JSES International 8 (2024) 176–184

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

A comprehensive analysis of age and 30-day complications following total shoulder arthroplasty: nonagenarians, octogenarians, and septuagenarians

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A R T I C L E I N F O

Keywords:
Total shoulder arthroplasty
Age
Nonagenarian
Octogenarian
Septuagenarian
Readmission
Mortality

Level of evidence: Level III; Retrospective Cohort Comparison Using Large Database; Prognosis Study

Background: Increased age is a well-known risk factor for development of osteoarthritis. Total shoulder arthroplasty (TSA) is a common treatment option for patients with severe glenohumeral osteoarthritis. The purpose of this study was to investigate the association between the septuagenarian, octogenarian, and nonagenarian populations and postoperative outcomes following TSA.

Methods: The American College of Surgeons National Surgical Quality Improvement Program database was queried for all patients who underwent TSA between 2015 and 2020. Patients were divided into cohorts based on age: sexagenarians (60-69), septuagenarians (70-79), octogenarians (80-89), and nonagenarians (90+). Multivariate logistic regression was used to identify associations between age and postoperative complications.

Results: On bivariate analysis, compared to sexagenarians, septuagenarians were significantly associated with higher rates of myocardial infarction (P = .038), blood transfusion (P < .001), organ/space surgical site infection (P = .048), readmission (P = .005), and nonhome discharge (P < .001. Compared to septuagenarians, octogenarians were significantly associated with higher rates of urinary tract infection (P < .001), blood transfusion (P < .001), readmission (P = .002), non-home discharge (P < .001), and mortality (P = .027). Compared to octogenarians, nonagenarians were significantly associated with higher rates of sepsis (P = .013), pneumonia (P = .003), reintubation (P = .009), myocardial infarction (P < .001), blood transfusion (P < .001), readmission (P = .026), nonhome discharge (P < .001), and mortality (P < .001).

Conclusion: From age 60, each decade of age was identified to be an increasingly significant predictor for blood transfusion, readmission, and nonhome discharge following TSA. From age 70, each decade of age was additionally identified to be an increasingly significant predictor for mortality.

Glenohumeral osteoarthritis affects up to 17% of patients with shoulder pain, greatly hindering quality of life and impairing activities of daily living.[15,25] Its prevalence increases with age, with radiographic evidence noted in 32.8% of individuals aged older than 60.[16] The aging population is on the rise, with the proportion of Americans over age 65 expected to increase from 16% to 23% by 2060.[26] As the US population ages and osteoarthritis becomes more prevalent, it is important to optimize the management of individuals who choose to undergo surgical treatment.

Total shoulder arthroplasty (TSA), including both anatomic and reverse TSA, is a common treatment option for patients with severe glenohumeral osteoarthritis.[15] TSA also may be considered to treat patients with massive rotator cuff tears or proximal humerus fractures, although primary osteoarthritis remains the most common indication for TSA.[12,18,39] Specifically, reverse TSA has proven to be particularly beneficial to treat osteoarthritis in the elderly, due to severe bone loss and joint deformation.[2] Overall, joint replacement has shown to significantly decrease pain and improve function of the shoulder joint in patients with a history of osteoarthritis, especially among older individuals.[25]

Increased age is a well-known risk factor for development of osteoarthritis, along with female sex, genetics, past trauma, and obesity.[31] Since arthritis is common in the aging population, the

Institutional review board approval was not required for this study.

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https://doi.org/10.1016/j.jseint.2023.08.025
2666-6383/

safety and efficacy of TSA as a treatment option is valuable to investigate. Prior studies on joint replacement surgery among older patients compared to younger patients have reported increased risk of multiple medical complications, longer hospital stays, readmission, and mortality.[4,9-11,19,21] However, understanding how each increased decade of life affects adverse outcomes has not been explored. Further investigation to stratify postoperative outcomes within older age groups may help to better understand as to which adverse outcomes certain patient groups are at higher risk.

The purpose of this study was to investigate the association between the septuagenarian, octogenarian, and nonagenarian populations and postoperative outcomes following TSA. We hypothesized that increased age will be associated with increased rate of postoperative adverse outcomes.

Methods

The American College of Surgeons National Surgical Quality Improvement Program database was queried for all patients who underwent TSA between 2015 and 2020. The NSQIP database is fully deidentified, therefore rendering this study exempt from approval by our University's institutional review board. Data in the NSQIP database are obtained from over 600 hospitals in the United States and are collected by trained surgical clinical reviewers. The data are periodically audited to maintain high fidelity.

Current Procedural Terminology code 23472 was used to identify patients who underwent TSA, both anatomic and reverse, from 2015 to 2020. Cases for patients younger than 18 years of age or TSA performed for trauma were automatically excluded from the database. Cases were excluded if any of the following variables had missing information: age, height, weight, functional status, discharge destination, American Society of Anesthesiologists (ASA) classification. Cases were also excluded for age <60.

