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Use of a 5-item modified Fragility Index for risk stratification in patients undergoing surgical management of proximal humerus fractures

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Hypothesis: We hypothesized that the modified Fragility Index (mFI) would predict complications in patients older than 50 years who underwent operative intervention for a proximal humerus fracture.
Methods: We retrospectively reviewed the American College of Surgeons National Surgery Quality Improvement Program database, including patients older than 50 years who underwent open reduction and internal fixation of a proximal humerus fracture. A 5-item mFI score was then calculated for each patient. Postoperative complications, readmission and reoperation rates as well as length of stay (LOS) were recorded. Univariate as well as multivariable statistical analyses were performed, controlling for age, sex, body mass index, LOS, and operative time.
Results: We identified 2,004 patients (median age, 66 years; interquartile range: 59-74), of which 76.2% were female. As mFI increased from 0 to 2 or greater, 30-day readmission rate increased from 2.8% to 6.7% (P-value = .005), rate of discharge to rehabilitation facility increased from 7.1% to 25.3% (P-value < .001), and rates of any complication increased from 6.5% to 13.9% (P-value < .001). Specifically, the rates of renal and hematologic complications increased significantly in patients with mFI of 2 or greater (P-value = .042 and P-value < .001, respectively). Compared with patients with mFI of 0, patients with mFI of 2 or greater were 2 times more likely to be readmitted within 30 days (odds ratio = 2.2, P-value .026). In addition, patients with mFI of 2 or greater had an increased odds of discharge to a rehabilitation center (odds ratio = 2.3, P-value < .001). However, increased fragility was not significantly associated with an increased odds of 30-day reoperation or any complication after controlling for demographic data, LOS, and operative time.
Conclusion: An increasing level of fragility is predictive of readmission and discharge to a rehabilitation center after open reduction and internal fixation of proximal humerus fractures. Our data suggest that a simple fragility evaluation can help inform surgical decision-making and counseling in patients older than 50 years with proximal humerus fractures.

Proximal humerus fractures (PHFs) comprise about five percent of all fractures in older adults, representing the third most common osteoporotic fracture type in elderly patients after distal radius and hip fractures.[6,13,26,35] These fractures tend to occur in active, elderly individuals and have a unipolar age distribution, with the highest age-specific incidences occurring in women between 80 and 89 years of age.[13] While this is certainly an older patient cohort, a population study of 1,027 PHFs revealed that more than 90% of injured patients lived at home, with more than 80% performing their own shopping and housework,[13] highlighting the importance of maintaining independence among this population.[35,43]

The treatment of PHFs includes either nonoperative immobilization or surgical fixation, with no current widely accepted consensus on indications for surgical treatment.[59,63] Nonoperative management with sling immobilization has been shown to be an

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effective form of treatment in some studies.[62,76] Nonetheless, a sample of Medicare patients treated for PHFs between 1999 and 2005 revealed a 25.6% relative increase in the rate of surgically managed fractures over this time period.[6] Open reduction and internal fixation (ORIF) has typically proved to be a reasonable option in patients with adequate bone quality, with the added benefit of reduced implant-related complications when compared with fractures treated with reverse shoulder arthroplasty (RSA).[10,61,75] Generally, elderly patients with severe osteoporosis and high degree of fracture displacement and/or comminution are offered RSA rather than ORIF.[17,20,40,63] Demand for RSA is increasing at a rate of 12.1% growth rate per year in the elderly[42] with emerging evidence to suggest that these patients have improved long-term outcomes when compared with patients who underwent plate fixation.[20] However, there is still no consensus on its indications or the standard of care of these fractures in general.[6]

With a high incidence of PHFs in elderly populations, age alone is not an adequate measure to determine candidacy for ORIF. Instead fragility, defined as a generalized decrease in multisystem physiologic reserve and function, should be considered.[73] Patients of the same age can have greatly different degrees of fragility and, therefore, vastly different operative risk profiles.[7,51,66] Several studies have used fragility, quantified as the modified Fragility Index (mFI), to predict surgical outcomes and complications in both orthopedics and other surgical specialties.[2,7,18,19,30,45,57,58,71,73] The mFI is an 11-item index of functional status and comorbidities originally developed as a simplified version of the Canadian Study of Health and Aging Frailty Index, a full 70-item scale designed to quantify frailty.[66] The mFI has compared well with other fragility indices, specifically the Charlson Comorbidity Index, in both orthopedic and general surgery.[5,16,41] A subsequent abbreviated 5-item index was recently validated against the 11-item mFI score and has been used to successfully predict complications to permit risk stratification in the preoperative period.[64,71,74] A 2018 retrospective review of 6,494 patients older than 50 years who had undergone ORIF for distal radius fractures revealed that patients with an mFI of 2 or greater were nearly 2.5 times more likely to incur a postoperative complication.[71] A larger cohort study encompassing orthopedic, vascular, and general surgery revealed a linear dose-dependent relationship between the mFI and 30-day unplanned readmission, postdischarge emergency department visits, predischarge and postdischarge complications, and postdischarge mortality.[70] These studies highlight the value of the mFI in the preoperative decision-making and surgical management of these patients.

