3.2)
Evidence of pulsatile vessels (n = 10)	56	4.1 ± 0.2 (3.7-4.5)	3.3 ± 0.2 (2.4-3.0)	2.7 ± 0.2 (2.4-3.0)[*]	2.56 ± 0.2 (2.3-2.9)	4.4 ± 0.3 (3.9-4.9)	3.5 ± 0.2 (3.0-3.9)	3.0 ± 0.2 (2.5-3.4)	2.8 ± 0.2 (2.4-3.2)
No evidence of pulsatile vessels (n = 8)	44	4.4 ± 0.3 (3.8-5.1)	3.8 ± 0.3 (3.3-4.3)	3.3 ± 0.2 (2.9-3.7)[*]	3.1 ± 0.2 (2.7-3.5)	4.4 ± 0.4 (3.7-5.2)	3.8 ± 0.3 (3.2-4.4)	3.2 ± 0.3 (2.6-3.8)	3.0 ± 0.3 (2.5-3.5)

NOTE. Data reported as mean ± standard error (95% confidence interval).
[*] $P < .05$.
[†] $P < .01$.
[‡] $P < .001$.

vessels during the first year, and 1 graft showed signs of persistent vascularization at 25 months.

The SCR has been theorized to play a role in stabilization of the joint, as opposed to merely acting as a spacer. We have found that an explanted SCR graft demonstrated on histology an asymmetrical distribution of cells, with fibrocartilage-like tissue on the articular aspect of the graft, indicating the graft responds to mechanical stresses.[17] In an analysis of a biopsied SCR allograft 6 months after implantation, Plachel et al.[18] also identified cellular infiltration throughout the graft and appreciably higher expression levels of tendon gene markers toward the lateral graft compared with the medial graft. In this series, graft tissue was thickest at the site of bone attachment and maintained its implantation thickness medially, implying that the vascularization and mechanical stress caused the graft to thicken near the bony attachment site. This variance in graft thickness further contributes to the theory that the SCR plays a key role in stabilization and highlights the necessity for ensuring the graft is implanted with the appropriate tension. We hypothesize that the graft should also thicken at the glenoid due to the same vascularization and mechanical stress; however, we are unable to prove this because of the limitations of ultrasound such that we are unable to reliably and easily image the glenoid attachment.

When the dermal allograft is decellularized during processing, the vasculature channels are maintained (Fig 4A). When examining the histology of the explanted SCR graft, Hirahara et al.[17] observed signs of vascularization of the graft (Fig 4B). Evidence of vessels was also identified in the histologic study by Plachel et al.,[18] particularly near the humeral attachment. Expanding on the findings of the initial outcomes study by Hirahara et al.[9] and these histologic analyses,[17,18] neovascularization was demonstrated in this ultrasound assessment in the first year. For evaluations that showed signs of vasculature on ultrasound (pulsatile vessels on color Doppler) in this study, the minimum time from surgery was 4 months and the maximum time from surgery was 9 months, except in 1 case. The evidence of these vessels within the graft suggests that the patients' bodies use the persistent vasculature channels, which could assist in the incorporation and recellularization process. Combined with previous histologic data,[17,18] the present study's findings of graft thickening and the emergence of pulsatile vessels imply that the graft is viable and integrated by the patient's body.

The evidence of blood flow within the graft ceased by 1 year, but vasculature was maintained on top of the graft on ultrasound and has been observed on second-look SCR surgeries (Fig 5). These findings are consistent with normal rotator cuff tendons as venous and arterial flow is observed at the typical

