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Changes in deltoid muscle tension after reverse shoulder arthroplasty as quantified by shear wave elastography: relationship with radiographic parameters and functional outcomes

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A R T I C L E I N F O

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Reverse shoulder arthroplasty (RSA)
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Massive rotator cuff tear (MRCT)
Shear wave elastography (SWE)

A B S T R A C T

Introduction: Implantation of a reverse shoulder arthroplasty (RSA) impacts deltoid length, shape and tension. Quantification of changes in deltoid muscle tension with implantation of RSA has remained elusive. The purpose of this study was to use shear wave elastography (SWE) to quantify deltoid muscle stiffness preoperatively, intraoperatively and postoperatively in patients undergoing RSA.

Methods: Twenty patients scheduled to undergo RSA (ReUnion, Stryker) were prospectively enrolled in this study. A single observer trained in SWE quantified deltoid stiffness preoperatively, intraoperatively, and postoperatively. Clinical evaluation included pain, motion, quickDASH, ASES, Oxford, and subjective shoulder value scores. Preoperative and postoperative radiographs were measured by an independent observer to determine the lateralization and distalization shoulder angles (LSA and DSA). A statistical analysis was then performed to determine whether changes in deltoid muscle stiffness correlated with any of these parameters.

Results: Implantation of a RSA lead to an increase SWE deltoid stiffness value from 22.4 $\pm$ 4.2 kPa preoperatively to 29.9 $\pm$ 5.23 kPa ($P< .0001$) immediately after surgery, and 26.6 $\pm$ 6.6kPa ($P= .03$) at most recent follow-up. Preoperative SWE deltoid stiffness values did not differ when measured in the office or under anesthesia. Reverse arthroplasty did not significantly change the LSA ($P= .051$), but did increase the DSA ($P< .0001$). Greater SWE deltoid stiffness values correlated with better active elevation ($P= .0128$) better external rotation ($P= .0247$), and larger DSA ($P= .0026$). Elevation and external rotation showed a positive correlation with the DSA and a negative correlation with the LSA.

Conclusion: After implantation of one RSA design incorporating glenoid and humeral lateralization, deltoid stiffness as measured with SWE increased significantly. Deltoid stiffness seems to correlate with joint distalization, elevation and external rotation. SWE seems to be reliable to quantify deltoid stiffness after reverse shoulder arthroplasty.

Mayo Clinic Institutional Review Board approved this study (IRB: 15-006839).

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Level of Evidence: Level IV; Diagnostic Study

Reverse shoulder arthroplasty (RSA) is a reliable surgical option for patients with substantial shoulder pain and loss of function due to rotator cuff tear arthropathy (CTA), massive rotator cuff tear (MRCT), selective osteoarthritic shoulders (OA[2,7,9]) and other conditions. Restoration of motion and function after RSA for the cuff-deficient shoulder has been predicated to be the result of the fixed-fulcrum nature of reverse implants and changes in deltoid moment arm, length and other variables.[5,8]

Currently, there is a wide range of RSA implants available with very different biomechanical consequences regarding the final position of the humerus in reference to the scapula, and thus very different effects on deltoid and cuff changes in length, moment arm, line of pull and tension.[21] The surgeon may also influence the impact of RSA on the shoulder musculature through size selection and component positioning.[8,15,21] Substantial advances in preoperative planning, implant design, and surgical technique have been made to optimize perimeter impingement-free range of motion.[15,21] However, quantification of muscle changes after RSA have remained elusive, especially in the office or the operating room.

While the effect of deltoid tension on RSA outcomes is considered important, determining the optimal implant size combination, implant design and deltoid tension for each individual patient is currently based on subjective surgeon assessment during preoperative and intra-operative evaluation. Implant selection directly impacts humeral lateralization and distalization and therefore deltoid tension, which in turn influences deltoid function and the patient's ability to achieve satisfactory glenohumeral elevation.[8] Deltoid tension both before and after RSA has been found to closely relate to success, because of the deltoid's critical role as the only source of elevation postoperatively in patients with a deficient rotator cuff.[5,10,12] An over-tensioned deltoid can generate substantial pain, restrict motion postoperatively, and potentially lead to acromion or spine stress fracture or chronic fatigue and failure of the muscle.[6,8,19] Conversely, an under-tensioned deltoid may contribute to weakness and even instability, as the deltoid assumes a role as primary glenohumeral stabilizer in the absence of an intact rotator cuff.[8,10]

