J Shoulder Elbow Surg (2020) 29, 2548–2555

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Shoulder arthroplasty in solid organ transplant patients: a retrospective, match paired analysis

Paul Rizk, MD, Scott A. Rizzi, BS, Maharsh K. Patel, MD, Thomas W. Wright, MD, Aimee M. Struk, MEd, MBA, ATC, Matthew Patrick, MD*

Department Orthopaedic Surgery and Rehabilitation, University of Florida, Gainesville, FL, USA

Background: Several studies have evaluated total hip and knee arthroplasty in solid organ transplant (SOT) patients; however, there are limited studies evaluating shoulder arthroplasty in SOT patients. This study compares the complications and functional outcomes of SOT patients undergoing shoulder arthroplasty with a matched control group.

Methods: The institution's database was retrospectively reviewed for patients with a history of SOT undergoing primary shoulder arthroplasty (with minimum 2-year follow-up) and compared with a control group matched for age, sex, preoperative diagnosis, and surgical procedure. Preoperative and postoperative range of motion and outcome scores, perioperative surgical and medical complications, hospital length of stay, and mortality were compared.

Results: Fifteen patients with previous SOT underwent 19 shoulder arthroplasties. Thirty-four underwent 35 shoulder arthroplasties in the control group. At last follow-up, the SOT group had a significantly worse UCLA score. The SOT group had a significantly worse improvement in UCLA, active elevation, and passive elevation scores in pre- to postoperative scores. There was no difference in length of stay, infection, or surgical complications. Ninety-day readmissions, medically related complications, and required blood transfusion were significantly higher in the SOT group. There was increased mortality in the SOT compared with the control group (death occurred on average 1577 days after arthroplasty).

Conclusion: Shoulder arthroplasty in patients with previous SOT appears safe and effective for degenerative shoulder disorders. Patients should be counseled preoperatively that their range of motion and function may not improve as much as their nontransplant cohorts. SOT patients may have increased incidence of postoperative blood transfusions and medically related complications.

Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords: Shoulder arthroplasty; blood transfusions; length of stay; mortality; range of motion; solid organ transplant

Solid organ transplantation (SOT) has become the preferred definitive treatment for patients suffering from end-stage disease of the kidney, liver, heart, and lungs.[5] The increasingly favorable outcomes and improved longevity of SOT recipients can be attributed to advancements in improved immunosuppression, surgical techniques, and donor/patient matching.[3,4,12,27] As a result, SOT operations have nearly doubled in frequency in the United States since the 1990s.[24]

Because of various comorbidities and medications, patients who have received SOT have an increased risk of developing arthropathies and tendinopathies as compared with the general population.[2,6,13,23] This fact, coupled with increasing survivability of patients after SOT, has led to an increase in the annual number of total hip arthroplasties (THA) and total knee arthroplasties (TKA) in SOT

Approval for this study was received from the Institutional Review Board of the University of Florida (IRB201701155).

*Reprint requests: Matthew Patrick, MD, Orthopaedics and Sports Medicine Institute, University of Florida, 3450 Hull Road, Gainesville, FL 32611, USA.

E-mail address: patrimr@ortho.ufl.edu (M. Patrick).

1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2020.03.035

patients.[17,24] A number of studies have demonstrated an increased complication rate after hip and knee arthroplasty in SOT patients compared with controls.[7,11,15-17,19,20,24] SOT patients have been found to have a higher periprosthetic joint infection rate after THA and TKA.[1,7,16] SOT patients have also been found to have increased hospital length of stay (LOS) after hip and knee arthroplasty.[17,24] Although SOT patients have a higher complication rate, studies have shown improvements in functional outcome scores and satisfaction in SOT patients after THA and TKA.[18-20]

Although THA and TKA outcomes in SOT patients have been well documented, outcomes after shoulder arthroplasty (SA) in SOT patients have remained largely unexplored. A recent study by Malcolm et al[21] evaluated SA in SOT patients using the Nationwide Inpatient Sample database. The study reported that SOT patients had an increased complication rate and increased hospital LOS compared with nontransplant patients. However, because of limitations of the study, functional outcomes were not reported.

The aim of the present study is to evaluate and report functional outcomes measures, complications, hospital LOS, blood transfusion rates, and 90-day readmission rates in SOT patients undergoing SA at a single institution and compare these measures with a nontransplant population control group.

Patients and methods

Patient selection

A retrospective review of the institution's SA database was performed. All patients who had an SOT (defined as heart, lung, kidney, pancreas, liver, and/or bowel) before SA were identified by reviewing the patient's medical history. To be included in the study, patients must have a history of SOT before SA surgery, age greater than 18 years at the time of SA, and have a minimum of 2-year follow-up. Patients in the SOT group with less than 2-year follow-up were excluded from postoperative functional outcome analysis; however, preoperative functional outcome scores, perioperative variables, and complications were used for analysis. Patients undergoing revision arthroplasty or nonsolid organ transplants were excluded.