Variables collected in this study included patient demographics, comorbidities, surgical characteristics, preoperative laboratory values, and 30-day postoperative complication data. Patient demographics included age, body mass index (BMI), gender, functional status, ASA classification, and smoking status. Preoperative comorbidities included insulin-dependent and noninsulin dependent diabetes, severe chronic obstructive pulmonary disease (COPD), hypertension requiring medication, bleeding disorders, open wound/wound infection, disseminated cancer, and congestive heart failure (CHF). Surgical characteristics included operative duration in minutes. Preoperative laboratory values included hematocrit to assess for preoperative anemia. Postoperative complications within 30 days included sepsis, septic shock, pneumonia, reintubation, urinary tract infection (UTI), stroke, cardiac arrest, myocardial infarction, blood transfusion, deep vein thrombosis, pulmonary embolism, failure to wean off ventilator, deep incisional surgical-site infection (SSI), superficial incisional SSI, organ/space SSI, wound dehiscence, readmission, reoperation, nonhome discharge, and mortality.

The initial pool of patients was divided into cohorts based on age: sexagenarians (60-69), septuagenarians (70-79), octogenarians (80-89), nonagenarians (90+). Of note, the NSQIP database codes for all patients over the age of 90 as "90+." Therefore, it was possible that the nonagenarian cohort included patients who were older than the nonagenarian range of 90-99. Three sets of analyses were performed, such that sexagenarians, septuagenarians, and octogenarians each served as the reference cohort for patients older than the reference cohort.

A total of 27,050 patients who underwent primary TSA were identified in NSQIP from 2015 to 2020. Cases were excluded as follows: 152 for missing height/weight, 11 for missing discharge destination, 29 for missing ASA classification, 2 for missing readmission status, 227 for missing functional health status prior to surgery, 3736 for age <60. Of the 26,629 patients remaining after exclusion criteria, 9085 (39.7%) patients were included in the sexagenarian cohort, 10,307 (45.0%) in the septuagenarian cohort, 3335 (14.6%) in the octogenarian cohort, and 166 (0.7%) in the nonagenarian cohort.

All statistical analyses were conducted using SPSS Software version 29.0 (IBM Corp., Armonk, NY, USA). Patient demographics and comorbidities were compared between cohorts using bivariate logistic regression. Postoperative complications were also compared between cohorts using bivariate logistic regression.

Multivariate logistic regression, adjusted for all significantly associated patient demographics and comorbidities, was used to identify associations between age and postoperative complications. Odds ratios (OR) were reported with 95% confidence intervals (CI). The level of statistical significance was set at $P < .05$.

Results

Sexagenarians as reference cohort

Compared to sexagenarians, the patient demographics and comorbidities significantly associated with septuagenarians were BMI 18.5-29.9 ($P < .001$), female gender ($P < .001$), dependent functional status ($P < .001$), ASA ≥3 ($P < .001$), nonsmoker status ($P < .001$), hypertension ($P < .001$), COPD ($P = .010$), bleeding disorder ($P < .001$), preoperative anemia ($P < .001$), and operative duration 0-79 minutes ($P < .001$) (Table I). The patient demographics and comorbidities significantly associated with octogenarians were BMI 18.5-29.9 ($P < .001$), female gender ($P < .001$), dependent functional status ($P < .001$), ASA ≥3 ($P < .001$), nonsmoker status ($P < .001$), hypertension ($P < .001$), COPD ($P = .039$), bleeding disorder ($P < .001$), no chronic steroid use ($P = .039$), CHF ($P = .007$), preoperative anemia ($P < .001$), and operative duration 0-79 minutes ($P < .001$). The patient demographics and comorbidities significantly associated with nonagenarians were BMI 18.5-29.9 ($P < .001$), female gender ($P < .001$), dependent functional status ($P < .001$), ASA ≥3 ($P < .001$), non-smoker status ($P < .001$), hypertension ($P < .001$), CHF ($P < .001$), preoperative anemia ($P < .001$), and operative duration 0-79 minutes ($P = .008$).

Bivariate analysis identified postoperative complications significantly associated with each age cohort, with reference to the sexagenarian cohort (Table II). Septuagenarians had significantly higher rates of myocardial infarction ($P = .038$), blood transfusion ($P < .001$), organ/space SSI ($P = .048$), readmission ($P = .005$), and nonhome discharge ($P < .001$). Octogenarians had significantly higher rates of septic shock ($P = .033$), pneumonia ($P = .023$), UTI ($P < .001$), stroke ($P = .050$), blood transfusion ($P < .001$), deep vein thrombosis ($P = .038$), failure to wean off ventilator ($P = .013$), readmission ($P < .001$), nonhome discharge ($P < .001$), and mortality ($P = .016$). Nonagenarians had significantly higher rates of sepsis ($P = .008$), pneumonia ($P < .001$), reintubation ($P < .001$), UTI ($P < .001$), myocardial infarction ($P < .001$), blood transfusion ($P < .001$), pulmonary embolism ($P = .044$), failure to wean off ventilator ($P = .019$), readmission ($P < .001$), nonhome discharge ($P < .001$), and mortality ($P < .001$).

After adjusting for the patient variables significantly associated with each age cohort, multivariate logistic regression identified the complications independently associated with each cohort, with reference to the sexagenarian cohort (Table III). Septuagenarians were independently associated with higher rates of blood transfusion (OR 1.67, 95% CI 1.27-2.19; $P < .001$), readmission (OR 1.24, 95% CI 1.02-1.50; $P = .028$), and non-home discharge (OR 1.82, 95% CI 1.59-2.08; $P < .001$). Octogenarians were independently associated with higher rates of UTI (OR 1.73, 95% CI 1.09-2.76; $P = .021$), blood transfusion (OR 2.13, 95% 1.53-2.97; $P < .001$),

Table I
Patient demographics/comorbidities based on age for patients who underwent total shoulder arthroplasty between 2015 and 2020, with age 60-69 as the reference group.