Several technologies may be used to measure various muscle properties. Shear wave elastography (SWE) is an ultrasound-based technology that quantifies tissue stiffness by measuring shear wave propagation speed, which is directly related to intrinsic tissue mechanics.[1,4,19] When combined with B-mode ultrasound, SWE quantifies structural tissue properties that are related to elasticity, or stiffness. To date, SWE has been utilized in cadavers to quantify stiffness of the rotator cuff[14] and deltoid.[11] Prior investigations exploring the utility of SWE in measuring deltoid stiffness demonstrated satisfactory intra- and inter-observer reliability of SWE measurements for all deltoid regions with ICCs of 0.88-0.96.[14] Although cadaver based studies had demonstrated that SWE is reproducible for evaluation of deltoid stiffness in several distinct regions, the true relevance of SWE in cadaveric noncontractile muscle is debatable.

As such, the current study sought to evaluate the in-vivo utilization of SWE to quantify changes in deltoid stiffness with implantation of a RSA. The goals of this study were to (1) quantify perioperative mechanical properties of the deltoid in patients undergoing RSA, (2) explore the relationship between deltoid stiffness and standardized radiographic measures, and (3) investigate the relationship between quantified deltoid stiffness and postoperative function. We hypothesized that implantation of a reverse arthroplasty would lead to consistent increases in deltoid stiffness as measured with SWE and that differences in stiffness would correlate with clinical and radiographic outcomes.

Materials and methods

Patients

Patients undergoing RSA by a single surgeon at a large academic institution were consented preoperatively for participation in this study as a subgroup of an ongoing prospective randomized clinical trial comparing glenosphere sizes in RSA. All RSA involved implantation of ReUnion implants (Stryker, Mahwah, NJ, USA). This RSA system consists of an onlay platform humeral bearing component, baseplate, screws for glenoid fixation including a center screw, glenosphere, and a modular humeral bearing with a metal base and a polyethylene liner. The neck-shaft angle of the ReUnion implant is 135°. All patients in this study received uncemented humeral components, with a proximally textured and hydroxyapatite coated stem. This implant design lateralizes on the humeral side with the onlay humeral bearing design. The design of the clinical trial randomly assigned patients to receive one of 4 glenosphere sizes: 36 mm of diameter with 2 mm of lateral offset (36 + 2), 36 mm of diameter with 6 mm of lateral offset (36 + 6), 40 mm of diameter with 2 mm of lateral offset (40 + 2), or 40 mm of diameter with 6 mm of lateral offset (40 + 6). All patients received a preoperative interscalene catheter blockade of the brachial plexus. All procedures were performed under general anesthesia using a deltopectoral approach. The height of the humeral cut was performed flush with the junction between the humeral head and the infraspinatus footprint at 30° of retroversion. Selection of humeral bearing thickness was performed by the treating surgeon subjectively after assessment of soft-tissue tension with implant trials. This was based mostly on ease of relocation of the prosthesis.

Deep exposure was achieved through a subscapularis tenotomy and the subscapularis could be repaired in all shoulders at the end of the procedure. None of the patients received muscle relaxants during the procedure. Patients were consented to have their deltoid stiffness measured with

SWE at the following time points: preoperatively, three times intraoperatively (prior to incision, after humeral head resection, and after component implantation) and at regular follow-up intervals the first year after surgery (3 months and 1 year postoperatively).

Shear wave elastography measurements

Shear wave elastography requires use of an ultrasound system and ideally is performed by a single observer. It is best also to standardize position of the arm when the measurements are performed. For the purposes of this study, we used a General Electric ultrasound system (GE Company, Boston, MA, USA). The following parameters were used in all measurements: center frequency 6 MHz, pitch 0.2 mm, 192 elements, bandwidth 80%, and elevation focus at 30 mm.