Once SOT SA patients were identified, a match-paired control group (2:1) of patients with no history of SOT was created. Only patients greater than 18 years of age at the time of SA who underwent a primary SA procedure with a minimum of 2-year follow-up were included. The control group was matched paired for age, sex, preoperative diagnosis, and SA type.

Perioperative variables

Demographic information (age, sex, and preoperative diagnosis), number of medical comorbidities, type of solid organ transplant, number of transplant immunosuppressant medications, and surgery performed (hemiarthroplasty [HA], anatomic total SA [aTSA], or reverse total SA [rTSA]) were recorded. The hospital LOS and whether intensive care unit (ICU) admission was required during surgical admission were documented. Preoperative and first postoperative day hematocrit values were identified, and the change from pre- to postoperative hematocrit was calculated and recorded. Patients receiving a packed red blood cell transfusion were identified, and the number of units of blood transfused was documented. Each patient received blood transfusion for symptomatic anemia; however, there were no formal transfusion criteria. SOT patients did not have a lower transfusion threshold compared with controls. Tranexamic acid was not used in any patient in this study. Finally, discharge disposition (home, skilled nursing facility, or in-patient rehabilitation hospital) was recorded.

Complications

Both medical and procedurally related complications were documented and categorized accordingly. Only medical complications occurring within 90 days of surgery were reported. Postoperative 90-day readmission and the reason for admission were recorded. Finally, any procedurally related complication, any complication requiring reoperation, or a revision procedure for any reason was documented.

Functional outcomes

The patients were evaluated and scored preoperatively, at 1-year follow-up, and at latest follow-up using the SST, UCLA, ASES, Constant, SPADI, and SF-12 scoring metrics. In addition, the patients' active abduction, active forward flexion, active external rotation, passive elevation, and passive external rotation were also measured preoperatively, at 1-year follow-up, and at latest follow-up. Internal rotation was measured by vertebral segments and was scored by the following discrete assignment: $0^\circ = 0$, hip = 1, buttocks = 2, sacrum = 3, L5-L4 = 4, L3-L1 = 5, Th12-Th8 = 6, and Th7 or higher = 7. The change from preoperative to final postoperative follow-up was calculated for each functional scoring metric.

Patients requiring revision arthroplasty for any reason were excluded from postoperative functional outcome analysis; however, preoperative functional outcome scores, perioperative variables, and complications were used for analysis.

Statistical analysis

Descriptive statistics (means and standard deviations for continuous variables, frequencies and percentages for categorical variables) were calculation on all study variables and demographics. A Fisher's exact test was used for the analysis of all categorical data, where $P < .05$ denoted a significant difference. A Student's 2-tailed, unpaired t-test was used for the analysis of continuous variables, where $P < .05$ denoted a significant difference.

Results

Demographics and patient variables

The study identified 15 patients with previous SOT, who underwent 19 SAs. All 19 SAs had 1-year follow-up;

however, 16 (84%) SAs had minimum 2-year follow-up. The match-paired control comprised 38 patients who underwent 39 SAs.

SOT comprised 6 renal transplant, 3 heart transplant, 3 lung transplant, and 3 liver transplant patients. SOT patients received on average 1.8 immunosuppressant medications (range, 1-3). Immunosuppressant medication used included the following: prednisone (13 patients), tacrolimus (6 patients), cyclosporine (6 patients), mycophenolate mofetil (5 patients), sirolimus (4 patients), azathioprine (1 patient), and mycophenolate sodium (1 patient). No medication was held for the procedure.

The patient demographics are presented in Table I. There was no difference between the study group and control groups concerning sex, age, preoperative diagnosis, or surgical procedure. However, the SOT patients had significantly more medical comorbidities compared with the control group.

Table I Demographics

	Transplant	Control	*P* value
Sex			.78
Male	5	11	
Female	10	27	
Avg. age (yr)	57.8 ± 10.5	60.3 ± 10.6	.39
Preop diagnosis			
Inflammatory arthritis	3	5	.11
Osteoarthritis	3	11	
Osteoarthritis with RTC tear	1	2	
Avascular necrosis (AVN)	4	7	
Cuff tear arthropathy	7	10	
Fracture sequela	1	2	
Irrepairable RTC	0	2	
Arthoplasty type			
Total	19	39	.63
HA	3	9	
aTSA	7	15	
rTSA	8	14	
Resurfacing	1	1	
Medical comorbidities			
Number of patients with comorbidity	15 (100%)	27 (69%)	>***.01***
Total number of comorbidities	52	49	>***.01***

RTC, rotator cuff; *HA*, hemiarthroplasty; *aTSA*, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.

