# Results of total shoulder arthroplasty in patients aged 55 years or younger versus those older than 55 years: an analysis of 1135 patients with over 2 years of follow-up

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**Background:** The results of anatomic total shoulder arthroplasty (TSA) in younger patients have not been clearly elucidated. The purpose of this study was to compare early outcomes after TSA in patients aged 55 years or younger versus patients older than 55 years.

**Methods:** A total of 1135 patients who were treated with TSA for glenohumeral arthritis and had a mean follow-up period of over 4 years were retrospectively reviewed. Etiologies included osteoarthritis (n = 1044), osteonecrosis (n = 35), inflammatory arthritis (n = 34), and post-traumatic arthritis (n = 22). Validated outcome measures, range of motion, and patient satisfaction were recorded. Preoperative and postoperative metrics were compared, and a multivariate analysis was performed to isolate age from sex, body mass index, previous surgery, and diagnosis as independent factors.

**Results:** Female patients, patients with a history of surgery, and patients with a diagnosis of osteonecrosis were more likely to undergo TSA when aged 55 years or younger. Both age groups showed similar preoperative range of motion and showed no differences in recorded outcome scores. Postoperatively, patients older than 55 years had slightly greater active abduction (P = .004) and internal rotation (P = .030). A higher percentage of patients older than 55 years rated their outcome as better or much better compared with those aged 55 years or younger (P = .003).

**Conclusions:** Female sex, a history of surgery, and a diagnosis of osteonecrosis were associated with undergoing TSA when aged 55 years or younger. Despite similar preoperative function and minor differences in postoperative range of motion and outcome scores, patients aged 55 years or younger reported lower overall satisfaction with their TSA.

Glenohumeral arthritis has become increasingly prevalent with the aging population.[13,21] For patients with degenerative shoulder arthritis and an intact rotator cuff, an anatomic total shoulder arthroplasty (TSA) has been shown to provide significant pain relief with consistent, reproducible results.[2,4,11,19,20,28] Demand for TSA is anticipated to rise by 333% in patients aged 55 years or younger and by almost 755% in individuals older than 55 years by the year 2030.[21] As the procedure becomes more common, efforts have been directed at optimizing postoperative outcomes. For the elderly patient with glenohumeral arthritis, studies have shown that TSA can reliably decrease pain and improve function.[2,11,28] However, as the procedure becomes more frequently used in younger patients, there has been variability in the reported results.

Prior studies have investigated outcomes after TSA based on age group.[5,9,15,18,26] These studies encompassed a broad range of patients, examining individuals younger than 50 years to subjects older than 90 years.[1,2,5,9,12,14,16,23,24,26,28] Significant interest remains in outcomes after TSA for the younger patient. Higher activity levels and greater functional demand in younger patients may predispose these individuals to a greater risk of early revision and worse outcomes.[12] Matsen et al[18] performed a large-scale analysis of patients who underwent any form of shoulder arthroplasty, and they cited younger age as a risk factor for early revision; however, this study was not limited to TSA. On the other hand, Garcia et al[8] reported a high satisfaction rate and no revisions at 61 months in 59 patients ranging in age from 25-55 years undergoing TSA. These studies demonstrate the discrepancy in the literature on reported results of TSA in younger populations. In addition, although some studies have evaluated age-based outcomes in TSA at immediate follow-up, the data do not capture longer follow-up.

The purpose of this study was to compare early outcomes after TSA in patients aged 55 years or younger versus patients older than 55 years. Our hypothesis was that in patients undergoing TSA, those aged 55 years or younger would show equivalent improvements in early range of motion and outcome scores to those older than 55 years.

## Materials and methods

We performed a retrospective review of multicenter data from all patients undergoing primary TSA performed by 16 fellowship-trained shoulder surgeons from April 2006 to May 2015. The inclusion criteria consisted of patients undergoing primary anatomic TSA with a minimum of 2 years' follow-up and documented preoperative and postoperative functional scores. Patients were excluded if they had less than 2 years of documented follow-up and/or had incomplete preoperative functional scores or postoperative outcome scores. Ultimately, all patients were indicated for total shoulder replacement for glenohumeral joint degeneration for which all other treatment options had failed. All surgeons used the Equinoxe Total Shoulder System (Exactech, Gainesville, FL, USA) through a standard deltopectoral approach and technique.