A single observer trained in SWE of the deltoid performed the measurement of middle deltoid muscle stiffness at all time points. In the office clinic setting, the patient was directed to sit on the exam table with the forearm of their affected extremity resting in their lap. Patients were asked to relax their arm and avoid movement. The tip of the acromion was identified by palpation, and a ruler was used to measure the first SWE position 5 cm directly below the tip of the acromion, over the location of the middle head of the deltoid. The transducer was positioned 5 cm below the tip of the acromion, vertically and parallel to the muscle fibers, data was recorded, and the transducer was fully removed from the mid deltoid before performing additional consecutive measurements. The SWE system software obtains measurements in units of elastic modulus (kPa). Ten measurements were recorded in each session, from which the median SWE elastic modulus value was calculated.

In the operative setting, the patient was placed in a beach chair position. The arm was free throughout the surgery, without aid of a pneumatic arm holder. Deltoid measurements were taken with the patient's forearm resting on their lap, closely resembling the position used in the office setting. Measurements were performed at the following intraoperative time points: prior to skin incision, after humeral head resection, and after implantation of the final components (Fig. 1). Retractors were removed before all intraoperative measurements after incision. Prior to and the proximal humerus was confirmed to be reduced within the glenoid prior to obtaining the measurement following humeral head resection. As mentioned earlier, glenosphere size and lateral offset were predetermined by randomization, whereas the surgeon selected the humeral bearing that subjectively provided the best combination of stability and soft-tissue tension.

Radiographic measurements

All radiographic measurements completed for the purpose of this study were performed by a single observer