Hospitalization variables

All patients included in the study were admitted postoperatively. A summary of the inpatient variables analyzed is presented in Table II. There was no difference in the hospital LOS between groups. One patient in the SOT required ICU admission after surgery due to hypotension due to acute blood loss anemia, whereas 2 patients required admission to the ICU in the control group. One patient was admitted for hypotension and respiratory distress and the other was admitted due to cardiac arrhythmia. There was no difference in preoperative HCT or postoperative change in HCT between groups; however, significantly more patients received a blood transfusion in the SOT group. Five patients (26%) received a blood transfusion in the SOT compared with 2 (5%) patients in the control group. Of note, the patients in the SOT who received a blood transfusion had an average preoperative HCT of 31.5. Finally, there was no difference in discharge disposition.

Table II Hospital admission variables

	Transplant	Control	*P* value
LOS	2.6 ± 1.3	2.5 ± 0.9	.85
ICU admission	1	2	.88
Preop HCT	36.9 ± 6.0	38.9 ± 5.1	.24
Change in HCT	7.4 ± 5.0	7.5 ± 3.4	.94
Number of patients receiving blood transfusion	5 (26%)	2 (5%)	***.02***
Avg. number of units transfused	2.6 ± 1.1	2 ± 0	.3
Discharge disposition			.34
Home	19	37	
In-patient rehab	0	2	

LOS, length of stay; *ICU*, intensive care unit; *HCT*, hematocrit.

Functional outcomes

Functional outcome scores and range of motion are summarized in Table III. The SOT group had a significantly lower SPADI (63 ± 11 vs. 75 ± 14; $P \geq .01$) score, whereas the control group had significantly lower SST12 (2.7 ± 1.9 vs. 4.5 ± 2.7; $P = .04$) score, ASES (29 ± 15 vs. 41 ± 12; $P = .01$), active external rotation (19 ± 24 vs. 35 ± 31; $P = .05$), and passive external rotation (32 ± 36 vs. 52 ± 27; $P = .02$) preoperatively. There was no statistical difference in any functional outcome metrics or range of motion values at 1-year follow-up. Final follow-up was not different between groups in follow-up duration (SOT [4.0 ± 2.9] vs. control [6.7 ± 9.3]; $P = .13$). The SOT group had significantly worse UCLA scores (20 ± 9 vs. 29 ± 8; $P = .02$) and active elevation (77 ± 42 vs. 114 ± 34; $P = .03$), whereas the control group had significantly worse passive external rotation (64 ± 17 vs. 50 ± 15; $P = .04$). Finally, the SOT group had significantly worse UCLA scores, Constant scores, and active elevation when the difference between the preoperative and final follow-up functional values was evaluated.

Table III Functional outcome scores

	Preoperative			Final follow-up			Change from pre- to final postoperative		
	Transplant	Control	*P* value	Transplant	Control	*P* value	Transplant	Control	*P* value
Final follow-up (yr)				4.0 ± 2.9	6.7 ± 9.3	.13			
SPADI	63 ± 11	75 ± 14	***>.01***	35 ± 29	31 ± 22	.71	38 ± 26	45 ± 30	.47
SST12	4.5 ± 2.7	2.7 ± 1.9	***.04***	7.9 ± 4.4	10.6 ± 11.0	.24	3.8 ± 4.8	5.9 ± 3.7	.23
ASES	41 ± 12	29 ± 15	***.01***	68 ± 27	73 ± 20	.54	34 ± 22	44 ± 27	.28
UCLA	14 ± 4	12 ± 5	.07	20 ± 9	29 ± 8	***.02***	7 ± 8	17 ± 7	***.03***
Constant	42 ± 13	33 ± 13	.08	51 ± 22	66 ± 20	.10	8 ± 24	36 ± 25	***.05***
SF-12	31 ± 4	30 ± 6	.68	34 ± 6	35 ± 8	.69	7 ± 13	7 ± 10	.86
Active external rotation	35 ± 31	19 ± 24	***.05***	43 ± 19	32 ± 19	.15	5 ± 34	14 ± 26	.54
Active elevation	85 ± 29	83 ± 31	.81	77 ± 42	114 ± 34	***.03***	−17 ± 35	35 ± 46	***.01***
Passive external rotation	52 ± 27	32 ± 26	***.02***	64 ± 17	50 ± 15	***.04***	15 ± 26	20 ± 31	.77
Passive elevation	120 ± 27	110 ± 34	.23	136 ± 24	142 ± 18	.56	−24 ± 68	39 ± 52	.10
Internal rotation	4.1 ± 1.8	3.4 ± 2.0	.24	4.0 ± 2.2	4.7 ± 1.6	.43	−0.3 ± 3.1	0.6 ± 3.3	.55
Active abduction	73 ± 32	76 ± 35	.79	82 ± 41	105 ± 33	.16	2 ± 39	35 ± 44	.09
Avg. daily pain (1-10)	5.1 ± 2.3	6.4 ± 1.9	.16	3.5 ± 3.2	2.4 ± 2.6	.29	−0.3 ± 3.7	2.0 ± 3.9	.27