Fragility measures have played a promising part in the patient selection process and assessing patient risk factors and comorbidities to decrease readmissions, reoperations, and overall complications. We hypothesized that the 5-item mFI would successfully predict 30-day surgical complications in patients older than 50 years with PHFs.

Materials and methods

Data collection

In this study, the American College of Surgeons National Surgery Quality Improvement Program database was queried for patients based on Current Procedural Terminology codes. In brief, the National Surgery Quality Improvement Program (NSQIP) database collects prospective, international data regarding patient preoperative demographic characteristics and comorbidities, surgical categorization, and 30-day surgical outcomes and complications.

The following Current Procedural Terminology codes were used in this retrospective cohort database study: 23615 (open treatment of PHF ± tuberosities ± fixation), 23616 (open treatment of PHF ± tuberosities with prosthesis), and 23630 (open treatment of greater tuberosity fracture ± internal/external fixation). All patients from 2014 to 2017 were initially included in this study. Patients younger than 50 years and those with open injuries were excluded. Finally, patients meeting sepsis or presepsis criteria before surgery were excluded, as were patients with incomplete data available for analysis.

Patient demographics

The following patient demographic information was included: age, sex, body mass index kg/m^2 (BMI), race (stratified into white, black, Asian, and other/unknown), American Society of Anesthesiologists class, wound classification, smoking status, postoperative length of stay (LOS), and operative time (minutes).

Modified fragility index

The 5-item mFI used in this study was developed from the NSQIP 11-item mFI and has been validated against it.[11] The 5-item mFI includes the following five patient history items: history of diabetes mellitus, new diagnosis of congestive heart failure (CHF) or an exacerbation of chronic CHF within 30 days of surgery, hypertension (HTN) requiring medication, history of chronic obstructive pulmonary disease or pneumonia, and nonindependent functional status (partially or completely dependent in activities of daily living within the last 30 days before surgery). The 5-item mFI score was calculated for every patient by summing the variables present in patients, with a possible score from 0 to 5 (Table I). These scores were then stratified into 0, 1, and 2+ for the statistical analysis.

Outcome and complication data

The 30-day outcome data were collected for each patient. Primary outcome data included in the analysis were 30-day readmission, reoperation, and mortality. Complications were classified into the following broad categories: wound (wound dehiscence or other complications, not including surgical site infection), cardiac (cardiac arrest or myocardial infarction), pulmonary (pneumonia, pulmonary embolism, unplanned reintubation), hematology (deep vein thromboembolism, need for transfusion), renal (progressive renal insufficiency, acute kidney failure), and adverse hospital discharge (discharge to other than home). In addition, data for all complications were analyzed as Clavien-Dindo IV complications, which are those that are life-threatening and cause end-organ dysfunction. Clavien-Dindo IV complications included cardiac arrest, myocardial infarction, septic shock, pulmonary embolism, and renal failure.

Statistical analysis

Initial statistical comparison of demographic variables and the mFI score was performed with the chi-square test for categorical independent variables and simple logistic regressions for continuous independent variables. To assess for confounders, a bivariate analysis of the association of demographic variables to outcomes and complications was performed with a logistic model for continuous independent variables and the chi-square test for categorical independent variables. Age, BMI, race, smoking status, and length of stay (LOS) were identified as possible confounders. To assess for association between the mFI and each complication and outcome, a bivariate analysis was performed using a logistic model. A subanalysis comparing each mFI component and each outcome