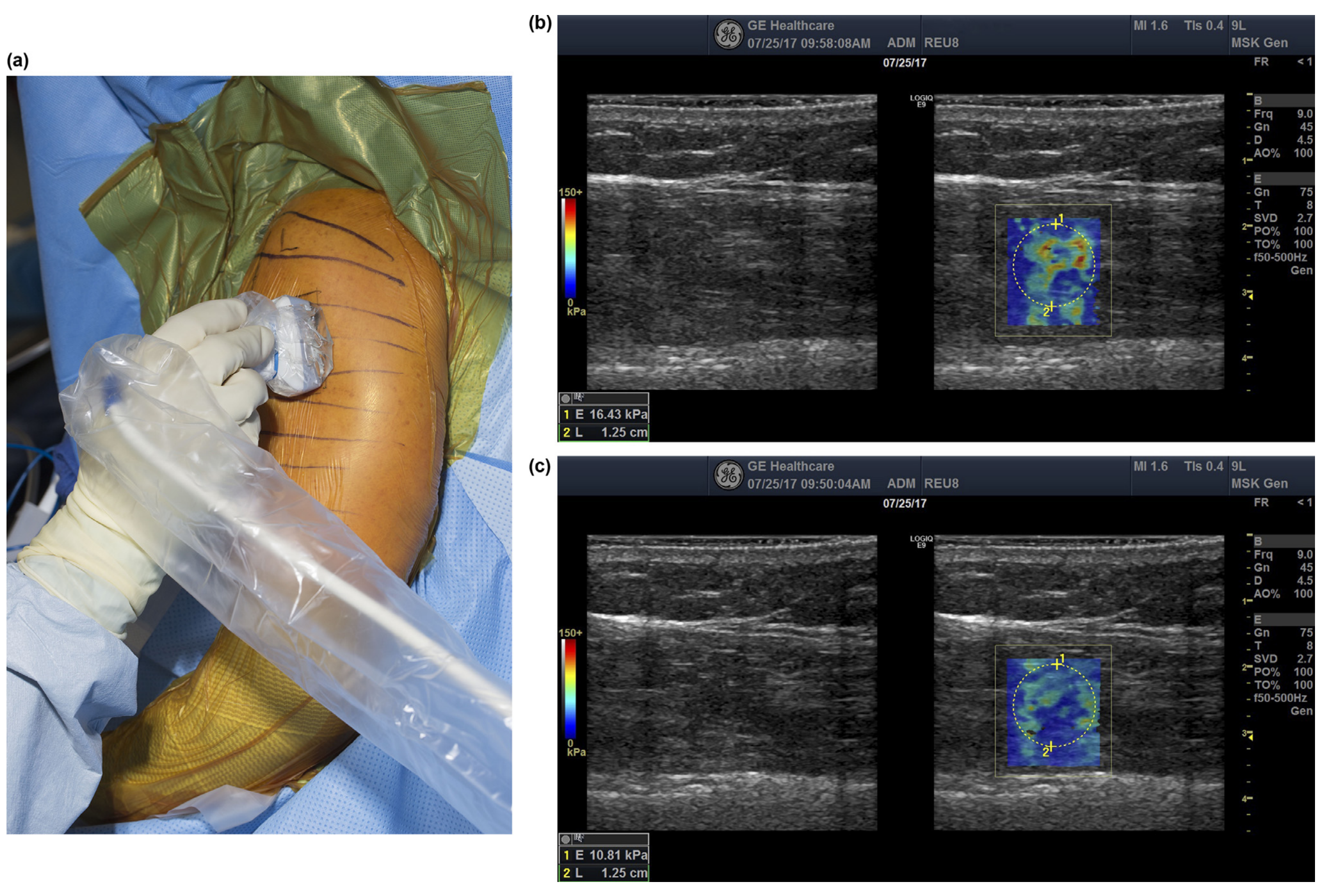


Figure 1 – Intraoperative measurements of deltoid stiffness using shear wave elastography. (a) Ultrasound transducer over the region of interest. (b) Captured measurement before component implantation. (c) Captured measurement after component implantation.

independent of the surgeon and independent of the researcher who performed the SWE measurements. All measurements were performed on standardized high-quality anteroposterior radiographs performed with the humerus in approximately 25° of external rotation per institutional protocol.

Regarding preoperative radiographs, as depicted in Fig. 2, first a best fit circle of the humeral head was drawn, followed by a line parallel to the greater tuberosity (GT), a perpendicular line at the superior limit of the GT, and a line parallel to this at the superior limit of the humeral head. Using these reference lines, the following distances were measured: lateral acromion to lateral GT, acromion to superior GT, acromion to humeral head, glenoid to the humeral center of rotation (COR), and glenoid to GT.

Postoperative measurements were obtained in the same manner. Notably the lateral border of the GT becomes more difficult to detect after RSA. For the purposes of this study, we used the point where the horizontal portion of the GT meets the vertical portion of the GT, as this was the point least likely to be affected by humeral rotation. The lateralization shoulder angle (LSA) was measured by drawing a line connecting the superior glenoid tubercle and the most lateral border of the acromion, followed by a line connecting the most lateral border of the acromion with the most lateral border of the greater tuberosity; the angle between these 2 lines was measured as the LSA. The distalization shoulder angle (DSA) was calculated by drawing a line connecting the most lateral border of the acromion and the superior glenoid tubercle and a second line between the superior glenoid tubercle and the most superior border of the greater tuberosity; the angle between these 2 lines formed the DSA.[3]