A subanalysis of the SOT patients was performed comparing functional outcome metrics and range of motion values of nonconstrained SAs (HA, aTSA, and resurfacing) with constrained SAs (rTSA). After excluding the 2 patients who required revision arthroplasty procedures and 3 patients who did not have minimum 2-year follow-up, 14 patients were evaluated (8 nonconstrained and 6 rTSA). The subanalysis functional outcome scores and range of motion are summarized in Table IV. Preoperative, final follow-up, and change from pre- to postoperative functional outcome metrics and range of motion values were compared in the same manor described previously. There was no difference in preoperative, final follow-up, or improvement from pre- to postoperative outcome metrics or range motion values, except for active external rotation at final follow-up. At final follow-up, rTSA had significantly better active external rotation (57 ± 13 vs. 39 ± 20; $P = .05$). On average, rTSA had superior outcome metrics and range of motion values for every variable at final follow-up and for improvement from pre- to postoperative functional

Table IV SOT patient subanalysis of rTSA vs. aTSA/HA

	Preoperative			Final follow-up			Change from pre- to final postoperative		
	rTSA	aTSA/HA	*P* value	rTSA	aTSA/HA	*P* value	rTSA	aTSA/HA	*P* value
Final follow-up (yr)				4.3 ± 3.6	3.8 ± 2.5	.74			
SPADI	66 ± 9	60 ± 13	.34	26 ± 30	41 ± 29	.38	40 ± 27	35 ± 26	.78
SST12	4.2 ± 2.4	5.2 ± 3.3	.60	9.6 ± 3.9	6.4 ± 4.6	.20	5.7 ± 2.9	1.6 ± 5.9	.21
ASES	40 ± 14	43 ± 11	.72	79 ± 29	60 ± 26	.22	37 ± 19	31 ± 28	.69
UCLA	13 ± 3	16 ± 3	.11	22 ± 16	19 ± 8	.85	8 ± 11	4 ± 12	.76
Constant	39 ± 14	46 ± 12	.32	55 ± 27	50 ± 23	.85	16 ± 19	5 ± 27	.59
SF-12	33 ± 3	29 ± 3	***.04***	37 ± 7	32 ± 6	.13	4 ± 9	11 ± 17	.47
Active external rotation	32 ± 38	33 ± 26	.97	57 ± 13	39 ± 20	***.05***	3 ± 20	8 ±38	.80
Active elevation	76 ± 37	87 ± 22	.49	112 ± 28	68 ± 41	.10	22 ± 36	−26 ± 30	.13
Passive external rotation	61 ± 23	43 ± 29	.17	63 ± 12	66± 19	.82	2 ± 28	23 ± 23	.32
Passive elevation	124 ± 32	117 ± 26	.64	148 ± 10	130 ± 26	.21	17 ± 24	34 ± 73	.14
Internal rotation	3.3 ± 2.4	4.3 ± 1.3	.33	5.0 ±1.0	3.6 ± 2.4	.22	1.6 ± 0.6	0.9 ± 3.3	.09
Active abduction	71 ± 40	78 ± 28	.69	113 ± 33	74 ± 39	.16	32 ± 1	−7 ± 22	.38
Avg. daily pain (1-10)	4.8 ± 2.4	4.7 ± 2.1	.93	1.8 ± 3.5	5.0 ± 2.2	.12	−0.75 ± 1.5	0.5 ± 7.8	.86

SOT, solid organ transplant; *rTSA*, reverse total shoulder arthroplasty; *aTSA*, anatomic total shoulder arthroplasty; *HA*, hemiarthroplasty.

outcome metrics and range of motion values; however, only active external rotation reached statistical significance.