Characteristic	Age 60-69		Age 70-79			Age 80-89			Age 90+		
	Number	Percent	Number	Percent	*P* value	Number	Percent	*P*-value	Number	Percent	*P* value
Total	9085	100.0	10,307	100.0		3335	100.0		166	100.0	
Body mass index (kg/m^2)					**<.001**			**<.001**			**<.001**
<18.5	66	0.7	69	0.7		33	1.0		6	3.6	
18.5-29.9	3863	42.5	5122	49.7		2100	63.0		126	75.9	
30-34.9	2420	26.6	2781	27.0		810	24.3		24	14.5	
35-39.9	1525	16.8	1397	13.6		256	7.7		6	3.6	
≥40	1201	13.2	921	8.9		130	3.9		4	2.4	
Gender					**<.001**			**<.001**			**<.001**
Female	4810	52.9	6061	58.8		2245	67.3		132	79.5	
Male	4275	47.1	4246	41.2		1090	32.7		34	20.5	
Functional status					**<.001**			**<.001**			**<.001**
Independent	8953	98.5	10,093	97.9		3185	95.5		144	86.7	
Dependent	132	1.5	214	2.1		150	4.5		22	13.3	
ASA classification					**<.001**			**<.001**			**<.001**
1-2	4251	46.8	3954	38.4%		1007	30.2		38	22.9	
≥3	4834	53.2	6353	61.6		2328	69.8		128	77.1	
Smoker					**<.001**			**<.001**			**<.001**
No	7903	87.0	9778	94.9		3248	97.4		164	98.8	
Yes	1182	13.0	529	5.1		87	2.6		2	1.2	
Diabetes mellitus					.090			.056			.120
No diabetes	7396	81.4	8266	80.2		2806	84.1		143	86.1	
Non-insulin dependent	1187	13.1	1459	14.2		400	12.0		15	9.0	
Insulin dependent	502	5.5	582	5.6		129	3.9		8	4.8	
Hypertension					**<.001**			**<.001**			**<.001**
No	3365	37.0	2841	27.6		768	23.0		39	23.5	
Yes	5720	63.0	7466	72.4		2567	77.0		127	76.5	
COPD					**.010**			**.039**			.146
No	8517	93.7	9567	92.8		3092	92.7		151	91.0	
Yes	568	6.3	740	7.2		243	7.3		15	9.0	
Bleeding disorders					**<.001**			**<.001**			.056
No	8900	98.0	10,013	97.1		3197	95.9		159	95.8	
Yes	185	2.0	294	2.9		138	4.1		7	4.2	
Chronic steroid use					.808			**.015**			.425
No	8633	95.0	9802	95.1		3204	96.1		160	96.4	
Yes	452	5.0	505	4.9		131	3.9		6	3.6	
Open wound/wound infection					.525			.197			.056
No	9058	99.7	10,271	99.7		3320	99.6		164	98.8	
Yes	27	0.3	36	0.3		15	0.4		2	1.2	
Disseminated cancer					.907			.697			.998
No	9064	99.8	10,284	99.8		3326	99.7		166	100.0	
Yes	21	0.2	23	0.2		9	0.3		0	0.0	
Congestive heart failure					.087			**.007**			**<.001**
No	9036	99.5	10,231	99.3		3302	99.0		158	95.2	
Yes	49	0.5	76	0.7		33	1.0		8	4.8	
Preoperative anemia					**<.001**			**<.001**			**<.001**
No	6869	75.6	7467	72.4		2184	65.5		94	56.6	
Yes	1147	12.6	1778	17.3		872	26.1		67	40.4	
Operative duration (minutes)					**<.001**			**<.001**			**.008**
0-79	2164	23.8	2841	27.6		1037	31.1		54	32.5	
80-128	4539	50.0	5204	50.5		1657	49.7		83	50.0	
≥129	2382	26.2	2262	21.9		641	19.2		29	17.5	

ASA, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease.
Bold *P* values indicate statistical significance with *P* < .05.

failure to wean off ventilator (OR 7.67, 95% CI 1.70-34.72; *P* = .008), readmission (OR 1.39, 95% CI 1.07-1.81; *P* = .012), and nonhome discharge (OR 5.47, 95% CI 4.67-6.40; *P* < .001). Nonagenarians were independently associated with higher rates of pneumonia (OR 5.05, 95% CI 1.72-14.81; *P* = .003), reintubation (OR 4.53, 95% CI 1.02-20.17; *P* = .048), UTI (OR 3.26, 95% CI 1.12-9.42; *P* = .030), myocardial infarction (OR 6.30, 95% CI 1.59-25.01; *P* = .009), blood transfusion (OR 3.07, 95% CI 1.52-6.18; *P* = .002), nonhome discharge (OR 10.94, 95% CI 7.33-16.32; *P* < .001), and mortality (OR 5.80, 95% CI 1.31-25.59; *P* = .020).