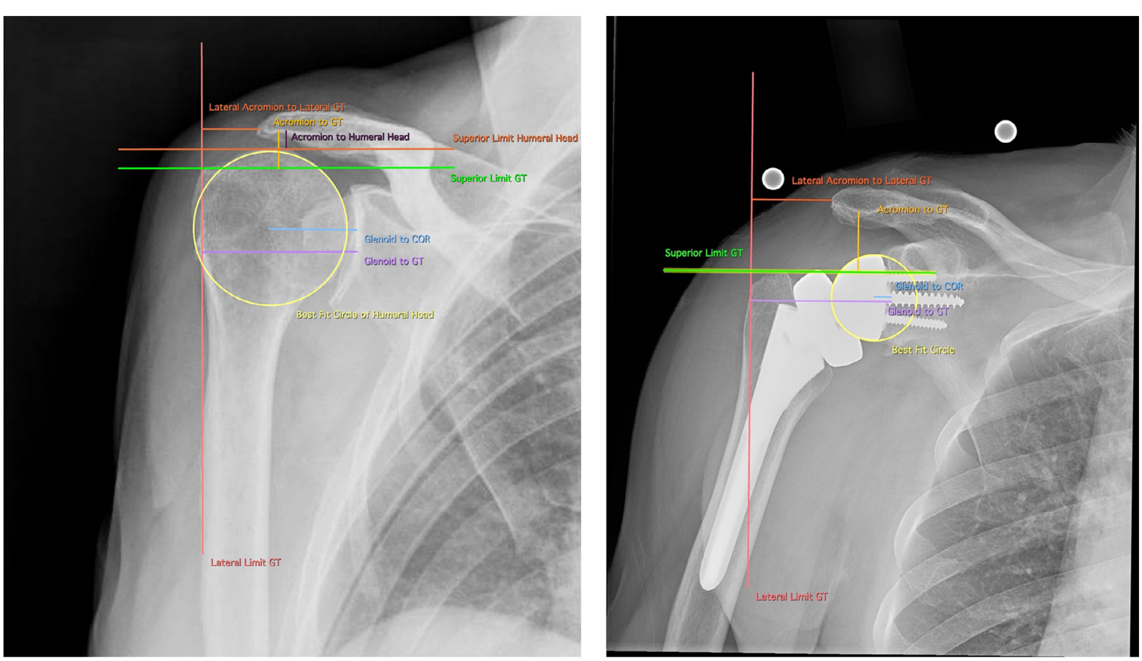
Statistical analysis

Collected data were stored in Microsoft Excel (2010; Microsoft Corp) and analyzed with JMP Pro (v 14.1.0; SAS Institute). After analyzing data for parametric and nonparametric assumptions, continuous variables were compared between groups utilizing linear regression; SWE measurements were set as the dependent variable, and the independent variables included patient factors, radiographic measurements, and clinical measurements. Pairwise comparisons between SWE timepoints were completed with paired t-tests assuming unequal variances. ANOVA analyses were used to compare categorical and continuous variables. P values $< .05$ were considered significant.

Results

Demographics

A total of 20 shoulders (20 patients) were included in this SWE study (Table 1). There were 6 females and 14 males with a mean age of 72 ± 6.6 years (range, 55-83 years) and mean BMI of 30.9 ± 3.66 kg/m^2 (range, 24.5-38.6 kg/m^2). The underlying diagnosis leading to RSA included cuff tear arthropathy in 7 patients, osteoarthritis in 8 patients with intraoperative confirmation of an intact rotator cuff (all with a B2 or B3 glenoid according to the modified Walch classification), and functionally irreparable cuff tear in 5 patients. According to their randomization, 5 patients received a 36 + 2 glenosphere, 6 patients were received a 36 + 6 glenosphere, 6 patients received a 40 + 2 glenosphere and 3 patients received a 40 + 6 glenosphere.



(a) (b)

Figure 2 – Measurements performed on preoperative radiographs (a) and at most recent follow-up (b).

Table 1 – Patient demographics.

Demographic	(n = 20)
Male	70%
Age	72.2 ± 6.62 years
Body Mass Index	30.9 ± 3.66 kg/m^2
Cuff Tear Arthropathy	35%
Osteoarthritis	40%
Massive Irreparable Cuff Tear	25%

BMI, body mass index.

SWE measurements

The average preoperative SWE deltoid stiffness value was 22.4 ± 4.20 kPa (Tables 2 and 3). These preoperative values were not significantly different from the intraoperative SWE measurements performed immediately prior to skin incision with the patient under general anesthesia and interscalene blockade (22.4 ± 4.20 vs. 21.4 ± 4.16, P= .3198). Deltoid stiffness did not change significantly between preincision and humeral head resection, with a mean stiffness after humeral head resection of 21.9 ± 4.56 kPa (P= .5208). After implantation of the RSA components, the mean deltoid stiffness did significantly increase to 29.9 ± 5.23 kPa (P< .0001) when compared to pre-incision stiffness. Additionally, deltoid stiffness significantly decreased between the intraoperative postimplant values and in-office measurements at one year after surgery (29.9 ± 5.23 vs. 26.6 ± 6.60, P= .0265).

Relationship between SWE measurements and patient characteristics

With the numbers available, no statistically significant associations were found between SWE values and sex (P> .05). The same was true for age (P> .05) BMI (P> .05), underlying diagnosis, (P> .05), and glenosphere size (P> .05).