Table 3. Subjective Outcomes by Patient

	Preoperative		0-12 mo		>12 mo	
Patient	ASES	VAS	ASES	VAS	ASES	VAS
1	58	5	97	0	97	0
2	25	6	92	0	77	0
3	53	4	76	1.5	92	0
4	33	8	75	2	100	0
5	34	9	75	0	98	0
6	18	10	37	6	68	2
7	37	8	60	4	72	3
8	65	1	90	0	88	0
9	84	1.5	80	1	97	0
10	68	3	77	2	87	0
11*	60	4.5	78	1.5	61	4.5
12	40	7	83	1	77	1
13	53	5	96	0	88	0
14	43	6	79	3	83	1.5
15	67	2	67	1	87	1
16	72	5	76	0	100	0
17	45	3	83	3	82	1
18	44	7.5	67	3	100	0
Average	49.9	5.3	74.5	1.8	85.1	0.9
SE	4.0	0.6	4.1	0.4	2.9	0.3
			Compared with Preoperative		Compared with Preoperative	
P value	d		<.001	<.001	<.001	<.001
					Compared with 0-12 mo	
P value				.02		.03

ASES, American Shoulder and Elbow Society; VAS, visual analog scale; SE, standard error.
*Patients who had a failure.

tendon—deltoid interface but not within the tendon itself. The initial appearance and subsequent disappearance of pulsatile vessels within the graft suggest a tissue transformation. We hypothesize that as the graft undergoes a conversion from dermal to capsular-ligamentous tissue, the arterial and venous flow appropriately transforms into capillary flow that cannot be detected on ultrasound and appropriate arterial and venous flow appears on the bursal-sided surface of the graft.

Ultrasound correlates well with MRI for the rotator cuff and SCR[9,12,14] but is not meant to replace it. Denard et al.[8] reported 1-year outcomes for 59 patients after SCR with dermal allograft, but only 20 of these patients had postoperative MRI to assess graft fixation and healing. In this limited MRI series, Denard et al.[8] noted that graft failures occurred most commonly on the humeral side in their patients. Ultrasound allows for complete visualization of this area without the risks and pitfalls associated with MRI, such as cost, claustrophobia, or metal interference. Ultrasound obviates the need for MRI to evaluate the humeral aspect of the construct and can be conducted in-clinic with minimal downtime, providing patients and clinicians with immediate results. The efficiency, cost-effectiveness, and accessibility of ultrasound can help to improve patient retention and satisfaction throughout the postoperative period.

Because diagnostic ultrasound uses sound waves to produce an image, understanding the properties of these waves and how they can be affected is imperative. We have found that anisotropy and posterior acoustic shadowing are typical artifacts that frequently arise when evaluating the SCR. Changing the angle of the transducer can help to confirm the integrity of the graft or the presence of a true defect. Posterior acoustic shadowing often occurs when the FiberTape sutures (Arthrex) on the superior aspect of the graft come into view and can be visualized well on different machines (Fig 6). The sutures are dense relative to the surrounding tissue, causing virtually all incoming waves to reflect. When viewed on the monitor, this can be

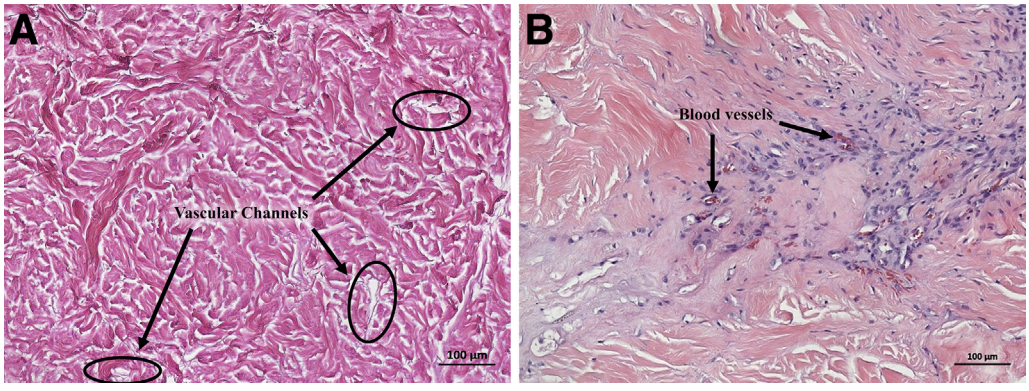

Fig 4. (A) Histologic sectioning of an ArthroFlex (LifeNet Health, Virginia Beach VA) dermal allograft prior to implantation. Vascular channels can be observed (black arrows). Photo courtesy of LifeNet Health. (B) Histologic sectioning of a superior capsular reconstruction (SCR) ArthroFlex dermal allograft (LifeNet Health, Virginia Beach VA) explanted 13 months after implantation. Blood vessels can be observed throughout the dermal allograft (black arrows). Photo courtesy of Evan Lederman, MD.