Complications

Ten complications occurred in 9 (47%) patients in the SOT group, whereas 12 complications occurred in 11 (28%) patients in the control group. Complications were stratified based on surgery-related complications and medically related complications. Four medically related complications occurred in 4 patients in the SOT group. The complications consisted of appendicitis 2 weeks after SA, worsening renal function (acute renal failure), chronic diarrhea requiring intravenous fluid resuscitation, and influenza infection. Six surgically related complications occurred in 5 patients in the SOT group. The complications consisted of transient ulnar nerve neuropraxia, prosthetic dislocation 4 weeks after surgery requiring a revision arthroplasty and subsequent development of infection, rotator cuff tear 4 years after HA, postoperative hematoma, and shoulder pain/stiffness recalcitrant to therapy requiring a revision arthroplasty. Three medically related complications occurred in 3 patients in the control group. The complications consisted of dyspnea 1 week after surgery requiring admission to the hospital, a myocardial infarction 2 weeks after surgery, and severe depression requiring admission for psychiatric evaluation. Nine surgically related complications occurred in 9 patients. The complications consisted of one patient with scapular spine fracture that occurred approximately 6 months after surgery and another patient with humeral shaft fracture that occurred distal to the implant 2 years after surgery; both were managed nonoperatively. One patient suffered a shoulder dislocation and declined further treatment. Three patients reported persistent pain, with one patient electing to undergo a revision from aTSA to rTSA 14 months after initial surgery. An additional patient underwent arthroscopic capsular release due to persistent stiffness after aTSA. Finally, 2 patients developed periprosthetic infections requiring revision arthroplasties.

There was no statistical difference in the total number of complications between groups; however, when complications were stratified based on medically related or procedurally related complications, the SOT group was found to have statistically more medical complications (4 [21%] vs. 3 [8%]; $P = .02$). There was no difference in surgery-related complications, complications requiring reoperation, or postoperative infections between groups. The number of 90-day hospital readmissions was also found to be higher in the SOT group (4 [21%] vs. 3 [8%]; $P = .02$). All readmission was due to medically related complications except for one patient in the SOT group, who was admitted due to a prosthetic dislocation 4 weeks postoperatively. The SOT group did have a higher number of deaths reported in the follow-up period compared with the control group (6 [38%] vs. 3 [8%]; $P \geq .01$); however, none of the deaths occurred in the immediate postoperative period. The average number of days from surgery to death was 1578 ± 586 in the SOT group and 1985 ± 1680 ($P = .72$) in the controls. A summary of the complications is reported in Table V.

Discussion

Because of medical advancements, the rate of successful SOT is increasing, resulting in an increasing SOT population and longer post-transplant life expectancy. As a result, an increasing number of SOT patients are expected to undergo joint arthroplasty in the future.[21,28] Although outcomes in TKA and THA after SOT have been well documented, outcomes after SA remain largely unexplored. As the number of SAs performed annually continues to increase,[9] it is expected that the increasing number of SOTs will also undergo SA; this was confirmed in a recent study by Malcolm et al.[21] Malcolm et al[21] reported a greater than 3-fold increase in the number of SOT patients undergoing SA from 2004 to 2014.

One of the greatest concerns with performing elective arthroplasty procedures in the SOT population is increased complications. This is largely imparted to SOT patients being more medically fragile and complex.[21] Although the present series did not find a difference in total complications between groups, there was a significantly higher rate of medical complications and 90-day readmission rates. These findings are supported by Malcolm et al[21] and Strotman et al,[26] who reported that SOT had higher adverse events after SA compared with nontransplant patients. Similarly, increased medical complications and readmissions have also been reported in SOT patients undergoing TKA and THA series.[15,17,19,20,24] The increase in medical complications is

Table V Complications

	Transplant	Control	*P* value
90-day readmission	4 (21%)	3 (8%)	***.02***
Number of patients with complication	9 (47%)	11 (28%)	.53
Total number of complications	10	12	.74
Medical complications	4 (21%)	3 (8%)	***.02***
Procedurally related complications	6 (32%)	9 (23%)	.74
Complications requiring reoperation	2 (11%)	4 (10%)	.86
Infection	1 (5%)	2 (5%)	.86
Number of deaths	6 (38%)	3 (8%)	>***.01***
Number of days from surgery to death	1578 ± 586	1985 ± 1680	.72

likely due to SOT patients having more medical comorbidities and an immunocompromised state.[21]

Increased hospital resources and resulting increased hospital LOS are also frequently associated with SOT patients undergoing arthroplasty.[24] This was again supported by the work of Malcolm et al[21] and Strotman et al,[26] who found that SOT patients had longer LOS. Increased LOS has also been reported in numerous TKA and THA series.[16-18,20,24] Although the present series did show that the SOT group had a longer LOS vs. the control group (2.6 ± 1.3 vs. 2.4 ± 0.8; $P = .86$), the difference failed to reach statistical significance. Interestingly, the LOS difference was similar to the report of Malcolm et al. This failure to reach significance could be due to a relatively small sample size. However, at the authors' institution, the anesthesia and transplant medicine teams are made aware of SOT patients preoperatively and are medically optimized before the procedure. The transplant medicine team is also actively involved in patient care and co-management starting immediately after surgery. The multidisciplinary approach may act to lessen LOS. Larger series and further research are needed before definitive conclusions can be made.

