



## Six-Item Modified Frailty Index independently predicts complications following total shoulder arthroplasty



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**Background:** In the realm of orthopedic surgery, frailty has been associated with higher rates of complications following total hip and total knee arthroplasties. Among various measures of frailty, the Six-Item Modified Frailty Index (MF-6) has recently gained popularity as a predictor for postoperative complications. The purpose of this study was to investigate MF-6 as a predictor for early postoperative complications in the elderly patient population following total shoulder arthroplasty (TSA).

**Methods:** The authors queried the American College of Surgeons National Surgical Quality Improvement Program database for all patients who underwent TSA between 2015 and 2020. Patient demographics and comorbidities were compared between cohorts using bivariate logistic regression analysis. Multivariate logistic regression, adjusted for all significantly associated patient demographics and comorbidities, was used to identify associations between the MF-6 score and postoperative complications.

**Results:** Of total, 9228 patients were included in this study: 8764 (95.0%) had MF-6 <3, and 464 (5.0%) patients had MF-6 ≥3. Multivariate analysis found MF-6 ≥3 to be independently associated with higher rates of urinary tract infection (odds ratio [OR]: 2.79, 95% confidence interval [CI]: 1.49-5.23;  $P = .001$ ), blood transfusion (OR: 1.53, 95% CI: 1.01-2.32;  $P = .045$ ), readmission (OR: 1.58, 95% CI: 1.06-2.35;  $P = .024$ ), and non-home discharge (OR: 2.60, 95% CI: 2.08-3.25;  $P < .001$ ).

**Conclusion:** A high MF-6 score (≥3) in patients aged 65 and older is independently associated with higher rates of urinary tract infection, blood transfusion, readmission, and non-home discharge following TSA. The MF-6 score can be easily calculated preoperatively and may allow for better preoperative risk stratification.

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Total shoulder arthroplasty (TSA) has proven to be an effective surgical treatment for various degenerative diseases of the glenohumeral joint.<sup>9</sup> Anatomic TSA has been found to provide favorable outcomes for patients with osteoarthritis or inflammatory arthropathy. Reverse TSA has been found to be beneficial for patients with rotator cuff tear arthropathy, proximal humerus fractures, and revision surgery.<sup>14</sup> Advancements in reverse TSA have led to a significant increase in the surgical volume of TSA, with a concomitant decrease in hemiarthroplasty.<sup>1</sup> Between 2011 and 2017, the total number of TSA performed each year in the United States increased from 57,179 to 109,734.<sup>18</sup>

Age is an important contributing factor to the increase in TSA volume. With increasing life expectancy, there is an increasing prevalence of degenerative diseases of the glenohumeral joint. Advancements in medicine now allow a greater proportion of elderly patients to be eligible for TSA.<sup>13</sup> However, an older patient population will likely present with more chronic medical comorbidities prior to surgery. Therefore, investigation into strategies that would allow for more thorough preoperative risk stratification may greatly benefit this patient population.

In the realm of orthopedic surgery, frailty has been associated with higher rates of complications following total hip and total knee arthroplasties.<sup>11,21</sup> Among various measures of frailty, the Six-Item Modified Frailty Index (MF-6) has recently gained popularity as a predictor for postoperative complications.<sup>3,6,10</sup> One study found that a high MF-6 score was associated with readmission, non-home discharge, and mortality following open reduction and

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internal fixation of lower extremity, pelvic, and acetabular fractures.<sup>12</sup>

MF-6 accounts for 6 variables: hypoalbuminemia, diabetes mellitus, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD) or current pneumonia, hypertension requiring medication, and dependent functional status. The MF-6 builds upon the Five-Item Modified Frailty Index (MF-5) by adding hypoalbuminemia as a variable. A study from 2019 investigated MF-5 as a predictor for complications following TSA in patients older than 50 years from 2005 to 2019. This previous study found a high MF-5 to be associated with higher rates of readmission, reoperation, non-home discharge, and increased hospital length of stay.<sup>5</sup> The purpose of this study was to investigate MF-6 as a predictor for early postoperative complications in patients older than 65 years undergoing TSA. We hypothesized that a high MF-6 would be associated with higher rates of readmission.