Relationship between SWE measurements and clinical outcomes

RSA resulted in a significant decrease in pain, from a mean of 6.4 ± 2.4 preoperatively to 0 ± 0.5 using VAS scale (Table 4). RSA also translated into statistically significant improvements in elevation (preoperatively 121 ± 37 degrees, postoperatively 133 ± 24 degrees, P= .008). External rotation also significantly increased from 39 ± 25 degrees preoperatively to 55 ± 18 degrees postoperatively (P= .005). Internal rotation did not change significantly after RSA, with a mean IR to the sacroiliac joint both before and after surgery. QuickDash, ASES, Oxford, and SSV scores improved from 48.6 ± 16.8 to 20.5 ± 16.1, 44.0 ± 22.1 to 80.8 ± 16.5, 23.8 ± 8.4 to 39.44 ± 10.5, and 40.4 ± 21.5% to 83.1 ± 20.9%, respectively.

When comparing SWE measurements with patients' functional outcomes, SWE deltoid stiffness at the time RSA implantation was positively associated with postoperative external rotation (P= .0448). Additionally, deltoid stiffness measured at postoperative clinic follow-up visits was positively correlated with increased active elevation (P= .0128) and increased active external rotation (P= .0247), but not with active internal rotation (P= .6982). When evaluating the change in deltoid stiffness compared to patient function, a larger increase in stiffness between pre-incision and implant placement was associated with increased active external rotation at most recent follow-up (P= .0219).

Relationship between SWE and radiographic measurements

RSA using this particular implant did not result in a significant change in the LSA (P= .0503), but it did result in significant increases in the values of the DSA (P< .0001; Table 5). A larger vertical distance between the acromion and the GT after surgery showed a positive correlation with increases in deltoid stiffness (P= .0049). Regarding the LSA and DSA,

Table 2 – Individual variables for each of the 20 shoulders included in this study.

Case	Age	Gender	Diagnosis	Glenosphere size and offset	Humeral bearing thickness	Change in LSA	Change in DSA	Elevation	External Rotation	Internal Rotation	SWE preop	SWE intraop pre-implant	SWE intraop post-implant	SWE at follow-up
1	78	Male	OA	40 mm +6mm	12	16.33	37.38	150	SIJ	70	26.57	30.62	35.60	31.76
2	74	Male	MRCT	36 mm +2mm	9	21.78	35.2	140	L1	60	24.04	23.02	35.13	19.77
3	80	Male	OA	40 mm +2mm	12	0.57	15.15	130	SIJ	70	18.78	21.74	30.31	24.71
4	61	Male	CTA	40 mm +6mm	8	10.51	24.64	140	L5	50	28.00	27.41	24.97	27.55
5	75	Male	OA	36 mm +6mm	10	34.09	36.07	130	SIJ	60	20.03	16.10	35.25	33.05
6	74	Male	MRCT	40 mm +2mm	12	18.9	22.47	130	SIJ	60	17.14	15.28	23.03	21.78
7	75	Female	OA	40 mm +2mm	8	0.64	12.69	90	T12	60	23.21	17.20	27.62	26.44
8	83	Male	CTA	36 mm +2mm	12	10.06	29.88	120	SIJ	60	24.94	19.45	35.01	35.82
9	73	Male	OA	40 mm +6mm	8	8.32	15.46	150	S1	70	19.88	17.71	23.90	25.49
10	72	Male	OA	40 mm +2mm	8	1.48	23.05	130	SIJ	40	23.81	23.31	25.95	28.13
11	68	Male	MRCT	36 mm +6mm	8	16.54	33.48	165	SIJ	80	25.83	21.01	34.14	27.89
12	64	Male	OA	36 mm +2mm	18	5.73	22.61	150	L3	70	16.98	21.12	28.78	30.48
13	75	Female	CTA	40 mm +2mm	8	8.89	20.44	130	T8	20	20.61	17.65	20.96	27.40
14	71	Male	OA	36 mm +6mm	8	26.35	38.3	165	T12	70	18.04	21.64	35.22	27.24
15	74	Female	CTA	36 mm +6mm	8	23.08	37.5	70	L1	20	17.60	16.99	26.80	13.64
16	71	Female	CTA	36 mm +2mm	10	2.5	25.89	100	IC	20	19.29	22.57	23.61	10.77
17	73	Male	MRCT	36 mm +2mm	10	16.76	28.82	160	T12	60	30.51	31.76	31.58	36.36
18	55	Male	MRCT	40 mm +2mm	8	12.32	18.51	150	SIJ	60	27.93	25.10	32.84	32.45
19	68	Female	CTA	36 mm +6mm	8	15.28	25.77	140	SIJ	60	26.22	25.02	28.54	21.65
20	80	Female	CTA	36 mm +6mm	8	8.83	21.29	120	L1	40	18.57	22.90	39.16	28.87