Another interesting finding in the present study is the number of SOT patients requiring significantly more blood transfusions than the control group (5 [26%] vs. 2 [5%]; $P = .02$). However, there was no difference in preoperative HCT or change in preoperative-to-postoperative day 1 HCT between study groups. On further analysis of SOT patients receiving a blood transfusion, patients requiring a transfusion had a significantly lower preoperative HCT (31.3 ± 3.0 vs. 38.4 ± 5.8; $P = .004$) than those who did not require a transfusion. However, in the series by Malcolm et al,[21] there was no difference in blood transfusions between SOT and nontransplant patients (7.1% vs. 4.8%; $P = .17$). It is possible that preoperative anemia as opposed to history of SOT is the cause for the increased need for blood transfusion. However, anemia is a known complication of SOT. Preoperative HCT lower than 35 has been shown to be predictive of a need for transfusion.[14,22] This indicates that patients noted to have preoperative anemia should be counseled of the increased need for postoperative transfusion and should attempt preoperative medical management to correct anemia.

Another concern with arthroplasty in SOT patients is periprosthetic infections, due to being in an immunocompromised state from their disease state and medications. Interestingly, the present series did not find an increased infection rate in the SOT group (1 [5%] vs. 2 [5%]; $P = .86$). Sperling and Cofield[25] reported the outcomes of 5 SOT patients undergoing SA and reported no infections in the 5 patients 2 years after surgery. Recently, Hatta et al[10] reported on the outcomes of 30 SOT patients undergoing SA. The authors found no difference in infections when compared with control (0 vs. 1; $P = .53$). Similarly, Malcolm et al[21] also found no difference in PPI in SOT patients compared with nontransplant patients, but it did trend toward significance (0.6% vs. 0.1%; $P = .09$). However, several other series have reported an increased infection rate in TKA and THA.[18,19] It remains unclear if SOT increases infection rates in SA and further larger prospective series are needed to elucidate definitive conclusions.

SOT patients were also noted to have a higher mortality rate compared with control group (6 [38%] vs. 3 [8%]; $P \geq .01$). However, none of the deaths occurred in the immediate postoperative period, with the death occurring on average 1578 days after SA, indicating that the deaths were likely unrelated to the surgical procedure. In a recent series by Hatta et al,[10] the authors noted that there was a significantly higher 1-year mortality after SA in SOT patients (10% vs. <1%; $P \leq .001$). Malcolm et al[21] noted no difference in mortality between SOT and nontransplant patients (0.6% vs. 0.1%; $P = .1$); however, the parameters of determining mortality rate were not clearly defined in the study. Chalmers et al[8] reported the outcomes of SOT patients undergoing THA and reported a 13% mortality rate 5 years postoperatively. These findings demonstrate that SOT patients likely do not bear an increased perioperative mortality rate but likely do have a long-term increased mortality rate compared with their nontransplant peers. This finding is most certainly due to their underlying comorbidities.

To the authors' knowledge, there is only one other study comparing the functional outcomes of SOT patients undergoing SA with nontransplant controls. Hatta et al[10] reported on the outcomes of 30 patients undergoing SA after SOT. The authors found no difference in pain scores, forward flexion, external rotation, or ASES scores in SOT patients when compared with controls. The only other report on the functional outcomes of SA in SOT patients is a 5-patient case series by Sperling and Cofield.[25] In their work, the authors reported excellent results in 4 patients and 1 satisfactory result in the remaining patient.

The present series more objectively reports outcomes by examining 6 functional outcome scores as well as range of motion and pain scores. Preoperatively, SOT patients had a significantly lower SPADI score (63 ± 11 vs. 75 ± 14; $P \geq .01$), whereas the control group had a significantly lower SST12 (2.7 ± 1.9 vs. 4.5 ± 2.7; $P = .04$) score, ASES (29 ± 15 vs. 41 ± 12; $P = .01$), active external rotation (19 ± 24 vs. 35 ± 31; $P = .05$), and passive external rotation (32 ± 36 vs. 52 ± 27; $P = .02$). Otherwise, the remaining functional metrics and range of motion values showed no difference. At final follow-up, SOT patients had significantly worse UCLA scores (20 ± 9 vs. 29 ± 8; $P = .02$) and active elevation (77 ± 42 vs. 114 ± 34; $P = .03$), whereas the control group had significantly worse passive external rotation (50 ± 15 vs. 64 ± 17; $P = .04$). There was no significant difference in the remaining functional outcome metric scores or range of motion values. Finally, SOT patients were found to have significantly lower pre- to postoperative improvement in UCLA scores (7 ± 8 vs. 17 ± 7; $P = .03$) and Constant score (8 ± 24 vs. 36 ± 25; $P = .05$). The SOT patients were also found to have a significantly less improvement in active elevation (−17 ± 35 vs. 35 ± 46; $P = .01$). Interestingly, SOT patients actually demonstrated a loss of elevation over time. This is likely due to patients receiving

HA and aTSA subsequently developing rotator cuff dysfunction over time, resulting in a loss in motion. Aside from active elevation motion loss, SOT patients on average showed improvements in all functional outcome scores and range of motion values compared with preoperative values, indicating that patients did functionally benefit from SA surgery.