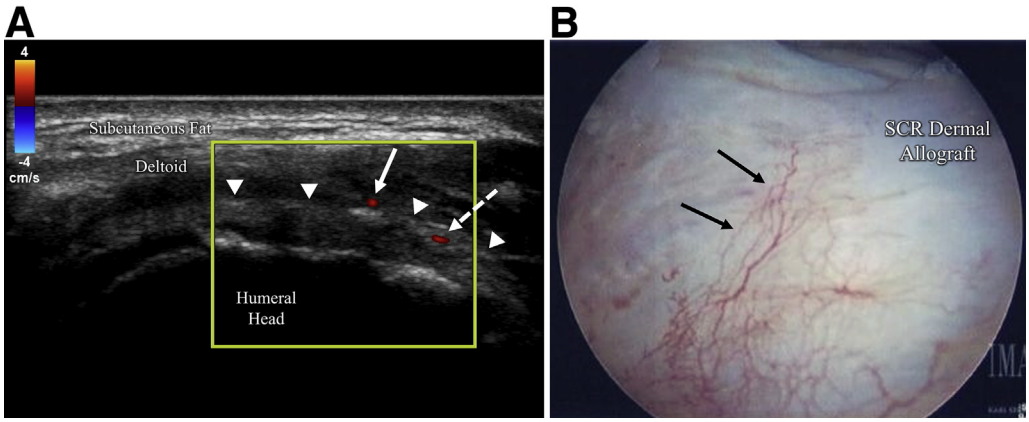

Fig 5. (A) A long axis view of the dermal allograft (white arrowheads) of the superior capsular reconstruction (SCR) on the right shoulder at 6 months postoperatively. Vasculature at the deltoid-dermal allograft interface (solid white arrow) can be seen. This vasculature is distinct from the pulsatile vessel observed within the graft (dashed white arrow). The pulsatile vessels at the deltoid-dermal allograft interface is similar to what is typically present at the interface between the deltoid and a healthy supraspinatus tendon. This image was captured on the Sonosite Xporte (FUJIFILM Sonosite, Bothell, WA). (B) An intraoperative view of the subacromial space of a previously implanted SCR ArthroFlex dermal allograft (LifeNet Health, Virginia Beach VA) on the right arm. Vasculature can be seen on top of the dermal allograft (black arrows). The location of this vasculature is consistent with a typical rotator cuff-deltoid interface where arterial and venous flow can be observed between the tissues, but not within the rotator cuff tendon itself. This image was taken one year from the original SCR procedure. Photo courtesy of Julie Bishop, MD.

suggestive of a defect within the graft and the bone cortex. Furthermore, articular cartilage is significantly hypoechoic on ultrasound and can be mistakenly identified as fluid accumulation, which presents in the same manner (Fig 7). Knowledge of the specific SCR technique and the materials used can assist in correctly evaluating the image.

Color Doppler is an outstanding function of ultrasound not found on other modalities, but it has limitations as well. Visualizing arterial or venous flow with color Doppler is dependent on the size of vessel, directional flow, and technique of scanning. Small vessels or those that travel obliquely to the ultrasound beam during scanning can be missed. We did not expect to have so many patients demonstrate pulsatile vessels on evaluation because we expected capillary flow, which is not displayed well with color Doppler.