Table 3 – Deltoid stiffness by time point.

SWE Measurements (kPa)	Preop	P value	Intraop before incision	P value	Intraop before closure	P value	Follow Up Visit	P value
All Patients (n = 20)	22.4 ± 4.20		21.4 ± 4.16		29.9 ± 5.23		26.6 ± 6.60	
CTA (n = 7)	22.2 ± 1.54	.2229	23.6 ± 1.45	.0971	28.4 ± 2.03	.6359	23.7 ± 2.48	.3674
MRCT (n = 5)	25.1 ± 1.82		22.0 ± 1.72		31.3 ± 2.41		27.6 ± 2.94	
OA (n = 8)	20.9 ± 1.44		19.1 ± 1.36		30.3 ± 1.90		28.4 ± 2.32	

CTA, Cuff tear arthropathy; *MRCT*, Massive rotator cuff tear; *OA*, Osteoarthritis; *kPa*, kilopascal.

Table 4 – Clinical outcomes measures.

Outcome measure	Preoperative	Postoperative	P value
Elevation	121 ± 37	133 ± 24	.008
External Rotation	39 ± 25	55 ± 18	.005
Internal Rotation	SIJ	SIJ	
VAS	6.4 ± 2.4	0 ± 0.5	
QuickDash	48.6 ± 16.8	20.5 ± 16.1	
ASES	44.0 ± 22.1	80.8 ± 16.5	
Oxford	24 ± 9	43 ± 8	
SSV	40.4 ± 21.5%	83.1 ± 20.9%	

VAS, Visual Analog Scale kilopascal; *ASES*, American Shoulder and Elbow Surgeons score; *SSV*, Subjective Shoulder Value.

greater deltoid stiffness after component implantation was inversely associated with postoperative LSA values (*P*= .0035), whereas it was positively correlated with larger DSA values (*P*= .0026). In examining patient function, patients with a lower LSA on post op imaging had a greater increase in shoulder elevation, and external rotation from pre to postsurgery (*P*= .0118, .0002). Increased DSA on postoperative imaging was also associated with increased gains in elevation and external rotation after surgery (*P*= .0470, .0030).

Discussion

Restoration of motion and function after RSA has been predicated on the semiconstrained nature of the implant as well as changes in deltoid moment arm and other variables.[9] Although many accept that RSA facilitates the ability for the deltoid muscle to actively elevate the arm, understanding the ideal soft-tissue tension after RSA has remained elusive. This has been partly due to paucity of methods to objectively measure changes in the periarticular shoulder muscles as a result of RSA implantation, and it becomes particularly relevant with the very different biomechanical effects of the various RSA implants in the market.[13,16,21]

The results of our study seem to confirm previous cadaveric work regarding the value of SWE in measuring changes in deltoid stiffness after RSA.[11] In our study, RSA resulted in an average increase of 7 kPa of deltoid stiffness. Other interesting findings of our study included the similar SWE values obtained preoperatively either in the office or under anesthesia with a brachial plexus block, the slight decrease in deltoid stiffness during follow-up, and several statistically significant correlations between SWE and elevation, external rotation and the DSA. On the contrary, in this study and with the numbers available, no relationships could be found between SWE values and gender, age, underlying diagnosis, or glenosphere size.