The loss in elevation and less improvement from functional outcome metrics may be due to rotator cuff dysfunction in SOT patients. One patient in the SOT group who underwent an HA was noted to have a rotator cuff tear 4 years postoperatively. Because of medical comorbidities and medication, SOT patients have an increased rate of tendinopathies.[2,23] As such, SOT may benefit from a rTSA over nonconstrained SAs (HA, aTSA, and resurfacing). A subanalysis of SOT patients did not yield significant differences between rTSA and nonconstrained SAs except for active external rotation at final follow-up. However, rTSA did have better scores for every outcome metric and range of motion values at final follow-up and in pre- to postoperative improvement when compared with nonconstrained SAs. The inability to find statistical significance is likely due to small sample size.

The authors acknowledge that there are limitations in this study. This is a retrospective review of a prospectively collected database. Second, all procedures were performed at a single institution and outcomes may not translate to other institutions. Finally, this study involves a small number of patients and is likely underpowered to make a definitive conclusion. However, this is one of the largest series to report on outcomes and complications in SA after SOT.

Conclusion

SA in patients with previous SOT appears to be safe and effective for treating degenerative disorders of the shoulder. Patients should be counseled preoperatively that their range of motion and function should improve, but may not improve as much as their nontransplant cohorts. SOT patients may also have an increased need for postoperative blood transfusions and medically related complications. Finally, although there was an increased mortality rate in the SOT group, the average death occurred 1578 days after arthroplasty, suggesting that surgery is likely not a contributing cause of mortality. To the authors' knowledge, this is one of the largest reported series on the clinical outcomes of SA in patients with a history of SOT and 1 of only 2 studies comparing the functional outcomes of SA in SOT with a control group.

Disclaimer

Thomas W. Wright receives royalties from and has a consultancy agreement with Exactech, Inc.

The other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Angermeier EW, Demos HA, Del Schutte H, Barfield WR, Leddy LR. Complications of hip and knee joint replacement in solid-organ transplant patients. J Surg Orthop Adv 2013;22:204-12. https://doi.org/10.3113/jsoa.2013.0204
2. Barge-Caballero E, Crespo-Leiro MG, Paniagua-Martin MJ, Muniz J, Naya C, Bouzas-Mosquera A, et al. Quinolone-related Achilles tendinopathy in heart transplant patients: incidence and risk factors. J Heart Lung Transplant 2008;27:46-51. https://doi.org/10.1016/j.healun.2007.09.021
3. Barry JM. Current status of renal transplantation. Patient evaluations and outcomes. Urol Clin North Am 2001;28:677-86.
4. Bia M. Evaluation and management of bone disease and fractures post transplant. Transplant Rev (Orlando) 2008;22:52-61. https://doi.org/10.1016/j.trre.2007.09.001
5. Black CK, Termanini KM, Aguirre O, Hawksworth JS, Sosin M. Solid organ transplantation in the 21st century. Ann Transl Med 2018;6:409. https://doi.org/10.21037/atm.2018.09.68
6. Bradford DS, Szalapski EW Jr, Sutherland DE, Simmons RL, Najarian JS. Osteonecrosis in the transplant recipient. Surg Gynecol Obstet 1984;159:328-34.
7. Cavanaugh PK, Chen AF, Rasouli MR, Post ZD, Orozco FR, Ong AC. Total joint arthroplasty in transplant recipients: in-hospital adverse outcomes. J Arthroplasty 2015;30:840-5. https://doi.org/10.1016/j.arth.2014.11.037
8. Chalmers BP, Ledford CK, Statz JM, Perry KI, Mabry TM, Hanssen AD, et al. Survivorship after primary total hip arthroplasty in solid-organ transplant patients. J Arthroplasty 2016;31:2525-9. https://doi.org/10.1016/j.arth.2016.04.012
9. Day JS, Lau E, Ong KL, Williams GR, Ramsey ML, Kurtz SM. Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elbow Surg 2010;19:1115-20. https://doi.org/10.1016/j.jse.2010.02.009
10. Hatta T, Statz JM, Itoi E, Cofield RH, Sperling JW, Morrey ME. Shoulder arthroplasty in patients with immunosuppression following solid organ transplantation. J Shoulder Elbow Surg 2020;29:44-9. https://doi.org/10.1016/j.jse.2019.05.042
11. Heaf JG. Bone disease after renal transplantation. Transplantation 2003;75:315-25. https://doi.org/10.1097/01.Tp.0000043926.74349.6d
12. Holt CD. Overview of immunosuppressive therapy in solid organ transplantation. Anesthesiol Clin 2017;35:365-80. https://doi.org/10.1016/j.anclin.2017.04.001
13. Kart-Koseoglu H, Yucel AE, Isiklar I, Turker I, Akcali Z, Haberal M. Joint pain and arthritis in renal transplant recipients and correlation with cyclosporine therapy. Rheumatol Int 2003;23:159-62. https://doi.org/10.1007/s00296-002-0283-y
14. King JJ, Patrick MR, Schnetzer RE, Farmer KW, Struk AM, Garvan C, et al. Multivariate analysis of blood transfusion rates after shoulder arthroplasty. J Surg Orthop Adv 2017;26:40-7.
15. Klatt BA, Steele GD, Fedorka CJ, Sanchez AI, Chen AF, Crossett LS. Solid organ transplant patients experience high rates of infection and other complications after total knee arthroplasty. J Arthroplasty 2013;28:960-3. https://doi.org/10.1016/j.arth.2013.02.005
16. Klement MR, Penrose CT, Bala A, Green CL, Mather RC III, Wellman SS, et al. Complications of total hip arthroplasty following solid organ transplantation. J Orthop Sci 2017;22:295-9. https://doi.org/10.1016/j.jos.2016.12.004