## Methods

The authors queried the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database for all patients who underwent TSA between 2015 and 2020. This study was deemed exempt from approval by our university's Institutional Review Board, as the NSQIP database is fully deidentified. Data in the NSQIP database are obtained from over 600 hospitals in the United States and are collected by trained surgical clinical reviewers.

*Current Procedural Terminology* code 23472 was used to identify patients who underwent TSA, both anatomic and reverse, from 2015 to 2020. The exclusion criteria inherent to the NSQIP database exclude all cases for patients younger than 18 years of age or TSA performed for cases classified as trauma. More specifically, trauma cases are excluded if patients are admitted to the hospital for acute trauma and undergo an operation during that same stay. Therefore, the present evaluation of MF-6 does not include TSA performed for proximal humerus fractures during the same inpatient stay. However, TSA performed for proximal humerus fractures are still included for patients who were discharged from the emergency department and underwent surgery at a later date. Cases were excluded if any of the following variables had missing information: height/weight, discharge destination, American Society of Anesthesiologists (ASA) classification, functional health status, readmission status, and preoperative albumin levels. Cases were also excluded for age <65 years.

Variables collected in this study included patient demographics, comorbidities, preoperative laboratory values, surgical characteristics, and 30-day postoperative complication data. Patient demographics included age, body mass index, gender, ASA classification, functional health status, smoking status, and preoperative steroid use. Preoperative comorbidities included insulin-dependent and noninsulin-dependent diabetes, severe COPD, CHF, hypertension, disseminated cancer, open wound/wound infection, bleeding disorders, and transfusion prior to surgery. Preoperative laboratory values included hematocrit and albumin. Surgical characteristics included operative duration in minutes. Complications that occurred within 30 days postoperatively were included in the analysis. These complications included pneumonia, superficial incisional surgical site infection (SSI), deep incisional SSI, organ/space SSI, wound dehiscence, reintubation, pulmonary embolism, ventilator >48 hours, urinary tract infection (UTI), stroke, cardiac arrest, myocardial infarction, blood transfusion, deep vein thrombosis, sepsis, septic shock, readmission, reoperation, non-home discharge, and mortality. Of note, in some health-care systems other than those of the United States, non-home discharge after TSA is not encountered as a complication.

The initial pool of patients was divided into two cohorts based on their MF-6 score: MF-6  $\geq 3$  and MF-6 <3. The score cutoff point of 3 was based on a previous study that looked at MF-6 in lower extremity and pelvic fractures.<sup>12</sup> The MF-6 score was calculated using a 6-point system with one point given for each of the following conditions: COPD, CHF, insulin or noninsulin-dependent diabetes, hypertension, dependent functional status, and hypoalbuminemia. Albumin levels less than 3.5 g/dL were categorized as hypoalbuminemia.

A total of 27,050 patients underwent primary TSA 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, 227 for unknown functional health status, 2 for missing readmission status, 13,878 for missing preoperative albumin levels, and 3523 for age <65. Of the 9228 patients remaining after exclusion criteria, 8764 (95.0%) patients had MF-6 <3, and 464 (5.0%) patients had MF-6  $\geq 3$ .

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 analysis. Multivariate logistic regression, adjusted for all significantly associated patient demographics and comorbidities, was used to identify associations between the MF-6 score and postoperative complications. Odds ratios (ORs) were reported with 95% confidence intervals (CIs). The level of statistical significance was set at  $P < .05$ .