Patients were selected to undergo TSA based on the surgeon's discretion, and the indications for surgery were recorded, along with demographic information (Table I). Preoperative evaluation involved the collection of various outcome scores including the American Shoulder and Elbow Surgeons (ASES) score; Constant score; Simple Shoulder Test (SST) score; University of California, Los Angeles (UCLA) score; and Shoulder Pain and Disability Index (SPADI) score. Visual analog scale (VAS) pain scores were recorded, along with functional range of motion in 4 planes of motion (forward elevation, abduction, external rotation, and internal rotation). Patients were also asked to report their overall level of satisfaction at final follow-up, as well as a self-reported shoulder functional rating (from 1 to 10, in which 10 indicates best function) that was recorded preoperatively and postoperatively. All variables were subsequently collected postoperatively at a minimum of 2 years' follow-up. Demographic traits and surgical variables, such as implant component size, were also recorded.

Active forward elevation, abduction, and external rotation were measured by rotational angle in degrees and recorded as a continuous measure. Internal rotation was scored based on the most proximal vertebral level that could be reached by the patient's thumb. The ASES score (11 questions) and Constant score (23 questions) both include evaluations of pain and range of motion and are scaled on an interval from 0-100. The UCLA score (5 questions) evaluates forward flexion, pain, and subjective function, for a maximum score of 35. The SPADI score (13 questions) rates the level of disability and pain associated with the shoulder, with higher scores reflecting greater disability. Finally, the VAS score assessed patients' pain on a continuum from 0-10, with 10 being the worst level of pain.

## Statistical analysis

All continuous data are described as means with ranges or standard deviations as appropriate, whereas all categorical data are described as counts and column percentages. Spearmen correlation coefficients were used when comparing patients aged 55 years or younger with those older than 55 years both preoperatively and postoperatively. The absolute improvement in outcome scores and range of motion was compared between the 2 groups using an analysis of covariance adjusting for possible confounding factors. The $\chi^2$ test was performed to look at overall satisfaction rates between the 2 age groups. A multivariate analysis examined age, sex, and previous surgery as independent risk factors for postoperative outcomes. All analyses were performed using SAS software

**Table I** Demographic characteristics

| | Aged ≤ 55 yr (n = 118) | Aged > 55 yr (n = 1017) | P value |
|---|---|---|---|
| Average age, yr | 50.0 ± 6 | 68.5 | .001 |
| Body mass index | 30.7 ± 6.8 | 29.7 ± 6.2 | .146 |
| % female (n) | 69.8% (81) | 44.5% (452) | .001 |
| Previous surgery, % yes (n) | 32.2% (38) | 11.3% (115) | .001 |
| Diagnosis (n) | | | |
|   Osteoarthritis | 82.2% (97) | 93.1% (947) | .001 |
|   Osteonecrosis | 11.9% (14) | 2.1% (21) | .001 |
|   Inflammatory arthritis | 4.2% (5) | 2.9% (29) | .403 |
|   Post-traumatic arthritis | 1.7% (2) | 2.0% (20) | >.999 |
| Presence of comorbidities (n) | 42.4% (50) | 28.7% (292) | .002 |
| Comorbidity (n) | | | |
|   Inflammatory disease | 4.2% (5) | 9.5% (97) | .057 |
|   Hypertension | 27.1% (32) | 41.2% (419) | .003 |
|   Heart disease | 4.2% (5) | 10.9% (111) | .023 |
|   Diabetes mellitus | 8.5% (10) | 9.5% (97) | .708 |
| Tobacco use (n) | 11.9% (14) | 4.4% (45) | .001 |
| Shoulder injections, % yes (n) | 46.6% (55) | 38.3% (389) | .078 |
| Only steroid injection (n) | 92.7% (51) | 90.8% (353) | .631 |
| Only nonsteroidal injection (n) | 16.7% (9) | 10.2% (38) | .157 |

(version 9.4; SAS Institute, Cary, NC, USA), and statistical significance was set at $P < .05$.