17. Klika AK, Myers T, Szubski CR, Schiltz NK, Navale S, Barsoum WK. Early postoperative outcomes of primary total knee arthroplasty after solid organ transplantation in the United States, 1998-2011. J Arthroplasty 2015;30:1716-23. https://doi.org/10.1016/j.arth.2015.04.044
18. Ledford CK, Chalmers BP, Statz JM, Perry KI, Mabry TM, Hanssen AD, et al. Primary total knee arthroplasty after solid organ transplant: survivorship and complications. J Arthroplasty 2017;32:101-5. https://doi.org/10.1016/j.arth.2016.07.018
19. Ledford CK, Watters TS, Wellman SS, Attarian DE, Bolognesi MP. Outcomes of primary total joint arthroplasty after lung transplantation. J Arthroplasty 2014;29:11-5. https://doi.org/10.1016/j.arth.2013.03.029
20. Ledford CK, Watters TS, Wellman SS, Attarian DE, Bolognesi MP. Risk versus reward: total joint arthroplasty outcomes after various solid organ transplantations. J Arthroplasty 2014;29:1548-52. https://doi.org/10.1016/j.arth.2014.03.027
21. Malcolm TL, Chatha K, Breceda AP, Guo E, Friedman DJ, Sabesan VJ, et al. The impact of solid organ transplant history on inpatient complications, mortality, length of stay, and cost for primary total shoulder arthroplasty admissions in the United States. J Shoulder Elbow Surg 2018;27:1429-36. https://doi.org/10.1016/j.jse.2018.02.064
22. Millett PJ, Porramatikul M, Chen N, Zurakowski D, Warner JJ. Analysis of transfusion predictors in shoulder arthroplasty. J Bone Joint Surg Am 2006;88:1223-30. https://doi.org/10.2106/jbjs.E.00706
23. Murison MS, Eardley I, Slapak M. Tendinitis—a common complication after renal transplantation. Transplantation 1989;48:587-9.
24. Navale SM, Szubski CR, Klika AK, Schiltz NK, Desai PP, Barsoum WK. The impact of solid organ transplant history on inpatient complications, mortality, length of stay, and cost for primary total hip arthroplasty admissions in the United States. J Arthroplasty 2017;32:1107-16.e1. https://doi.org/10.1016/j.arth.2016.10.017
25. Sperling JW, Cofield RH. Case reports: shoulder arthroplasty in transplant recipients: a report of five cases. Clin Orthop Relat Res 2006;442:273-5. https://doi.org/10.1097/01.blo.0000191271.57657.07
26. Strotman PK, Kothari A, Kuo P. Shoulder arthroplasty in transplant recipients: complications and mortality. J Surg Orthop Adv 2019;28:41-7.
27. Weisinger JR, Carlini RG, Rojas E, Bellorin-Font E. Bone disease after renal transplantation. Clin J Am Soc Nephrol 2006;1:1300-13. https://doi.org/10.2215/cjn.01510506
28. Wolfe RA, Merion RM, Roys EC, Port FK. Trends in organ donation and transplantation in the United States, 1998-2007. Am J Transplant 2009;9:869-78. https://doi.org/10.1111/j.1600-6143.2009.02564.x