Septuagenarians as reference cohort

Compared to septuagenarians, the patient demographics and comorbidities significantly associated with octogenarians were BMI 18.5-29.9 (*P* < .001), female gender (*P* < .001), dependent functional status (*P* < .001), ASA ≥3 (*P* < .001), nonsmoker status (*P* < .001), no diabetes (*P* < .001), hypertension (*P* < .001), bleeding disorder (*P* < .001), no chronic steroid use (*P* = .021), preoperative anemia (*P* < .001), and operative duration 0-79 minutes (*P* < .001) (Table IV). The patient demographics and comorbidities significantly associated with nonagenarians were BMI 18.5-29.9 (*P* < .001), female gender (*P* < .001), dependent functional status (*P* < .001), ASA ≥3 (*P* < .001), nonsmoker status (*P* = .037), no CHF (*P* < .001), and preoperative anemia (*P* < .001).

Bivariate analysis identified postoperative complications significantly associated with each age cohort, with reference to the septuagenarian cohort (Table V). Octogenarians had significantly higher rates of UTI (*P* < .001), blood transfusion (*P* < .001), readmission (*P* = .002), nonhome discharge (*P* < .001), and mortality

Table II
Bivariate analysis of 30-day postoperative complications based on age group, with age 60-69 as the reference group.

Postoperative complication	Age 60-69		Age 70-79			Age 80-89			Age 90+		
	Number	Percent	Number	Percent	P value	Number	Percent	P-value	Number	Percent	P value
Sepsis	15	0.17	10	0.10	.193	5	0.15	.852	2	1.20	**.008**
Septic shock	1	0.01	7	0.07	.089	4	0.12	**.033**	0	0.00	1.000
Pneumonia	36	0.40	53	0.51	.227	24	0.72	**.023**	5	3.01	**<.001**
Reintubation	13	0.14	14	0.14	.984	10	0.30	.059	2	1.20	**<.001**
Urinary tract infection	51	0.56	71	0.69	.263	44	1.32	**<.001**	5	3.01	**<.001**
Stroke	5	0.06	9	0.09	.408	6	0.18	**.050**	0	0.00	.999
Cardiac arrest	4	0.04	4	0.04	.858	4	0.12	.156	0	0.00	.999
Myocardial infarction	18	0.20	37	0.36	**.038**	8	0.24	.652	4	2.41	**<.001**
Blood transfusions	88	0.97	200	1.94	**<.001**	125	3.75	**<.001**	18	10.84	**<.001**
Deep vein thrombosis	24	0.26	30	0.29	.723	17	0.51	**.038**	0	0.00	.998
Pulmonary embolism	25	0.28	28	0.27	.963	12	0.36	.444	2	1.20	**.044**
Failure to wean off ventilator	4	0.04	12	0.12	.092	7	0.21	**.013**	1	0.60	**.019**
Deep incisional SSI	9	0.10	5	0.05	.200	0	0.00	.999	0	0.00	.999
Superficial incisional SSI	25	0.28	19	0.18	.188	10	0.30	.818	1	0.60	.442
Organ/space SSI	24	0.26	14	0.14	**.048**	4	0.12	.143	0	0.00	.998
Wound dehiscence	6	0.07	3	0.03	.246	2	0.06	.906	0	0.00	.999
Readmission	218	2.40	315	3.06	**.005**	139	4.17	**<.001**	13	7.83	**<.001**
Reoperation	129	1.42	123	1.19	.165	50	1.50	.742	1	0.60	.390
Nonhome discharge	416	4.58	911	8.84	**<.001**	761	22.82	**<.001**	80	48.19	**<.001**
Mortality	9	0.10	12	0.12	.714	10	0.30	**.016**	4	2.41	**<.001**

SSI, surgical site infection.
Bold *P* values indicate statistical significance with *P* < .05.

Table III
Multivariate analysis of 30-day postoperative complications based on age group, adjusted for significantly associated patient demographics/comorbidities, with age 60-69 as the reference group.

Postoperative complication	Age 70-79			Age 80-89			Age 90+		
	OR	95% CI	P value	OR	95% CI	P-value	OR	95% CI	P value
Sepsis	-	-	-	-	-	-	3.95	0.74-21.02	.107
Septic shock	-	-	-	7.84	0.83-73.86	.072	-	-	-
Pneumonia	-	-	-	1.60	0.89-2.90	.118	5.05	1.72-14.81	**.003**
Reintubation	-	-	-	-	-	-	4.53	1.02-20.17	**.048**
Urinary tract infection	-	-	-	1.73	1.09-2.76	**.021**	3.26	1.12-9.42	**.030**
Stroke	-	-	-	1.2	0.33-4.39	.780	-	-	-
Myocardial infarction	1.51	0.83-2.77	.179	-	-	-	6.30	1.59-25.01	**.009**
Blood transfusions	1.67	1.27-2.19	**<.001**	2.13	1.53-2.97	**<.001**	3.07	1.52-6.18	**.002**
Deep vein thrombosis	-	-	-	1.82	0.86-3.86	.12	-	-	-
Pulmonary embolism	-	-	-	-	-	-	3.96	0.73-21.43	.110
Failure to wean off ventilator	-	-	-	7.67	1.70-34.72	**.008**	8.56	0.43-172.07	.161
Organ/space SSI	0.54	0.26-1.13	.101	-	-	-	-	-	-
Readmission	1.24	1.02-1.50	**.028**	1.39	1.07-1.81	**.012**	1.90	0.97-3.74	.063
Non-home discharge	1.82	1.59-2.08	**<.001**	5.47	4.67-6.40	**<.001**	10.94	7.33-16.32	**<.001**
Mortality	-	-	-	1.61	0.58-4.49	.362	5.80	1.31-25.59	**.020**

OR, odds ratio; *CI*, confidence interval; *SSI*, surgical site infection.
Bold *P* values indicate statistical significance with *P* < .05.