## Results

A total of 1135 patients (118 aged ≤ 55 years and 1017 aged > 55 years) were included in the study. The average age in the younger cohort was 50.2 years (range, 31-55 years) compared with an average age of 68.5 years (range, 56-91 years) in the older group ($P < .001$). Patients in the cohort aged 55 years or younger had an average body mass index of $30.7 ± 6.8$ compared with a body mass index of $29.7 ± 6.2$ in the older cohort ($P = .146$). Preoperative diagnoses included osteoarthritis (n = 1044), osteonecrosis (n = 35), inflammatory arthritis (n = 34), and post-traumatic arthritis (n = 22). The mean follow-up period was $4.2 ± 2.3$ years for patients aged 55 years or younger and $4.3 ± 2.4$ years for individuals older than 55 years. Notable demographic differences between the cohorts are listed in Table I. A sizeable portion of patients underwent previous surgery on their operative shoulders. The prevalence of previous surgery was higher in younger individuals: 32.3% versus 11.4% ($P = .001$). Most subjects in both cohorts underwent arthroscopic débridement, although arthroscopic rotator cuff repair was also common in both age groups (Table II). The duration from previous surgery to TSA was unknown as some patients had their previous surgical procedures performed by a different surgeon. An analysis of demographic factors showed that female sex, previous surgery, and a diagnosis of osteonecrosis were significantly associated with a TSA when aged 55 years or younger.

    No clinically significant differences were found in preoperative functional scores, forward flexion, final mean abduction, or internal rotation; however, external rotation was 12° and 17° ($P = .028$) in the younger and older patients, respectively. Postoperatively, both groups showed significant improvements in all outcome scores and range of motion. Final mean abduction was greater in older patients (125° vs 116°, $P = .004$). The internal rotation score was also slightly greater in older patients (5.2 vs 4.9, $P = .030$). No difference was found in postoperative forward flexion and external rotation. These trends continued regarding overall improvement from preoperative values. Older patients showed greater gains in active

**Table II** Previous surgical procedures

| Surgery | Aged ≤ 55 yr (n = 38) | Aged > 55 yr (n = 115) |
|---|---|---|
| Arthroscopic RCR | 8 | 16 |
| Arthroscopic stabilization | 4 | 3 |
| Arthroscopic débridement and/or SAD | 6 | 33 |
| Open RCR | 1 | 6 |
| Open stabilization | 1 | 5 |
| ORIF | 3 | 6 |
| Unknown | | |
|   Scope* | 12 | 29 |
|   Open† | 1 | 2 |
|   Surgery‡ | 2 | 15 |

*RCR*, rotator cuff repair; *SAD*, subacromial decompression; *ORIF*, open reduction–internal fixation of fracture.

  * The patient underwent some form of arthroscopic surgery, but no documentation of what was performed was available.

  † The patient underwent an open surgical procedure, but no documentation of what was performed was available.

  ‡ The patient underwent shoulder surgery but did not recall any details.

**Table III** Preoperative and postoperative range of motion

| Range of motion | AA, ° | FF, ° | ER, ° | IR score |
|---|---|---|---|---|
| Preoperative | | | | |
| Aged ≤ 55 yr | 81 ± 25 | 98 ± 28 | 12 ± 18 | 3.1 ± 1.7 |
| Aged > 55 yr | 82 ± 29 | 98 ± 32 | 18 ± 21 | 3.0 ± 1.5 |
| P value | .946 | .790 | .028 | .804 |
| Postoperative | | | | |
| Aged ≤ 55 yr | 116 ± 31 | 145 ± 25 | 46 ± 22 | 4.9 ± 1.5 |
| Aged > 55 yr | 125 ± 34 | 143 ± 31 | 50 ± 20 | 5.2 ± 1.4 |
| P value | .004 | .734 | .055 | .030 |

*AA,* active abduction; *FF,* forward flexion; *ER,* external rotation; *IR,* internal rotation.
The IR score is based on the most proximal vertebra.

