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Defining the younger patient: age as a predictive factor for outcomes in shoulder arthroplasty

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Background: The purpose of this study was to define an age cutoff at which clinical outcomes and revision rates differ for patients undergoing primary anatomic total shoulder arthroplasty (TSA) and patients undergoing primary reverse shoulder arthroplasty (RSA).
Methods: This retrospective cohort study included 1250 primary shoulder arthroplasties (1131 patients) with minimum 2-year clinical follow-up (mean, 50 months [range, 24-146 months]). TSA (n = 518; mean age, 68.1 years [range, 28-90 years]) was performed for osteoarthritis in most cases (99%), whereas the primary diagnoses for RSA (n = 732; mean age, 70.8 years [range, 22-91 years]) included rotator cuff arthropathy (35%), massive cuff tear without osteoarthritis (29.8%), and osteoarthritis (20.5%). Outcomes included range of motion, the American Shoulder and Elbow Surgeons (ASES) score, and the revision rate. The relationship between age at the time of surgery in 5-year increments (46-50 years, 51-55 years, and so on) and the revision rate was examined to identify the age cutoff; this was then used to assess clinical outcomes.
Results: In patients younger than 65 years, TSA was associated with a 3.4-fold increased risk of revision ($P = .01$). RSA performed in patients younger than 60 years was associated with a 4.8-fold increased risk of revision ($P < .001$). TSA patients aged 65 years or older and RSA patients aged 60 years or older had better total ASES scores (82 vs. 77 [$P = .03$] and 72 vs. 62 [$P = .002$], respectively) and better internal rotation (interquartile range, TSA 5-6 vs. 4-5 [$P = .002$] and RSA 4-5 vs 3-4 [$P = .04$])—where 6 represents T4 to T6 and 4 represents T11 to L1—than their younger counterparts.
Conclusion: Age at index arthroplasty affects outcomes and the risk of revision. Primary TSA patients younger than 65 years and RSA patients younger than 60 years have a significantly increased revision risk. These age cutoffs are also correlated with differences in ASES scores and internal rotation.
Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords: Younger patient; age dependent; shoulder arthroplasty; shoulder arthritis; clinical outcome; functional outcome

Several studies have demonstrated an increased incidence of shoulder arthroplasty in recent years within the United States.[1,9,15] With America's growing elderly population, shoulder arthroplasty in the United States will likely meet or exceed the reported projections. Part of this

This retrospective study was determined to be exempt from review by the Western Institutional Review Board.

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encountered increase is attributed to the expanding indications for multiple shoulder pathologies including fracture, osteoarthritis (OA), cuff tear arthropathy, and massive cuff tear (MCT) without arthritis.[8,20,25] With these expanding indications and improved results, shoulder arthroplasty has been performed in increasingly younger patients over the past several years.[15] Recently, Padegimas et al[15] has shown that the demand for shoulder arthroplasty is projected to substantially increase by 2030 in the younger patient (aged ≤ 55 years).

The definition of the "young" patient in shoulder arthroplasty has varied throughout the literature, with some studies describing age cutoffs of less than 65 years, less than 60 years, and more recently, less than 55 years.[7,10,14,18,21,24] Many of these studies had small sample sizes, presented inherent selection bias, or had a limited clinical or functional rationale for choosing those age cutoffs. Saltzman et al[18] demonstrated that shoulder arthroplasty patients younger than 50 years are more likely to have more severe and complex disease than their older counterparts. Theoretically, younger patients have higher demands with more severe disease and are likely to place more mechanical stress along the implant, leading to higher failure and revision rates and worse functional improvement than older populations. Furthermore, the potential impact on the revision burden has been largely unaddressed.

We therefore hypothesized that age would be an independent risk factor for outcomes in shoulder arthroplasty affecting both outcomes and the revision rate. The primary goal of this study was to define an age cutoff at which revision rates and clinical outcomes differ for patients undergoing primary anatomic total shoulder arthroplasty (TSA) and patients undergoing primary reverse shoulder arthroplasty (RSA).