## Results

Patient demographics and comorbidities that were significantly associated with MF-6  $\geq 3$  were body mass index >30 ( $P < .001$ ), female gender ( $P < .001$ ), ASA  $\geq 3$  ( $P < .001$ ), current smoking status ( $P < .001$ ), open wound/wound infection ( $P = .002$ ), chronic steroid use ( $P < .001$ ), bleeding disorder ( $P < .001$ ), preoperative anemia ( $P < .001$ ), and transfusion prior to surgery ( $P < .001$ ) (Table I).

Bivariate analysis was used to determine postoperative complications associated with MF-6  $\geq 3$  (Table II). The 30-day postoperative complications that were significantly associated with MF-6  $\geq 3$  were UTI ( $P < .001$ ), blood transfusion ( $P < .001$ ), readmission ( $P < .001$ ), reoperation ( $P = .006$ ), and non-home discharge ( $P < .001$ ).

After adjusting for all significantly associated patient variables, multivariate logistic regression identified the 30-day postoperative complications associated with MF-6  $\geq 3$  (Table III). Multivariate analysis found MF-6  $\geq 3$  to be independently associated with higher rates of UTI (OR: 2.79, 95% CI: 1.49–5.23;  $P = .001$ ), blood transfusion (OR: 1.53, 95% CI: 1.01–2.32;  $P = .045$ ), readmission (OR: 1.58, 95% CI: 1.06–2.35;  $P = .024$ ), and non-home discharge (OR: 2.60, 95% CI: 2.08–3.25;  $P < .001$ ). Reoperation was not independently associated after adjustment.

## Discussion

In this study, we used a large national database to report on 30-day postoperative complications associated with a high MF-6 score ( $\geq 3$ ) in elderly patients aged 65 and older who underwent TSA between 2015 and 2020. Our analysis included 9228 patients, of which 8764 (95.0%) patients had MF-6 <3, and 464 (5.0%) patients had MF-6  $\geq 3$ . Through bivariate analysis, we identified a high MF-6 score to be significantly associated with UTI, blood transfusion, readmission, reoperation, and non-home discharge. After controlling for significant patient demographics and comorbidities, we identified a high MF-6 score to be independently associated with higher rates of UTI, blood transfusion, readmission, and non-home discharge.

**Table I**  
Patient demographics and comorbidities for patients who underwent total shoulder arthroplasty, based on MF-6 score.

Characteristic	Normal (MF-6 <3)		MF-6 ≥3		P value
	Number	Percent	Number	Percent	
Total	8764	100.0	464	100.0	
Age					.055
65-74	5043	57.5	246	53.0	
≥75	3721	42.5	218	47.0	
Body mass index (kg/m <sup>2</sup> )					
<18.5	69	0.8	4	0.9	.272
18.5-29.9	4432	50.6	145	31.3	–
30.0-34.9	2323	26.5	127	27.4	<.001
35.0-39.9	1176	13.4	87	18.8	<.001
≥40.0	754	8.6	101	21.8	<.001
Gender					<.001
Female	5195	59.3	316	68.1	
Male	3569	40.7	148	31.9	
ASA classification					<.001
1-2	3298	37.6	25	5.4	
≥3	5466	62.4	439	94.6	
Current smoker					<.001
No	8227	93.9	406	87.5	
Yes	537	6.1	58	12.5	
Disseminated cancer					.786
No	8733	99.6	462	99.6	
Yes	31	0.4	2	0.4	
Open wound/wound infection					.002
No	8728	99.6	457	98.5	
Yes	36	0.4	7	1.5	
Chronic steroid use					<.001
No	8275	94.4	420	90.5	
Yes	489	5.6	44	9.5	
Bleeding disorders					<.001
No	8514	97.1	423	91.2	
Yes	250	2.9	41	8.8	
Preoperative anemia					<.001
No	6860	78.3	260	56.0	
Yes	1742	19.9	197	42.5	
Transfusion prior to surgery					<.001
No	8733	99.6	454	97.8	
Yes	31	0.4	10	2.2	
Operative duration (minutes)					
0-79	2404	27.4	127	27.4	.754
80-128	4472	51.0	228	49.1	–
≥129	1888	21.5	109	23.5	.299

MF-6, Six-Item Modified Frailty Index; ASA, American Society of Anesthesiologists. Bold P values indicate statistical significance with P < .05.