**Table IV** Range-of-motion improvements

| | AA, ° | FF, ° | ER, ° | IR score |
|---|---|---|---|---|
| Aged ≤ 55 yr | 31 ± 36 | 46.7 ± 32 | 34 ± 24 | 1.7 ± 1.8 |
| Aged > 55 yr | 42 ± 41 | 46 ± 40 | 33 ± 23 | 2.2 ± 1.8 |
| P value | .022 | .878 | .742 | .025 |

*AA,* active abduction; *FF,* forward flexion; *ER,* external rotation; *IR,* internal rotation.
The IR score is based on the most proximal vertebra.

abduction from preoperative values: 42° versus 31° (*P* = .022). Similarly, better improvement was noted in internal rotation scores for older patients: 2.2 points greater versus 1.7 points greater (*P* = .025) (Tables III and IV).

When we evaluated postoperative outcome scores between the 2 age groups, older patients performed statistically better on selected outcome measures. Notably, the postoperative VAS pain score was lower: 1.3 versus 1.9 (*P* = .001). Similarly, postoperative ASES, UCLA, and SPADI scores were higher in older individuals: 84.0 versus 79.2 (*P* = .008), 30.4 versus 29.2 (*P* = .053), and 18.0 versus 28.0 (*P* = .007), respectively (Table V). When comparing absolute changes in improvement, we found no differences in VAS, SST, Constant, ASES, UCLA, and SPADI scores (Table VI).

In addition to the aforementioned outcome scores, subjective reporting of overall satisfaction was examined. A satisfaction score of "better" or "much better" was reported in 90% of older patients versus 87% of subjects in the younger cohort (*P* = .003). Despite the different satisfaction rates, shoulder function was found to be similar. When the 2 age groups were asked to self-rate their level of global shoulder function on a scale of 1-10 (10 being the best possible function), the difference in mean postoperative shoulder function ratings between the older and younger patients was not statistically significant, at 8.3 versus 7.9 (*P* = .051).

Univariate analysis showed significance for differences in active abduction and pain, ASES, and SPADI scores. After we performed multivariate analysis (adjusting for female sex, body mass index, previous surgery, and diagnosis), higher postoperative pain scores and lower abduction remained significant in younger individuals (Table VII).

Complications were documented, and patients who required revision surgery were identified. A total of 77 subjects sustained a complication. In the younger cohort, 5.1% sustained a complication compared with 7% in the older group (*P* = .438). Within the younger cohort, the complications included bursitis, stiffness, aseptic loosening, and an unrelated fall. Among older patients, complications were similar but

**Table V** Preoperative functional scores and postoperative outcome scores

| | VAS pain score | SF rating | SST score | Constant score | ASES score | UCLA score | SPADI score |
|---|---|---|---|---|---|---|---|
| Preoperative functional score | | | | | | | |
| Aged ≤ 55 yr | 6.1 ± 1.7 | 4.0 ± 1.6 | 3.8 ± 2.7 | 37.3 ± 12.3 | 33.8 ± 12.5 | 14.2 ± 3.6 | 85.6 ± 20.2 |
| Aged > 55 yr | 6.3 ± 2.2 | 4.0 ± 1.9 | 4.0 ± 3.0 | 38.3 ± 13.8 | 36.3 ± 16.4 | 14.2 ± 4.0 | 82.2 ± 23.5 |
| P value | .282 | .766 | .747 | .766 | .245 | .778 | .524 |
| Postoperative outcome score | | | | | | | |
| Aged ≤ 55 yr | 1.9 ± 2.3 | 7.9 ± 2.3 | 10.2 ± 2.7 | 69.0 ± 16.4 | 79.2 ± 20.8 | 29.2 ± 6.3 | 28.0 ± 25.8 |
| Aged > 55 yr | 1.3 ± 2.2 | 8.3 ± 2.1 | 10.4 ± 2.5 | 70.5 ± 15.3 | 84.0 ± 20.2 | 30.4 ± 5.8 | 18 ± 24.3 |
| P value | .001 | .051 | .313 | .277 | .008 | .053 | .007 |

*VAS,* visual analog scale; *SF,* shoulder function; *SST,* Simple Shoulder Test; *ASES,* American Shoulder and Elbow Surgeons; *UCLA,* University of California, Los Angeles; *SPADI,* Shoulder Pain and Disability Index.