Methods

We retrospectively reviewed the records of 2335 shoulders treated with shoulder arthroplasty between January 2004 and December 2017 at our institution. These cases were performed by 1 fellowship-trained shoulder and elbow surgeon (M.A.F.). The surgical procedures were performed through the standard deltopectoral approach with mobilization of the cephalic vein medially with the pectoralis major when possible. The primary implants used for RSA were the RSP (n = 419), RSP Monoblock (n = 250), and AltiVate Reverse (n = 63) from DJO Surgical (Austin, TX, USA). The primary implants for TSA were the Foundation Shoulder System (n = 144) and Turon (n = 374) from DJO Surgical. The variation in implant type occurred as new iterations of implants were introduced to the market through extensive research and development. The implants are listed from the earliest to latest version.

Prospectively collected clinical data including the American Shoulder and Elbow Surgeons (ASES) score, diagnosis, arthroplasty type (TSA or RSA), and range of motion (ROM) in 4 planes were retrospectively reviewed for all patients included in this study. The inclusion criteria consisted of patients who had a minimum of 2 years' follow-up and corresponding preoperative functional outcome scores. Functional outcome scores were recorded using a standardized patient questionnaire. ROM was recorded using a standardized patient questionnaire in combination with clinical assessment by the senior author. All patients who underwent a subsequent revision were included in the calculation of the revision rates (including those who underwent revision in <2 years).

Outcomes included the revision rate, ROM, ASES score, and change in the ASES score. The minimal clinically important difference (MCID) was set at a change in the ASES score of greater than 20 points based on previously published data.[23] We examined the relationship between age at the time of surgery in 5-year increments (46-50 years, 51-55 years, 56-60 years, and so on) and the revision rate. The age increment at which the revision rate decreased and remained lower was identified and investigated as a cutoff. This cutoff was then used to further assess whether there was also a relationship between age and ROM, as well as the ASES score, among patients who did not undergo a revision.

Statistical analyses

Descriptive statistics are reported as frequencies and percentages for categorical variables and as means and 95% confidence intervals (CIs) or standard deviations for continuous variables. Univariate analyses were performed with *t* tests for continuous variables and the Fisher exact test for categorical variables. Logistic regression was used to estimate the odds of revision associated with the identified age cutoffs. $P < .05$ was considered statistically significant. All analyses were performed with STATA software (version 15.1; StataCorp, College Station, TX, USA).

Results

A total of 2335 shoulder arthroplasties were performed at our institution over the study interval. Because of the diagnosis type (fracture or failed arthroplasty), inadequate clinical or radiographic data, and/or inadequate follow-up (<2 years), 1085 shoulder arthroplasties were excluded. A total of 1250 shoulders (238 bilateral) in 1131 patients met the inclusion criteria (TSA in 518 shoulders and RSA in 732 shoulders; Table I). The average age overall was 70 years (95% CI, 69-70 years), and 48.8% of arthroplasties were performed in male patients. The youngest patient in our cohort (aged 22 years) underwent RSA after sequelae of failed instability procedures with glenoid bone loss and humeral chondrolysis progressing to end-stage disease. The most common preoperative diagnoses were OA (53%), rotator cuff arthropathy (20.6%), and MCT without OA (17.4%). The remaining diagnoses (infection, inflammatory mechanism, instability, and MCT with OA) all occurred in fewer than 5% of patients. Significant variation in diagnoses was found between the 2 surgical groups, with 99% of TSA patients having OA whereas diagnoses in RSA

Table I Patient characteristics by arthroplasty type (N = 1250)

	Anatomic total shoulder arthroplasty (n = 518)	Reverse shoulder arthroplasty (n = 732)
Age, mean (SD), yr	68 (9)	71 (9)
Male sex, n (%)	297 (57.3)	313 (42.8)
Operative side: right, n (%)	268 (51.7)	462 (63.1)
Implant type, n (%)		
Foundation	144 (27.8)	—
Turon	374 (72.2)	—
AltiVate	—	63 (8.6)
RSP	—	419 (57.2)
RSP Monoblock	—	250 (34.1)
Diagnosis, n (%)		
Infection	0	10 (1.4)
Inflammatory mechanism	2 (0.4)	26 (3.5)
Instability	0	16 (2.2)
MCT with OA	1 (0.2)	56 (7.6)
MCT without OA	0	218 (29.8)
OA	513 (99.0)	150 (20.5)
RCA	2 (0.4)	256 (35.0)

SD, standard deviation; *MCT*, massive cuff tear; *OA*, osteoarthritis; *RCA*, rotator cuff arthropathy.

patients were mostly distributed between MCT without OA (29.8%), OA (20.5%), and rotator cuff arthropathy (35%). The mean follow-up period was 50 months (range, 24-146 months). Although the data regarding sex were unpaired, no statistical difference in sex was found between TSA and RSA patients in our cohort (Table I).