(*P* = .027). Nonagenarians had significantly higher rates of sepsis (*P* < .001), pneumonia (*P* < .001), reintubation (*P* < .001), UTI (*P* = .001), myocardial infarction (*P* < .001), blood transfusion (*P* < .001), pulmonary embolism (*P* = .042), readmission (*P* < .001), nonhome discharge (*P* < .001), and mortality (*P* < .001).

After adjusting for the patient variables significantly associated with each age cohort, multivariate logistic regression identified the complications independently associated with each cohort, with reference to the septuagenarian cohort (Table VI). Octogenarians were independently associated with higher rates of UTI (OR 1.73, 95% CI 1.15-2.61; *P* = .009), readmission (OR 1.28, 95% CI 1.03-1.59; *P* = .029), and nonhome discharge (OR 2.81, 95% CI 2.50-3.17; *P* < .001). Nonagenarians were independently associated with higher rates of pneumonia (OR 5.02, 95% CI 1.85-13.63; *P* = .002), reintubation (OR 4.91, 95% CI 1.08-22.28; *P* = .039), UTI (OR 2.94, 95% CI 1.07-8.08; *P* = .037), myocardial infarction (OR 3.83, 95% CI 1.17-12.56; *P* = .027), blood transfusion (OR 1.86, 95% CI 1.03-3.35; *P* = .038), readmission (OR 2.17, 95% CI 1.17-4.01; *P* = .014), nonhome discharge (OR 12.80, 95% CI 1.28-128.40; *P* = .030), and mortality (OR 9.87, 95% CI 2.62-37.16; *P* < .001).

Octogenarians as reference cohort

Compared to octogenarians, the patient demographics and comorbidities significantly associated with nonagenarians were BMI 18.5-29.9 (*P* < .001), female gender (*P* < .001), dependent functional status (*P* < .001), ASA ≥3 (*P* = .046), CHF (*P* < .001), and preoperative anemia (*P* < .001) (Table VII).

Bivariate analysis identified postoperative complications significantly associated with nonagenarians, with reference to the octagenarian cohort (Table VIII). Nonagenarians had significantly higher rates of sepsis (*P* = .013), pneumonia (*P* = .003), reintubation (*P* = .009), myocardial infarction (*P* < .001), blood transfusion (*P* < .001), readmission (*P* = .026), nonhome discharge (*P* < .001), and mortality (*P* < .001).

After adjusting for the patient variables significantly associated with the nonagenarian cohort, multivariate logistic regression identified the complications independently associated with the nonagenarian cohort, with reference to octogenarians (Table IX). Nonagenarians were independently associated with higher rates of sepsis (OR 8.37, 95% CI 1.42-49.29; *P* = .019), pneumonia (OR

Table IV
Patient demographics/comorbidities based on age for patients who underwent total shoulder arthroplasty between 2015 and 2020, with age 70-79 as the reference group.

Characteristic	Age 70-79		Age 80-89			Age 90+		
	Number	Percent	Number	Percent	*P* value	Number	Percent	*P* value
Total	10,307	100.0	3335	100.0		166	100.0	
Body mass index (kg/m^2)					**<.001**			**<.001**
<18.5	69	0.7	33	1.0		6	3.6	
18.5-29.9	5122	49.7	2100	63.0		126	75.9	
30-34.9	2781	27.0	810	24.3		24	14.5	
35-39.9	1397	13.6	256	7.7		6	3.6	
≥40	921	8.9	130	3.9		4	2.4	
Gender					**<.001**			**<.001**
Female	6061	58.8	2245	67.3		132	79.5	
Male	4246	41.2	1090	32.7		34	20.5	
Functional status					**<.001**			**<.001**
Independent	10,093	97.9	3185	95.5		144	86.7	
Dependent	214	2.1	150	4.5		22	13.3	
ASA classification					**<.001**			**<.001**
1-2	3954	38.4	1007	30.2		38	22.9	
≥3	6353	61.6	2328	69.8		128	77.1	
Smoker					**<.001**			**.037**
No	9778	94.9	3248	97.4		164	98.8	
Yes	529	5.1	87	2.6		2	1.2	
Diabetes mellitus					**<.001**			.144
No diabetes	8266	80.2	2806	84.1		143	86.1	
Non-insulin dependent	1459	14.2	400	12.0		15	9.0	
Insulin dependent	582	5.6	129	3.9		8	4.8	
Hypertension					**<.001**			.245
No	2841	27.6	768	23.0		39	23.5	
Yes	7466	72.4	2567	77.0		127	76.5	
COPD					.836			.360
No	9567	92.8	3092	92.7		151	91.0	
Yes	740	7.2	243	7.3		15	9.0	
Bleeding disorders					**<.001**			.300
No	10,013	97.1	3197	95.9		159	95.8	
Yes	294	2.9	138	4.1		7	4.2	
Chronic steroid use					**.021**			.448
No	9802	95.1	3204	96.1		160	96.4	
Yes	505	4.9	131	3.9		6	3.6	
Open wound/wound infection					.410			.088
No	10,271	99.7	3320	99.6		164	98.8	
Yes	36	0.3	15	0.4		2	1.2	
Disseminated cancer					.628			.998
No	10,284	99.8	3326	99.7		166	100.0	
Yes	23	0.2	9	0.3		0	0.0	
Congestive heart failure					.157			**<.001**
No	10,231	99.3	3302	99.0		158	95.2	
Yes	76	0.7	33	1.0		8	4.8	
Preoperative anemia					**<.001**			**<.001**
No	7467	72.4	2184	65.5		94	56.6	
Yes	1778	17.3	872	26.1		67	40.4	
Operative duration (minutes)					**<.001**			.230
0-79	2841	27.6	1037	31.1		54	32.5	
80-128	5204	50.5	1657	49.7		83	50.0	
≥129	2262	21.9	641	19.2		29	17.5	