**Table VI** Outcome score improvements

| | VAS pain score | SF rating | SST score | Constant score | ASES score | UCLA score | SPADI score |
|---|---|---|---|---|---|---|---|
| Aged ≤ 55 yr | −4.7 ± 2.9 | 4.3 ± 2.7 | 6.2 ± 3.3 | 33.3 ± 15.0 | 46.0 ± 23.1 | 15.6 ± 6.2 | −58.6 ± 30.0 |
| Aged > 55 yr | −5.1 ± 2.9 | 4.5 ± 2.6 | 6.6 ± 3.3 | 33.1 ± 16.7 | 48.3 ± 23.0 | 16.7 ± 6.3 | −64.5 ± 30.0 |
| P value | .463 | .875 | .418 | .970 | .449 | .250 | .142 |

*VAS,* visual analog scale; *SF,* shoulder function; *SST,* Simple Shoulder Test; *ASES,* American Shoulder and Elbow Surgeons; *UCLA,* University of California, Los Angeles; *SPADI,* Shoulder Pain and Disability Index.

**Table VII**   Multivariate analysis

| Variable | P value | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | Preoperative | | Postoperative | | Improvement | |
| | Univariate | Multivariate | Univariate | Multivariate | Univariate | Multivariate |
| AA | .357 | .201 | .009* | .045* | .110 | .316 |
| FF | .638 | .819 | .738 | .429 | .485 | .457 |
| IR score | .943 | .699 | .162 | .688 | .197 | .333 |
| ER | .012* | .011* | .053 | .189 | .598 | .379 |
| VAS pain score | .207 | .280 | .004* | .030* | .364 | .564 |
| SF rating | .701 | .756 | .059 | .132 | .891 | .834 |
| SST score | .395 | .477 | .235 | .313 | .580 | .708 |
| Constant score | .351 | .453 | .564 | .630 | .698 | .667 |
| ASES score | .137 | .190 | .015* | .069 | .570 | .870 |
| UCLA score | .502 | .560 | .143 | .283 | .461 | .589 |
| SPADI score | .198 | .286 | .012* | .051 | .243 | .223 |

*AA*, active abduction; *FF*, forward flexion; *IR*, internal rotation; *ER*, external rotation; *VAS*, visual analog scale; *SF*, shoulder function; *SST*, Simple Shoulder Test; *ASES*, American Shoulder and Elbow Surgeons; *UCLA*, University of California, Los Angeles; *SPADI*, Shoulder Pain and Disability Index.

  * Differences between the age groups for the variables in the left column were statistically significant with $P < .05$ and are indicated for both univariate analysis and multivariate analysis after adjustment for female sex, body mass index, previous surgery, and diagnosis.

**Table VIII**   Cause of revision

| Cause of revision | Aged ≤ 55 yr | Aged > 55 yr |
| --- | --- | --- |
| Aseptic loosening | 2 | 16 |
| Rotator cuff tear | 0 | 9 |
| Instability | 0 | 4 |
| Infection | 0 | 5 |
| Residual osteophytes or bursitis | 0 | 1 |

also included nerve palsy, instability, infection, and fracture. A total of 37 revisions were performed between both groups. The average time to revision surgery was similar for both age groups (60 months vs 58.7 months, $P = .887$). Older patients had a relatively higher incidence of revision surgery compared with younger patients (49.3% vs 33.3%, $P = .003$). The cause of revision is highlighted in Table VIII.

## Discussion

As the incidence of TSA continues to increase, it is important to determine how age correlates with outcomes. Our study found that younger patients have equivalent objective endpoints to their older peers but do not appreciate the same level of satisfaction and subjective outcomes in certain categories.