The percentage of shoulders that reached the MCID in the ASES score is illustrated for the RSA and TSA groups in Figure 1. The MCID was achieved in 81% and 71% of patients undergoing TSA and RSA, respectively.

Age at time of primary TSA and revision rate

The revision rate for TSA was 3.5% (18 of 518 shoulders). The average time to revision was 54 months (95% CI, 39-69 months). The reasons for revision in the TSA group included glenoid component loosening (n = 6), rotator cuff failure (n = 5), instability (n = 2), painful shoulder (n = 2), subscapularis insufficiency (n = 1), infection (n = 1), and periprosthetic fracture (n = 1). When we examined age as a continuous variable, we found that patients who went on to have a revision were significantly younger at the time of surgery than patients who did not have a revision (average age, 63 years vs. 68 years; $P = .02$) over the length of the study. When we examined the revision rate across age categories (Fig. 2), we discovered a larger increase in risk for patients who were younger than 65 years at the time of surgery (6.9% in those aged < 65 years vs. 2.1% in those aged ≥ 65 years, $P = .01$). This finding corresponds to an odds ratio of 3.4 (95% CI, 1.31-8.74) for the odds of revision among patients younger than 65 years at the time of their primary arthroplasty.

Clinical outcomes of TSA associated with age

TSA performed in patients aged 65 years or older yielded slightly higher preoperative ASES scores (37 [95% CI, 35-39] vs. 34 [95% CI, 31-37]), but this difference did not achieve statistical significance ($P = .09$; Table II). Among the 500 TSA patients who did not have a revision, we examined whether this same age cutoff was also associated with other outcomes. We found that patients who were aged 65 years or older at the time of surgery had significantly higher total ASES scores ($P = .03$), as well as significantly better internal rotation at the time of final follow-up ($P = .02$; Table III). The group aged 65 years or older also achieved better ROM across all planes of motion, but these differences failed to reach statistical significance.

Age at time of primary RSA and revision rate

The revision rate for RSA was 4.9% (36 of 732 shoulders). The average time to revision was 35 months (95% CI, 24-48 months). The indications for revision in the RSA group included instability (n = 11), infection (n = 10), humeral stem loosening (n = 5), painful implant (n = 4), baseplate failure (n = 2), periprosthetic fracture (n = 2), glenosphere dissociation (n = 1), and humeral socket dissociation (n = 1). Similarly to the TSA group, RSA patients who went on to have a revision were significantly younger at the time of primary arthroplasty than patients who did not have a revision (average age, 66 years vs. 71 years; $P = .001$). When we examined the RSA revision rate across age categories (Fig. 2), we found an increased risk in patients who were younger than 60 years at the time of surgery (12.3% vs. 2.9%, $P < .001$). This finding corresponds to an odds ratio of 4.64 (95% CI, 2.35-9.17) for