ASA, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease.
Bold *P* values indicate statistical significance with $P < .05$.

3.92, 95% CI 1.41-10.91; $P = .009$), reintubation (OR 5.48, 95% CI 1.45-20.77; $P = .012$), myocardial infarction (OR 10.24, 95% CI 2.76-38.03; $P < .001$), blood transfusion (OR 1.84, 95% CI 1.04-3.27; $P = .037$), nonhome discharge (OR 2.36, 95% CI 1.68-3.32; $P < .001$), and mortality (OR 4.90, 95% CI 1.38-17.36; $P = .014$).

Discussion

In this study, we used a large national database to investigate the association between an aging population and 30-day postoperative outcomes in patients undergoing TSA between 2015 and 2020. By comparing each decade of life to an increasingly older age group, we were able to analyze the strength of significance between each age group and adverse postoperative outcomes. We identified age to be an increasingly significant predictor for blood transfusions, readmission, and nonhome discharge from age 60 and older. From the septuagenarian cohort, each increasing decade of age was found to be a significant predictor of mortality.

Arthritis is a major cause of disability in the older population due to a multitude of risk factors along with biological changes in joint structure with age.[14] Due to the functional importance of the upper extremity, glenohumeral osteoarthritis threatens the independence of many elderly patients. The degeneration of cartilage in osteoarthritis leads to unequal load distribution within the joint cavity, leading to inflammation, osteophyte formation, subchondral bone changes, and synovial proliferation.[15,25] These structural changes often lead to pain and limit range of motion.[2] TSA for osteoarthritis has successfully provided favorable outcomes, notable pain relief, and improved range of motion.[1,2,12,30] Surgical treatment can therefore drastically improve both physical

Table V
Bivariate analysis of 30-day postoperative complications based on age group, with age 70-79 as the reference group.

Postoperative complication	Age 70-79		Age 80-89			Age 90+		
	Number	Percent	Number	Percent	*P* value	Number	Percent	*P* value
Sepsis	10	0.10	5	0.15	.427	2	1.20	**.001**
Septic shock	7	0.07	4	0.12	.364	0	0.00	.999
Pneumonia	53	0.51	24	0.72	.171	5	3.01	**<.001**
Reintubation	14	0.14	10	0.30	.054	2	1.20	**<.001**
Urinary tract infection	71	0.69	44	1.32	**<.001**	5	3.01	**.001**
Stroke	9	0.09	6	0.18	.170	0	0.00	.999
Cardiac arrest	4	0.04	4	0.12	.110	0	0.00	.999
Myocardial infarction	37	0.36	8	0.24	.300	4	2.41	**<.001**
Blood transfusions	200	1.94	125	3.75	**<.001**	18	10.84	**<.001**
Deep vein thrombosis	30	0.29	17	0.51	.064	0	0.00	.998
Pulmonary embolism	28	0.27	12	0.36	.415	2	1.20	**.042**
Failure to wean off ventilator	12	0.12	7	0.21	.215	1	0.60	.114
Deep incisional SSI	5	0.05	0	0.00	.999	0	0.00	.999
Superficial incisional SSI	19	0.18	10	0.30	.213	1	0.60	.248
Organ/space SSI	14	0.14	4	0.12	.826	0	0.00	.999
Wound dehiscence	3	0.03	2	0.06	.428	0	0.00	.999
Readmission	315	3.06	139	4.17	**.002**	13	7.83	**<.001**
Reoperation	123	1.19	50	1.50	.171	1	0.60	.494
Non-home discharge	911	8.84	761	22.82	**<.001**	80	48.19	**<.001**
Mortality	12	0.12	10	0.30	**.027**	4	2.41	**<.001**

SSI, surgical site infection.
Bold *P* values indicate statistical significance with $P < .05$.

Table VI
Multivariate analysis of 30-day postoperative complications based on age group, adjusted for significantly associated patient demographics/comorbidities, with age 70-79 as the reference group.