Among our sample of patients who underwent TSA, individuals aged 55 years or younger were more likely to be women, to have undergone previous surgery on their affected shoulder, and to have a diagnosis of osteonecrosis. There has been conflicting evidence in the literature regarding sex predominance in young patients who undergo TSA.[5,8,22,26] Yu et al[30] examined the impact of race and sex on the utilization of TSA in a sample of over 10,000 patients and found that, over a 20-year period, TSA use increased by 417% in white men versus 420% in white women. Kim et al[13] reported

that the rate of shoulder arthroplasty has continued to rise at higher rates for women, with an incidence of 13 procedures per 100,000 persons compared with 11 per 100,000 in men. Although previous studies found small differences in sex in younger patients undergoing TSA, the exact nature of the differences has not been defined. The greater number of female subjects in our younger cohort is likely due to the multifactorial nature of indications for surgery and the variable rates of TSA between sexes. The finding of higher rates of previous surgery and a diagnosis of osteonecrosis in younger patients in our study demonstrates a possible cause of earlier degeneration of the glenohumeral joint requiring surgical intervention. Werthel et al[29] reported on 4577 patients who underwent primary shoulder arthroplasty (TSA, hemiarthroplasty, or reverse TSA) and reported that patients with previous surgery were younger (aged 61 years vs 67 years). In a large sample of all types of shoulder arthroplasty, Dillon et al[5] found a higher rate of osteonecrosis in their younger population, with an incidence of 10.9% in patients aged 59 years or younger compared with 1.2% in subjects aged 60 years or older. Recently, Mahony et al[17] examined 411 anatomic TSA procedures and found that patients with prior surgery reported a greater risk (odds ratio, 3.34) of failing to achieve a minimal clinically important difference (MCID) if they had undergone previous surgery. These studies illustrate the higher incidence of previous surgical procedures and osteonecrosis in young patients undergoing TSA. The history of surgery performed on the affected shoulder may affect postsurgical outcomes.

With respect to baseline objective measurements, our investigation found no clinically significant differences in preoperative range of motion or outcome scores compared with older patients. After surgery, both groups showed statistically similar net improvements in range of motion and validated outcome scores, although the older cohort

reported better postoperative VAS pain scores and had greater active abduction. All patients achieved improvements in outcome scores that exceeded the MCID as outlined by Simovitch et al.[25] It is interesting that Tashjian et al[27] found that the MCID is not uniform across age groups and that younger patients have higher threshold values for the MCID in select outcome scores. It is worth noting that among the outcome scores used, younger patients did worse on outcome scores (ASES, SPADI, VAS, and satisfaction) that incorporate a greater proportion (>50% of items) of questions that relate to a subjective experience (pain, perceived difficulty with tasks, or satisfaction). Contrastingly, no difference was seen in metrics that emphasized items that objectively measure shoulder function such as range-of-motion values, as well as SST and Constant scores. Moreover, it is important to appreciate that no difference was found between the 2 cohorts when we reported their global shoulder function postoperatively. Although subjects aged 55 years or younger may have greater demands for their shoulder, their preoperative and postoperative self-reported shoulder function was no different from that of their older peers. These findings offer some insight into the significance of age-dependent perceptions in the postoperative period that may not necessarily mirror objective findings.

Previous studies have not yet identified whether age affects the degree of functional improvement after TSA. Our study found no statistical difference between age cohorts in net improvement of range of motion after TSA. Levy et al[15] investigated predictive factors of range of motion in 230 patients undergoing TSA. They were unable to identify age as a predictor of range of motion; however, they concluded that preoperative range of motion was the best predictor of postoperative motion. The improvement in motion by both groups in our study is comparable with the existing literature, with an improvement of 47° in forward flexion in patients aged 55 years or younger and 46° in patients older than 55 years. Foruria et al[7] and Churchill[2] showed, on average, a 50° increase in forward flexion from preoperative baseline measurements in patients over 80 years and 90 years undergoing TSA, respectively. Denard et al[3] reported that, from their preoperative measurements, patients younger than 55 years showed, on average, a 35° increase in forward flexion after TSA. These studies show a significant improvement in range of motion in all age groups after TSA with no discernible differences between younger and older patients.