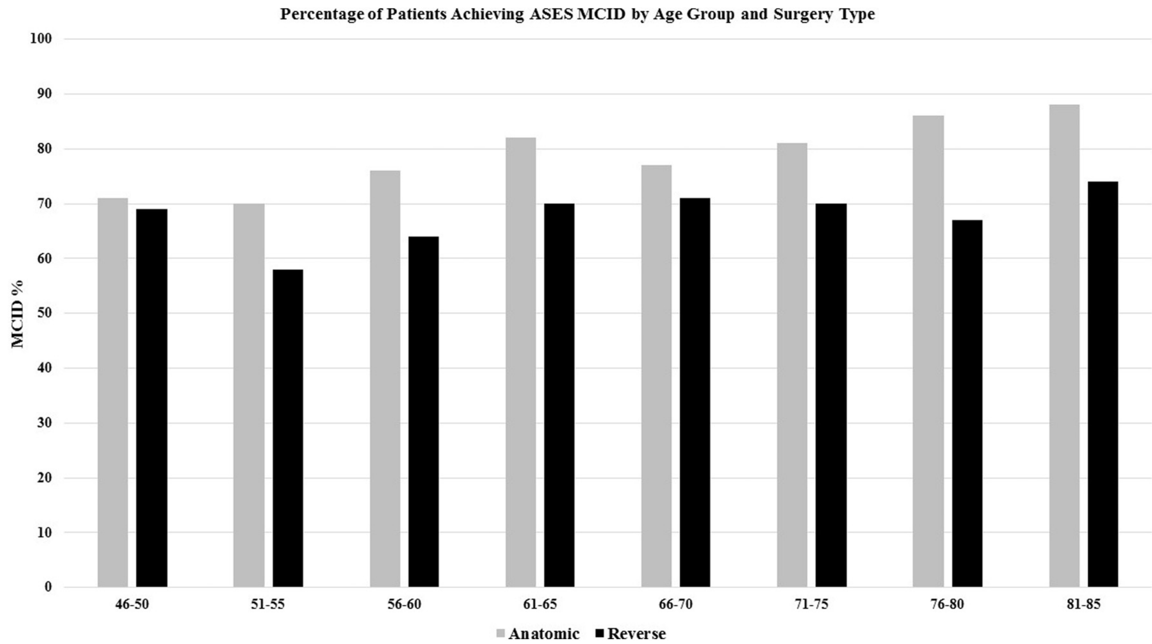

Figure 1 Percentage of patients achieving minimal clinically important difference *(MCID)* in American Shoulder and Elbow Surgeons *(ASES)* score by age group for anatomic total shoulder arthroplasty and reverse shoulder arthroplasty.

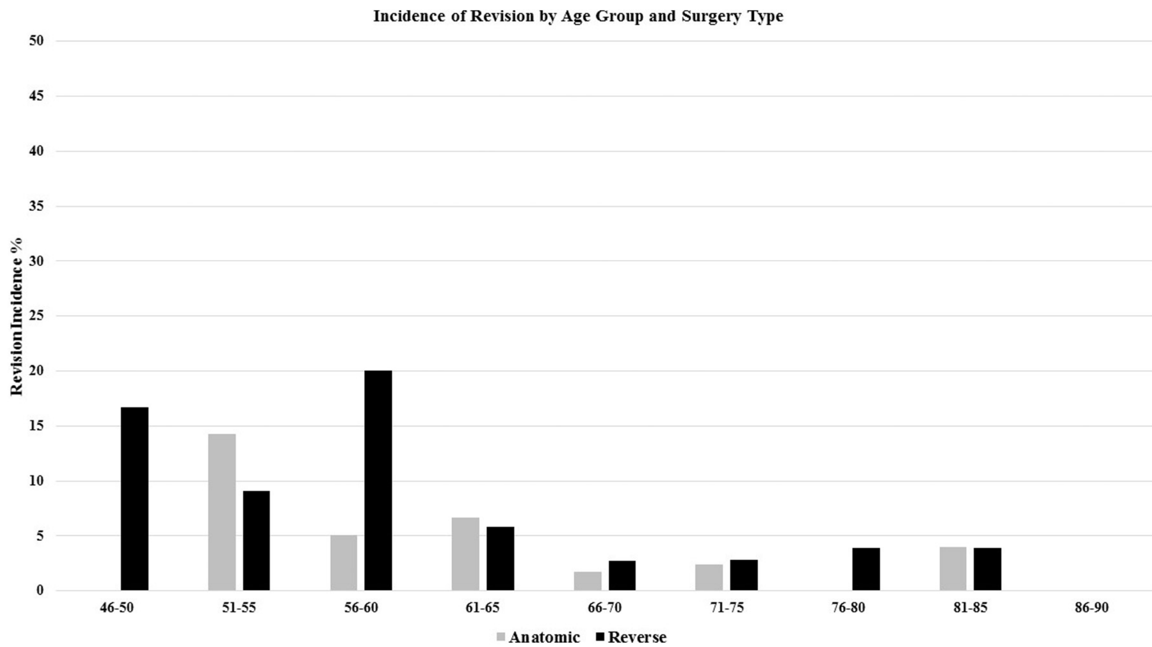

Figure 2 Incidence of revision by age category for anatomic total shoulder arthroplasty and reverse shoulder arthroplasty.

the odds of revision among patients younger than 60 years at the time of surgery.