Postoperative complication	Age 80-89			Age 90+		
	OR	95 CI	*P* value	OR	95% CI	*P* value
Sepsis	-	-	-	6.82	0.94-49.29	.057
Pneumonia	-	-	-	5.02	1.85-13.63	**.002**
Reintubation	-	-	-	4.91	1.08-22.28	**.039**
Urinary tract infection	1.73	1.15-2.61	**.009**	2.94	1.07-8.08	**.037**
Myocardial infarction	-	-	-	3.83	1.17-12.56	**.027**
Blood transfusions	1.22	0.95-1.57	.115	1.86	1.03-3.35	**.038**
Pulmonary embolism	-	-	-	4.16	0.89-19.39	.069
Readmission	1.28	1.03-1.59	**.029**	2.17	1.17-4.01	**.014**
Reoperation	-	-	-	-	-	-
Non-home discharge	2.81	2.50-3.17	**<.001**	12.80	1.28-128.40	**.030**
Mortality	2.40	0.97-5.89	.057	9.87	2.62-37.16	**<.001**

OR, odds ratio; *CI*, confidence interval.
Bold *P*-values indicate statistical significance with $P < .05$.

and emotional well-being.[15,23] A study by Cho et al reported improved psychological status in patients following TSA for the treatment of osteoarthritis.[7]

As the US population ages, a larger number of older individuals are seeking orthopedic surgery. However, the literature has consistently shown that older individuals are at higher risk of postoperative medical complications, including deep vein thrombosis, UTI, acute renal failure, and pneumonia.[35] Therefore, as a greater number of older individuals undergo TSA, it is important to understand potential adverse outcomes of these different age groups.

Our results align with those of previous studies in orthopedic literature, including studies on total hip and total knee arthroplasty (THA and TKA, respectively). For example, prolonged length of stay, non-home discharge, and postoperative mortality have been more commonly reported among elderly patient cohorts following total joint arthroplasty.[9,28,29] Furthermore, both octogenarian and nonagenarian patients have been found to be at increased postoperative risk of transfusions following TKA and THA compared to younger patients.[10,28] Multiple orthopedic studies have also reported associations between increased age and unplanned readmission.[4,6,13,28,32,40] Additionally, a study by Bovonratwet et al found that both older age and bleeding disorders increased risk of readmission following THA.[4,6] On the other hand, when compared to younger cohorts, older patients have been reported to be at decreased risk for dislocation, perioperative fracture, implant related complications, and surgical site infections.[35,38]

In our study, we identified the older-aged cohorts to be increasingly significant predictors of blood transfusions following TSA. Prior studies on shoulder arthroplasty have found female sex, low preoperative hemoglobin, and traumatic surgical indication to be significant predictors for postoperative transfusion.[33] These findings are consistent with clinical practice, as women are more likely to be anemic and their lower baseline hemoglobin may increase the need for transfusion. Similar to our results, a study on revision TSA cases also found older age to be a risk factor for postoperative transfusion.[1]

As one ages, the likelihood of developing anemia increases due to a number of different etiologies including anemia of chronic disease, chronic kidney disease, and iron deficiency anemia.[3,22,34] Anemia has been reported in 10% of individuals over age 65 and in over 50% of those over age 80.[3] The increasing incidence of anemia in older populations may increase the likelihood of low

Table VII
Patient demographics/comorbidities based on age for patients who underwent total shoulder arthroplasty between 2015 and 2020, with age 80-89 as the reference group.

Characteristic	Age 80-89		Age 90+		
	Number	Percent	Number	Percent	*P* value
Total	3335	100.0	166	100.0	
Body mass index (kg/m^2)					**<.001**
<18.5	33	1.0	6	3.6	
18.5-29.9	2100	63.0	126	75.9	
30-34.9	810	24.3	24	14.5	
35-39.9	256	7.7	6	3.6	
≥40	130	3.9	4	2.4	
Gender					**<.001**
Female	2245	67.3	132	79.5	
Male	1090	32.7	34	20.5	
Functional status					**<.001**
Independent	3185	95.5	144	86.7	
Dependent	150	4.5	22	13.3	
ASA classification					**.046**
1-2	1007	30.2	38	22.9	
≥3	2328	69.8	128	77.1	
Smoker					.274
No	3248	97.4	164	98.8	
Yes	87	2.6	2	1.2	
Diabetes mellitus					.785
No diabetes	2806	84.1	143	86.1	
Non-insulin dependent	400	12.0	15	9.0	
Insulin dependent	129	3.9	8	4.8	
Hypertension					.889
No	768	23.0	39	23.5	
Yes	2567	77.0	127	76.5	
COPD					.401
No	3092	92.7	151	91.0	
Yes	243	7.3	15	9.0	
Bleeding disorders					.960
No	3197	95.9	159	95.8	
Yes	138	4.1	7	4.2	
Chronic steroid use					.839
No	3204	96.1	160	96.4	
Yes	131	3.9	6	3.6	
Open wound/wound infection					.190
No	3320	99.6	164	98.8	
Yes	15	0.4	2	1.2	
Disseminated cancer					.999
No	3326	99.7	166	100.0	
Yes	9	0.3	0	0.0	
Congestive heart failure					**<.001**
No	3302	99.0	158	95.2	
Yes	33	1.0	8	4.8	
Preoperative anemia					**<.001**
No	2184	65.5	94	56.6	
Yes	872	26.1	67	40.4	
Operative duration (min)					.835
0-79	1037	31.1	54	32.5	
80-128	1657	49.7	83	50.0	
≥129	641	19.2	29	17.5	

ASA, American Society of Anesthesiologists; *COPD*, chronic obstructive pulmonary disease.
Bold *P* values indicate statistical significance with $P < .05$.