In an effort to capture the subjective satisfaction and global shoulder function achieved after TSA, patients were asked to rate their postoperative satisfaction, as well as their preoperative and postoperative global shoulder function, on a 10-point scale. Our study found that fewer younger patients reported satisfaction ratings of better or much better and that younger patients had lower overall postoperative global shoulder function ratings. Similar studies examining satisfaction levels by age group concluded that younger patients have overall greater expectations after TSA.[10] These findings reinforce the concern that younger patients may

not be as happy with their shoulder replacement as older subjects. Differences in the postoperative goals between age groups may account for the variable satisfaction rates. Older patients may focus on activities of daily living, whereas younger patients may be hoping to restore a much more active lifestyle.

Finally, concerns remain regarding a possible higher complication rate in younger patients. Our study found no differences in complication rates between the 2 age groups, with a 5.1% complication rate in younger patients versus a 7% complication rate in older patients. Farng et al[6] examined over 15,000 patients undergoing shoulder arthroplasty (TSA and hemiarthroplasty) to determine postoperative complications. Their study reported an overall 90-day complication rate of 4.8%. In their study, they found that the short-term complication rate was related to higher Charlson Comorbidity Index scores and not age. Furthermore, they were able to demonstrate increased implant longevity in older patients. Griffin et al[9] evaluated a nationwide sample of 58,790 patients undergoing TSA and hemiarthroplasty. Their study found that patients older than 80 years tended to have longer hospital stays and an increase in postoperative anemia. Unlike the previous studies that evaluated multiple shoulder surgical procedures at short-term follow-up, our study was limited to patients undergoing TSA. Although our study noted no significant difference in short-term complication rates between the 2 groups, we did find a greater incidence of revision surgery in the older group. In a series of 24 service members, Kusnezov et al[14] examined outcomes in young, high-demand military patients who underwent TSA; they found the average time to revision for atraumatic glenoid loosening was 40 months (range, 20-54 months). In a series of 59 young, active subjects (average age, 49 years) who had returned to sport, Garcia et al[8] reported no revisions at 61 months. In another series of 52 subjects who underwent TSA, Denard et al[3] reported a 5-year survivorship rate of 98% in individuals aged 55 years or younger. Although our younger cohort included 2 patients who required revision for aseptic loosening, it is possible that additional subjects with mechanical failure were not captured with our average of 4 years' follow-up. We continue to observe these patients in our registry to potentially capture these differences in the future. Young patients may impart greater demands on their implants; however, factors other than age and activity level, such as bone and tissue quality, may play a role in early revisions after TSA due to mechanical failure. Factors inherent to elderly patients may predispose patients to early revision surgery, such as increased susceptibility to infection or poor bone and tissue quality.

This study's limitations include its retrospective design and asymmetric cohort sizes. In addition, certain information is subject to recall bias. For instance, the exact nature of a previous surgical procedure may confound our findings. However, with large sample sizes, we hoped to minimize the effect of those variables. Although there is an imbalance in patient cohort sizes and sex representation, the subjects were

collected from multiple centers to minimize the effect of selection bias when performing a statistical comparison. In addition, it is expected that larger numbers of patients undergo TSA owing to the higher prevalence of osteoarthritis in the elderly population. However, with trends showing an increasing incidence of TSA in the younger population, it is important to understand differences based on age. The multicenter, retrospective design introduces the possibility of operator bias, patient selection bias, and performance bias based on nonstandardized rehabilitation protocols. Longer follow-up is likely needed to accurately compare late complications between the 2 age groups. The strengths of the study include a large patient sample size with follow-up exceeding 4 years and the use of several validated outcome measures to determine age differences in patients undergoing TSA.

## Conclusion

Our study found that female sex, a history of surgery, and a diagnosis of osteonecrosis were associated with undergoing TSA when aged 55 years or younger. Despite similar preoperative function and minor differences in postoperative range of motion and outcome scores, patients aged 55 years or younger reported lower overall satisfaction with their TSA.

## Disclaimer

Stephanie Muh receives personal fees from Exactech unrelated to and outside the subject of this work.

Thomas W. Wright receives personal fees from Exactech unrelated to and outside the subject of this work.

Pierre-Henri Flurin receives personal fees from Exactech unrelated to and outside the subject of this work.

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