Clinical outcomes of RSA associated with age

Among the 713 shoulders that underwent RSA, patients aged 60 years or older had significantly higher preoperative ASES scores (36 [95% CI, 35-38] vs. 30 [95% CI, 26-34], $P = .01$; Table IV). Among the 696 RSA patients who did not have a revision, we found that patients aged 60 years or older at the time of their primary arthroplasty had significantly better total ASES scores 95 CI (72 [95% CI, 70-73] vs. 62 [95% CI, 55-68], $P = .002$), as well as better internal rotation at the time of final follow-up ($P = .04$; Table V).

Table II Anatomic total shoulder arthroplasty preoperative scores overall and by age category (n = 514)

	Overall	<65 yr (n = 142)	≥65 yr (n = 372)	*P* value
Total ASES score	37 (35-38)	34 (31-37)	37 (35-39)	.09
Forward flexion, °	96 (93-100)	97 (90-104)	96 (92-100)	.80
Abduction, °	84 (81-87)	83 (77-89)	85 (80-89)	.67
External rotation, °	35 (32-38)	33 (26-39)	36 (33-40)	.34
Internal rotation*	3 (3-3)	3 (2-3)	3 (3-3)	.13

ASES, American Shoulder and Elbow Surgeons.
Data are presented as mean (95% confidence interval).
* Internal rotation is reported as a numerical value from 0 to 8 for the highest point the patient is able to reach behind the back: ipsilateral hip (0), ipsilateral back pocket (1), contralateral back pocket (2), S1 or L5 (3), T11 to L1 (4), T7 to T10 (5), T4 to T6 (6), T2 to T3 (7) and C8 to T1 (8).

Table III Clinical outcomes of anatomic total shoulder arthroplasty by age among patients who did not undergo revision (n = 500)

	<65 yr (n = 135)	≥65 yr (n = 365)	*P* value
Total ASES score	77 (73-81)	82 (79-84)	.03
Forward flexion, °	152 (146-159)	155 (151-159)	.49
Abduction, °	139 (132-147)	147 (143-151)	.07
External rotation, °	55 (50-61)	62 (58-66)	.08
Internal rotation*	5 (4-5)	5 (5-6)	.02

ASES, American Shoulder and Elbow Surgeons.
Data are presented as mean (95% confidence interval).
* Internal rotation is reported as a numerical value from 0 to 8 for the highest point the patient is able to reach behind the back: ipsilateral hip (0), ipsilateral back pocket (1), contralateral back pocket (2), S1 or L5 (3), T11 to L1 (4), T7 to T10 (5), T4 to T6 (6), T2 to T3 (7) and C8 to T1 (8).

Table IV Reverse shoulder arthroplasty preoperative scores overall and by age category (n = 713)

	Overall	<60 yr (n = 62)	≥60 yr (n = 651)	*P* value
Total ASES score	36 (34-37)	30 (26-34)	36 (35-38)	.01
Forward flexion, °	74 (71-77)	71 (60-82)	74 (71-78)	.56
Abduction, °	68 (65-71)	64 (53-75)	69 (65-72)	.40
External rotation, °	30 (27-33)	25 (16-34)	30 (27-34)	.29
Internal rotation*	3 (3-3)	3 (2-4)	3 (3-3)	.72

ASES, American Shoulder and Elbow Surgeons.
Data are presented as mean (95% confidence interval).
* Internal rotation is reported as a numerical value from 0 to 8 for the highest point the patient is able to reach behind the back: ipsilateral hip (0), ipsilateral back pocket (1), contralateral back pocket (2), S1 or L5 (3), T11 to L1 (4), T7 to T10 (5), T4 to T6 (6), T2 to T3 (7) and C8 to T1 (8).

After we controlled for diagnosis, these differences remained (Table VI). In addition, the group aged 60 years or older achieved better ROM in the 3 other planes; however, these differences failed to reach statistical significance.