When we first began to evaluate postoperative SCR patients with ultrasound, examinations were performed arbitrarily and primarily focused on determining if the graft was intact and attached to the tuberosity. The findings of vascularization were

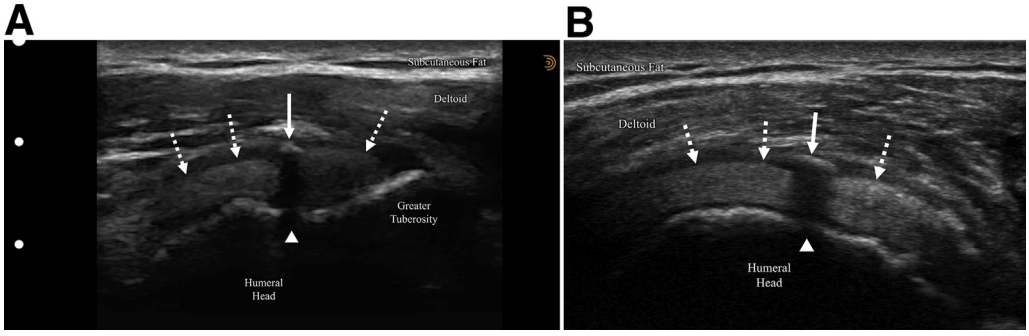

Fig 6. (A) A long axis view of the dermal allograft (dashed white arrows) of the superior capsular reconstruction on the right shoulder at three months postoperatively. A FiberTape (Arthrex, Naples, FL) suture is seen as a hyperechoic signal (solid white arrow) sitting on the superior aspect of the graft with corresponding posterior acoustic shadowing of the graft and bone cortex (white arrowhead). This image was captured on the Synergy Ultrasound Scanner (Clarius Mobile Health, Burnaby, BC, Canada). (B) A short axis view of the dermal allograft (dashed white arrows) of the SCR on the right shoulder at five months postoperatively. A hyperechoic signal on the superior aspect of the graft is representative of a FiberTape (Arthrex, Naples, FL) suture used to fix the graft to the humerus (white arrow). The FiberTape suture is dense, prohibiting the ultrasound waves from passing through it. This results in the posterior acoustic shadowing effect which can be misinterpreted as a defect in the graft and bone cortex (white arrowhead). This image was captured on the Sonosite Xporte (FUJIFILM Sonosite, Bothell, WA).

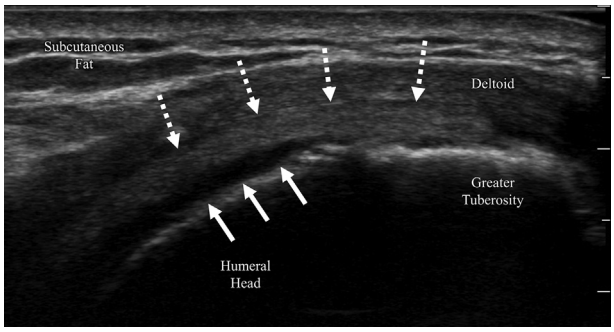

Fig 7. A long axis view of the dermal allograft (dashed white arrows) of the superior capsular reconstruction (SCR) on the right shoulder at five months postoperatively. A dark, hypoechoic signal representative of articular cartilage can be seen just deep to the graft, above the humeral head (solid white arrows). This signal can be misinterpreted as fluid accumulation, which has a similar appearance on ultrasound. This image was captured on the Sonosite Xporte (FUJIFILM Sonosite, Bothell, WA).

unexpected. As more procedures were performed and the number of ultrasounds grew, we began to standardize our postoperative ultrasound protocol. Based on our findings reported in the present study, we perform an ultrasound evaluation within the first 4 months, between 4 and 8 months, at the 1-year follow-up, and yearly thereafter.

Limitations

This study has several limitations. This is a case series with relatively few patients and is retrospective in nature, which potentially restrict its generalizability. Because those who received ultrasound evaluations were the only patients included in this study, selection bias could be present. The glenoid aspect of the graft was unable to be examined, limiting the ability to confirm the integrity of the entire construct. There was a lack of standardization in the timing of ultrasound assessments, and narrower follow-up intervals could help elucidate when the dermal allograft undergoes the changes observed in this study. Evaluation of the graft at the time of surgery to compare later would potentially yield a significant difference in thickness progression.

Conclusions

The SCR dermal allograft significantly thickens at its lateral aspect, presents with evidence of vasculature in most patients in the first year of implantation, and is not resorbed by the body.

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