Improvements in technology and techniques have contributed to TSA gaining significant popularity.<sup>14</sup> Anatomic TSA effectively treats patients with glenohumeral osteoarthritis and inflammatory arthropathy. Developments in reverse TSA have expanded indications to include cuff-tear arthropathy, proximal humerus fractures, and revision for failed TSA.<sup>4,14,15,19</sup> Overall, TSA has been shown to provide positive outcomes in terms of shoulder mobility, pain relief, and patient satisfaction.<sup>14</sup> With increasing surgical volume in the elderly population, investigation into patient risk factors may help to reduce adverse events and improve outcomes.

Frailty is characterized by physiological decline in function and increased vulnerability to stressors.<sup>20</sup> With more elderly patients undergoing orthopedic surgery, there has been increasing evidence that frailty is associated with adverse outcomes.<sup>2,7</sup> Due to this association, various instruments have been implemented in attempts to measure and quantify frailty. A recent systematic review by Lemos et al found the Modified Frailty Index to be the most

**Table II**  
Bivariate analysis of 30-day postoperative complications based on MF-6 score.

Complication	Normal (MF-6 <3)		MF-6 ≥3		P value
	Number	Percent	Number	Percent	
Pneumonia	58	0.66	4	0.86	.608
Superficial incisional SSI	15	0.17	1	0.22	.823
Deep incisional SSI	5	0.06	0	0.00	.999
Organ/space SSI	11	0.13	1	0.22	.605
Wound dehiscence	3	0.03	1	0.22	.111
Reintubation	28	0.32	2	0.43	.682
Pulmonary embolism	15	0.17	2	0.43	.219
Ventilator >48 hours	15	0.17	1	0.22	.823
Urinary tract infection	64	0.73	14	3.02	<.001
Stroke	12	0.14	0	0.00	.999
Cardiac arrest	4	0.05	1	0.22	.165
Myocardial infarction	29	0.33	2	0.43	.717
Blood transfusion	199	2.27	34	7.33	<.001
Deep vein thrombosis	25	0.29	2	0.43	.574
Sepsis	8	0.09	1	0.22	.418
Septic shock	9	0.10	0	0.00	.999
Readmission	276	3.15	32	6.90	<.001
Reoperation	110	1.26	13	2.80	.006
Non-home discharge	985	11.24	157	33.84	<.001
Mortality	19	0.22	2	0.43	.355

MF-6, Six-Item Modified Frailty Index; SSI, surgical site infection. Bold P values indicate statistical significance with P < .05.

**Table III**  
Multivariate analysis of 30-day postoperative complications adjusted for significant patient demographics/comorbidities, based on MF-6 score.

Complication	Odds ratio	95% CI	P value
Urinary tract infection	2.79	1.49-5.23	.001
Blood transfusion	1.53	1.01-2.32	.045
Readmission	1.58	1.06-2.35	.024
Reoperation	1.58	0.86-2.93	.142
Non-home discharge	2.60	2.08-3.25	<.001

MF-6, Six-Item Modified Frailty Index; CI, confidence interval. Bold P values indicate statistical significance with P < .05.

common instrument used among 24 different instruments.<sup>7</sup> The Modified Frailty Index originally included 11 items that was simplified to 5 items (diabetes mellitus, CHF, COPD or current pneumonia, hypertension requiring medication, and dependent functional status).<sup>12</sup> The modified 5-item frailty index was shown to retain its predictive power for frailty compared to the original 11-item frailty index.<sup>16</sup> Recently an MF-6 has gained popularity, which includes hypoalbuminemia as the sixth item. Hypoalbuminemia has been associated with complications after orthopedic surgery, hence its inclusion to create the MF-6.<sup>22,23</sup>