Discussion

Age-related outcomes in shoulder arthroplasty have not yet been clearly defined. Previous reported literature left a paucity in determining the rationale for reported outcomes in a particular age group. Studies arbitrarily used age margins of less than 50 years, 55 years, 60 years, or 65 years to compare patient outcomes in shoulder arthroplasty.[2-4,6,12-14,16,17,19,21,22] The most obvious concern in selecting a critical age cutoff anecdotally would be that in doing so, the study may miss a relationship between age and outcomes, as well as between age and risk of revision.

We predicted that age and outcomes would be correlated in primary shoulder arthroplasty. We examined age in association with achieving a 20-point increase in the ASES score at 2-year follow-up. We found no significant effect of age and the ability to achieve the MCID. When examining revision risk as an endpoint and its correlation to age, we identified age 65 years as a cutoff for TSA and age 60 years

Table V Clinical outcomes of reverse shoulder arthroplasty by age among patients who did not undergo revision (n = 696)

	Overall	<60 yr (n = 58)	≥60 yr (n = 638)	*P* value
Total ASES score	70 (68-72)	62 (55-68)	72 (70-73)	.002
Forward flexion, °	139 (135-142)	131 (117-144)	141 (137-144)	.12
Abduction, °	129 (125-132)	122 (108-136)	130 (127-134)	.23
External rotation, °	50 (47-53)	42 (30-53)	51 (47-54)	.13
Internal rotation*	4 (4-5)	4 (3-4)	4 (4-5)	.04

ASES, American Shoulder and Elbow Surgeons.
Data are presented as mean (95% confidence interval).
* Internal rotation is reported as a numerical value from 0 to 8 for the highest point the patient is able to reach behind the back: ipsilateral hip (0), ipsilateral back pocket (1), contralateral back pocket (2), S1 or L5 (3), T11 to L1 (4), T7 to T10 (5), T4 to T6 (6), T2 to T3 (7) and C8 to T1 (8).

Table VI Diagnoses broken down by age cutoffs for RSA and TSA

Diagnosis	RSA		TSA	
	<60 yr (n = 58)	≥60 yr (n = 638)	<65 yr (n = 135)	≥65 yr (n = 365)
Infection	0	7 (1.1)	0	0
Inflammatory mechanism	8 (13.8)	15 (2.3)	0	1 (0.3)
Instability	3 (5.2)	11 (1.7)	0	0
MCT with OA	4 (6.9)	50 (7.8)	1 (0.7)	0
MCT without OA	15 (25.9)	195 (30.6)	0	0
OA	13 (22.4)	130 (20.4)	134 (99.3)	362 (99.2)
RCA	15 (25.9)	230 (36.0)	0	2 (0.5)

RSA, reverse shoulder arthroplasty; *TSA*, total shoulder arthroplasty; *MCT*, massive cuff tear; *OA*, osteoarthritis; *RCA*, rotator cuff arthropathy.
Data are presented as number (percentage).

as a cutoff for RSA. When the clinical outcomes were examined based on these categories, patients showed clear differences in both patient-reported outcome scores (ASES scores) and internal rotation. Our clinical results are similar to those in previously reported literature but showed overall lower revision rates.

For example, in a retrospective review of 1135 patients undergoing TSA, Patel et al[16] reported that postoperative abduction and internal rotation were greater in patients older than 55 years than in those aged 55 years or younger. In addition, their younger cohort had lower patient satisfaction. In our study, TSA patients aged 65 years or older had better postoperative total ASES scores, with 81% achievement of the MCID. Roberson et al,[17] in a systematic review, found that TSA in patients younger than 65 years performed well in terms of improving ROM, decreasing pain, and improving patient outcomes but had a high revision rate of 17.4%. Gauci et al[7] reported similar results when examining 69 shoulders in 67 patients with primary OA, finding high revision rates of 22% for cemented glenoid components vs. 70% for metal-backed implants, with type B2 glenoids having the highest risk of failure. In contrast, our overall revision rate for TSA was 3.5%, but the risk of revision essentially doubled (6.9%) in patients younger than 65 years.