When comparing deltoid stiffness to patients' clinical outcomes, increased deltoid stiffness was associated with better range of motion. This data demonstrates the direct relationship between deltoid stiffness and patient function after RSA, and suggests that in order to optimize shoulder elevation and external rotation, implantation of a RSA should lead to some increase stiffness across the deltoid when compared to its preoperative state. However, the ideal target for deltoid stiffness remains undetermined.

Deltoid muscle stiffness is inherently related to the bony anatomy and biomechanics of the shoulder, which change significantly after RSA.[8,17] Presently there is not a consensus on the most reproducible and accurate method of measuring the ideal lateral and distal implant position. Our data demonstrate how increased radiographic distalization (DSA) postoperatively is associated with increased deltoid stiffness, while

Table 5 – Radiographic measurements.

	Preop LSA°	Preop DSA°	Preop Acromion to GT	Preop Glenoid to GT	Preop Glenoid to COR	F/U LSA°	F/U DSA°	F/U Acromion to GT	F/U Glenoid to GT	F/U Glenoid to COR
All Patients	98.61	20.51	1.32	4.97	2.67	89.06	47.35	3.29	0.77	89.06
CTA	97.72	9.76	0.68	4.43	2.40	95.32	38.77	2.84	0.78	95.32
MRCT	106.74	19.87	1.14	4.99	2.65	88.24	49.86	3.57	0.73	88.24
OA	95.23	28.90	1.90	5.38	2.89	84.77	52.53	3.49	0.77	84.77

CTA, Cuff tear arthropathy; *MRCT*, Massive rotator cuff tear; *OA*, Osteoarthritis; *LSA*, Lateralization shoulder angle; *DSA*, Distalization shoulder angle; *GT*, Greater tuberosity; *COR*, Center of rotation, glenohumeral joint.

increased lateralization (LSA) correlates with decreased deltoid stiffness. This suggests these two measurements are radiographic predictors of deltoid stiffness, specifically in the postoperative period. Work by Boutsiades et al initially found that these angles were reproducible correlated with patient clinical outcomes.[3] A 2020 retrospective cohort study further investigating DSA and LSA confirmed that both measurements are reproducible with nearly perfect interobserver reliability, and appropriately lateralized prostheses were significantly associated with both higher LSA and lower DSAs, though this study did not find evidence supporting an association with clinical outcomes.[18] Here we demonstrate that both DSA and LSA correlate with the mechanical stiffness of the deltoid in RSA. Additionally, our data show that increased distance from the GT to the acromion radiographically was associated with increased deltoid stiffness.

Overall, this pilot study describes a methodology for use of SWE in optimizing deltoid stiffness in RSA. As such, SWE may provide the opportunity for intraoperative optimization of deltoid stiffness in RSA, and may be a useful tool to inform implant selection in order to provide patients with the ideal functional outcome.

Our study has several limitations, including the relatively small sample size, use of only one implant, and subjective intraoperative selection of the humeral bearing thickness by a single surgeon. As such, our results cannot be extrapolated to other implant designs or alternative implantation methods. Additionally, patient habitus may confound SWE readings, or patients who have not used their operative extremity frequently may have more fatty infiltration of the deltoid, which may alter its mechanical properties. Patients' deltoid stiffness was measured in the seated position in the clinic setting, and in the beach chair position intraoperatively, which could alter deltoid stiffness by altering the vector of gravitational force across the humerus and changing the relationship of the humerus and scapula between measurements. The radiographic measurements of LSA and DSA are additionally not measures of absolute lateral offset and distalization, but instead composite measurements that may by confounded by patient-specific anatomy and size, as well as radiographic magnification. At this time, there is no ideal RSA measurement methodology that allows for quantification of lateralization and distalization, therefore we chose measurements that have been shown to be both reliable and highly reproducible. However, our study demonstrates several strengths, namely the standardization of the SWE technique for measurement of deltoid stiffness, the quality of the radiographic measurements, and the use of independent observers for each of the components of the study.

In conclusion, implantation of a particular reverse shoulder arthroplasty design that incorporates glenoid and humeral lateralization results in significant increases in deltoid stiffness as measured with SWE. Deltoid stiffness seems to correlate with joint distalization, elevation and external rotation. Further research will be required to validate our findings in larger populations and when implanting other RSA designs.

Disclaimers

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