Table VIII
Bivariate analysis of 30-day postoperative complications based on age group, with age 80-89 as the reference group.

Postoperative complication	Age 80-89		Age 90+		
	Number	Percent	Number	Percent	*P* value
Sepsis	5	0.15	2	1.20	**.013**
Septic shock	4	0.12	0	0.00	.999
Pneumonia	24	0.72	5	3.01	**.003**
Reintubation	10	0.30	2	1.20	**.009**
Urinary tract infection	44	1.32	5	3.01	.078
Stroke	6	0.18	0	0.00	.999
Cardiac arrest	4	0.12	0	0.00	.999
Myocardial infarction	8	0.24	4	2.41	**<.001**
Blood transfusions	125	3.75	18	10.84	**<.001**
Deep vein thrombosis	17	0.51	0	0.00	.999
Pulmonary embolism	12	0.36	2	1.20	.113
Failure to wean off ventilator	7	0.21	1	0.60	.324
Deep incisional SSI	0	0.00	0	0.00	-
Superficial incisional SSI	10	0.30	1	0.60	.505
Organ/space SSI	4	0.12	0	0.00	.999
Wound dehiscence	2	0.06	0	0.00	.999
Readmission	139	4.17	13	7.83	**.026**
Reoperation	50	1.50	1	0.60	.363
Non-home discharge	761	22.82	80	48.19	**<.001**
Mortality	10	0.30	4	2.41	**<.001**

SSI, surgical site infection.
Bold *P* values indicate statistical significance with $P < .05$.

Table IX
Multivariate analysis of 30-day postoperative complications based on age group, adjusted for significantly associated patient demographics/comorbidities, with age 80-89 as the reference group.

Postoperative complication	Age 90+		
	OR	95% CI	*P* value
Sepsis	8.37	1.42-49.29	**.019**
Pneumonia	3.92	1.41-10.91	**.009**
Reintubation	5.48	1.45-20.77	**.012**
Myocardial infarction	10.24	2.76-38.03	**<.001**
Blood transfusions	1.84	1.04-3.27	**.037**
Readmission	1.64	0.89-3.05	.115
Nonhome discharge	2.36	1.68-3.32	**<.001**
Mortality	4.90	1.38-17.36	**.014**

OR, odds ratio; *CI*, confidence interval.
Bold *P* values indicate statistical significance with $P < .05$.

preoperative hemoglobin and thus increase the probability of needing a postoperative transfusion. Additionally, preoperative anemia has been reported to be a risk factor for postoperative complications and mortality following TJA.[36] Therefore, preoperative evaluation and management of anemia in older populations may help to mitigate adverse outcomes.

We also identified increasingly significant rates of readmission as our patient cohorts aged. Although readmission rates following TSA are overall low, they have been reported to be as high as 5.5% among the elderly patient population.[17] Interestingly, prior research on THA and TKA have reported a majority of readmissions due to falls, which may be less likely following upper extremity surgery. Consistent with our results, other studies have reported increased age as an independent risk factor for readmission following TSA, with medical causes accounting for up to 50% of readmissions.[24,37,38] A study on primary TSA found that old age leads to higher rates of readmission, most commonly due to pneumonia, dislocation, pulmonary embolism, and surgical site infections.[8] Similarly, a study by White et al found older age was more likely to be associated with readmission, as well as multiple medical complications such as pulmonary embolism, infection, and respiratory complications.[38]

Across all age groups, we found increasing age to be a significant predictor of nonhome discharge. This is in line with prior research, as a study on octogenarian outcomes following TSA found increased risk of non-home discharge compared to nonoctogenarian patients.[5] Nonhome discharge following TSA may negatively impact postoperative outcomes and increase the likelihood of readmission, which raises important considerations for postoperative management of medically complex patients.[20] From age 70, our study also identified age to be a significant predictor of mortality. Although overall mortality and complication rates are low, patients older than age 80 have been reported to have higher rates of early mortality following TSA.[35] This again could be related to the medical complexity that often goes along with aging patients. However, a study by McCormick et al suggests that the mortality rate following TSA is still lower than that of THA and TKA.[27]

Our study is limited to the data that can be analyzed through the American College of Surgeons National Surgical Quality Improvement Program database. This database is limited to a 30-day postoperative outcomes period, and therefore is unable to identify complications that occur outside of this 30-day window. Potential long-term postoperative complications, such as implant failure or revision surgery, are unable to be accounted for. Additionally, operative factors such as hospital location and surgeon skill level were unable to be identified. Despite these limitations, we used a large national database to better understand the impact of our aging population on postoperative outcomes following TSA. Furthermore, this study allowed us to identify transfusion, nonhome discharge, readmission, and mortality to be increasingly statistically significant outcomes as a patient ages. Future research needs to be done to further understand which comorbidities are associated with adverse outcomes in the older population to better preoperatively manage these patients.

Conclusion

From age 60, each decade of age was identified to be an increasingly significant predictor for blood transfusion, readmission, and nonhome discharge following TSA. From age 70, each decade of age was additionally identified to be an increasingly significant predictor for mortality. Increasing age was consistently an independent predictor for non-home discharge. As the patient population continues to age, understanding the complications associated with increasing age may help to improve outcomes.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate families, and any research foundation 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.

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