In a large series of patients undergoing shoulder arthroplasty, including hemiarthroplasty and humeral head resurfacing, Dillon et al[2] reported that the risk of revision was 2 times higher (95% CI, 1.2-3.5; $P = .007$) in those aged 59 years or younger than in older patients, with a higher relative risk in hemiarthroplasty and RSA. Major causes of revision included glenoid arthritis, infection, and instability. Ernstbrunner et al,[4] in a long-term follow-up study of patients younger than 60 years, found an overall revision rate of 17%. Similarly, Otto et al[14] reported a revision rate of 12.5% in a small cohort younger than 55 years. At 5 to 15 years' follow-up in a small series of patients younger than 65 years with a diagnosis of irreparable rotator cuff tear, Ek et al[3] presented a revision rate of 25%. In our study, the overall revision rate for RSA was 4.9%, but the risk of revision more than tripled (15.9%) in patients younger than 60 years.

Studies have shown that when compared with older cohorts, younger patients with RSA have better clinical results.[13,19] Sershon et al[22] showed that ASES scores improved from 31.4 to 65.8 in 36 patients younger than 60 years undergoing RSA, with 9 clinical failures and a 14% revision rate at 4 years' follow-up. In a retrospective multicenter cohort of 82 patients, Leathers et al[10] found no difference in ASES scores but higher forward flexion, abduction, and external rotation in patients aged 65 years or younger vs. an older cohort. Friedman et al[5] reported that age at the time of surgery was associated with differences in clinical outcome scores after RSA; when they controlled for sex, a 1-year increase in age was associated with improvement in ASES and Shoulder Pain and Disability Index metric scores but a decrease in ROM as measured by active abduction and active forward flexion. Matthews et al,[12] in a series of 43 patients, showed lower functional outcome scores preoperatively and postoperatively for patients undergoing RSA at age 65 years or younger vs. those aged 70 years or older, with a mean follow-up period of 4.0 years. Similarly, in our study, patients aged 60 years or older at the time of their primary arthroplasty had significantly better postoperative total ASES scores (72 vs. 62, $P = .002$), as well as better internal rotation at the time of final follow-up ($P = .04$). In addition, patients in the RSA group who were younger than 60 years had significantly lower preoperative total ASES scores than the older cohort. Similarly to a previous study that showed that preoperative motion is a predictor of postoperative motion,[11] our study suggests that higher preoperative ASES scores may predict higher postoperative ASES scores.

Outcomes based on age and survivorship can be related to 2 factors: (1) a more severe presenting diagnosis and (2) high functional demand in younger patients. Saltzman et al[18] reported that younger patients undergoing shoulder arthroplasty irrespective of the type presented with more complex and severe disease. Similarly, in our patients undergoing RSA, an age of 60 years or older yielded significantly higher preoperative ASES scores (36 [95% CI, 35-38] vs. 30 [95% CI, 26-34], $P = .01$), and in our patients undergoing TSA, an age of 65 years or older yielded slightly higher preoperative ASES scores (37 [95% CI, 35-39] vs. 34 [95% CI, 31-37], $P = .09$), suggesting more severe clinical problems in younger patients.

There are several strengths to this study. This was a large, retrospective, single-institution study with a reproducible methodology for predicting which patient ages can affect surgical outcomes. The senior author has several years of experience, which reduces the probability that experience and technique may have affected outcomes. This study, however, has a few limitations. It was retrospective in nature and thus liable to recall bias, although the outcome measures were generated from a prospectively captured database.

RSA and TSA performed in this study were shown overall to improve patient-perceived outcomes and functional ROM. Patients aged 65 years or older in the TSA group and those aged 60 years or older in the RSA group had greater preoperative ASES scores and better ROM. Although we have identified cutoffs based on revision as an outcome and functional outcome scores, these cutoffs should not be viewed as an absolute indication or factor for considering a patient as a surgical candidate. However, our study provides evidence that age can impact outcome and revision risk.

Conclusion

Our study found that despite varying pathology, patients in whom a shoulder arthroplasty was indicated and who were treated with either RSA or TSA were able to achieve clinical improvement in ASES shoulder scores regardless of age. However, age younger than 60 years in patients undergoing RSA and age younger than 65 years in patients undergoing TSA were associated with an increased revision risk. Undergoing these procedures when patients were older than these age cutoffs was associated with better total ASES scores and internal rotation. Although these findings may have come closer to associating age and outcome in arthroplasty when performed in standard fashion, this information is not meant to deny a patient's access to care based on age. Rather, this information should help provide a significantly stronger discussion between the patient and surgeon regarding expectations and potential outcomes.

Disclaimer

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