A study by Pean et al investigated MF-6 as a predictor for short-term adverse events following lower extremity open reduction and internal fixation and found that a high MF-6 score was associated with higher rates of infectious complications, readmission, and non-home discharge.<sup>12</sup> The results of our study are consistent with those by Pean et al, as we also found MF-6 ≥3 to be associated with UTI, readmission, and non-home discharge. However, while Pean et al found an association between MF-6 and mortality, we did not find an association with mortality following TSA. This may be explained by the primarily elective nature of TSA compared to the nonelective nature of lower extremity fractures.

More specific to TSA, a study by Holzgrefe et al investigated the predictive ability of the MF-5 for postoperative complications.<sup>5</sup> Their study also used the NSQIP database and included 9861 patients aged 50 years or older. Holzgrefe et al found that a score of 2 or greater was associated with a higher likelihood of any

postoperative complication, readmission, reoperation, and adverse hospital discharge.<sup>5</sup> Another study by Traven et al also investigated the MF-5 for TSA using NSQIP data from 2005 to 2017.<sup>17</sup> Their study found that the frailty index was the strongest predictor for mortality, with the risk more than doubling per point increase. They also found increased risk for medical complications, increased length of stay, non-home discharge, and readmission.<sup>17</sup> Across both of these studies and our present study, the Modified Frailty Index consistently predicts higher rates of readmission and non-home discharge. There are several differences unique to our study that may explain the different findings with regards to reoperation and mortality. Our study examined more recent NSQIP data from 2015 to 2020. Additionally, we limited our study cohort to patients who were aged 65 and older, as frailty becomes increasingly relevant with older age. We also included hypoalbuminemia as an additional item in the frailty index, which may have allowed us to identify an increased risk for postoperative blood transfusion.

A study by Yi et al investigating the MF-5 in patients undergoing surgical treatment for proximal humerus fracture found frailty to be associated with various postoperative complications.<sup>24</sup> Among these complications were UTI and blood transfusion, consistent with the findings in our study. This common finding may be explained by reverse TSA becoming an increasingly popular treatment for proximal humerus fracture. Relating to proximal humerus fracture, a study by Ling et al found that the dependent functional status was an independent predictor for both readmission and non-home discharge following surgical treatment.<sup>8</sup> These findings coincide with ours and support the utility of MF-6 as an appropriate screening tool for complications, as dependent functional status is including in the index.

Our study was limited to the data present in NSQIP. The inherent nature of the database prevented operative factors such as the surgeon's experience, the clinical center where the operation took place, and postoperative care from being included in our analysis. The NSQIP also does not include postoperative complications that occur after 30 days. Therefore, we cannot consider long-term complications such as glenoid erosion, instability, periprosthetic fractures, and loosening. Additionally, the NSQIP does not distinguish between anatomic and reverse TSA, which may be of interest in the setting of proximal humerus fracture. Of note, since the NSQIP excludes cases classified as "trauma," we did not account for TSA performed for proximal humerus fracture if done during the same admission. Despite these limitations, we utilized a large, reputable national database to examine postoperative complications associated with an elevated MF-6 score in elderly patients undergoing TSA.

The findings of our study suggest that the MF-6 can be a helpful screening tool for orthopedic surgeons during the preoperative planning for TSA in elderly patients. The MF-6 may guide surgeons in determining which patients need more individualized perioperative care.

## Conclusion

A high MF-6 score ( $\geq 3$ ) in patients aged 65 and older is independently associated with higher rates of UTI, blood transfusion, readmission, and non-home discharge following TSA. The MF-6 score can be easily calculated preoperatively and may allow for better preoperative risk stratification. As the surgical volume of TSA increases in the elderly population, understanding the predictive value of frailty scores for postoperative complications may help to optimize outcomes.

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