Table I
Patient demographics and mFI score

Patient demographics	Total		mFI score						P value
			0		1		2+		
Age (years)-median (IQR)	66	59-74	62	57-69	69	61-76	68	63-75	
50-59	522	26.0%	292	38.6%	151	19.3%	79	17.0%	.000
60-69	742	37.0%	290	38.4%	271	34.7%	181	38.8%	
70-79	518	25.8%	134	17.7%	241	30.8%	143	30.7%	
80-89	222	11.1%	40	5.3%	119	15.2%	63	13.5%	
Sex									
Female	1,527	76.2%	571	75.5%	607	77.6%	349	74.9%	.473
Male	477	23.8%	185	24.5%	175	22.4%	117	25.1%	
BMI									
Underweight	54	2.8%	24	3.3%	24	3.2%	6	1.3%	.000
Normal weight	545	28.2%	263	36.5%	202	26.6%	80	17.6%	
Overweight	583	30.2%	234	32.5%	245	32.3%	104	22.9%	
Obese	394	20.4%	118	16.4%	167	22.0%	109	24.0%	
Severely obese	184	9.5%	44	6.1%	65	8.6%	75	16.5%	
Morbidly obese	172	8.9%	37	5.1%	55	7.3%	80	17.6%	
Race									
White	1,590	79.3%	575	76.1%	619	79.2%	396	85.0%	.000
Black	57	2.8%	14	1.9%	24	3.1%	19	4.1%	
Asian	38	1.9%	15	2.0%	17	2.2%	6	1.3%	
Other/unknown	319	15.9%	152	20.1%	122	15.6%	45	9.7%	
ASA score									
Healthy	71	3.5%	66	8.7%	3	0.4%	2	0.4%	.000
Mild	852	42.5%	453	59.9%	331	42.4%	68	14.6%	
Severe	988	49.3%	222	29.4%	421	53.9%	345	74.0%	
Life threat	92	4.6%	15	2.0%	26	3.3%	51	10.9%	
Wound categorization									
Clean	1,966	98.1%	742	98.1%	770	98.5%	454	97.4%	.793
Clean/contaminated	24	1.2%	9	1.2%	7	0.9%	8	1.7%	
Contaminated	8	0.4%	2	0.3%	3	0.4%	3	0.6%	
Dirty/infected	6	0.3%	3	0.4%	2	0.3%	1	0.2%	
Smoking status									
No	1,644	82.0%	607	80.3%	640	81.8%	397	85.2%	.094
Yes	360	18.0%	149	19.7%	142	18.2%	69	14.8%	
LOS (days)-median (IQR)	1	0-3	1	0-2	1	0-3	2	1-4	.000
Op time (mins)-median (IQR)	103	76.5-138	104	76-139	105	78-140	99	73-135	.875
Total	2,004	100.0%	756	37.7%	782	39.0%	466	23.3%	

mFI, modified Fragility Index; *IQR*, interquartile range; *BMI*, body mass index; *ASA*, American Society of Anesthesiologists; *LOS*, length of stay (days).

was also performed using a univariate and multivariate logistic model. This association was then further examined using a multivariate logistic regression control for potential confounders. A *P*-value of less than .05 was considered statistically significant. Statistical analysis was performed with Stata, version 16 (StataCorp, College Station, TX, USA).

Results

Patient demographics

A total of 2,025 patients who met study selection criteria were identified in the NSQIP database, of whom, 2,004 patients had complete data for calculation of the 5-item mFI. Most patients identified were female (76.2%), Caucasian (79.3%), and nonsmokers (82.0%), with a median patient age of 66 years (interquartile range [IQR]: 59 − 74). The median BMI of the study cohort was 27.9 (IQR: 24.1 − 33.2). Almost all the patients (91.8%) had an American Society of Anesthesiologists class of either 2 (42.5%) or 3 (49.3%) representing either mild or severe systemic disease, respectively. Nearly all patients' wounds were classified as clean (98.1%), the median LOS was 1 day (IQR: 0-3 days), and a median operative time was 103 minutes (IQR: 76.5 − 138 minutes).

5-Item mFI scores

The calculated mFI ranged from 0 to 5. The number of patients with each mFI level was follows: mFI = 0 in 756 patients (37.7%), mFI = 1 in 782 patients (39.0%), mFI = 2 in 400 patients (20.0%), mFI = 3 in 55 patients (2.7%), mFI = 4 in 10 patients (0.5%), and mFI = 5 in 1 patient (0.05%). Owing to low numbers of patients with mFI > 3, the scores were restratified into 0, 1, and 2 or greater. After restratification, 466 patients (23.3%) had an mFI score of 2 or greater.

mFI and 30-day postoperative outcomes and complications

Table II portrays the univariate analysis of complications and the mFI score. An increasing mFI score was significantly associated with an increased risk of readmission (odds ratio [OR]: 1.61 [1.28 − 2.02], $P < .001$), mortality (OR: 2.39 [1.42 − 4.00], $P = .001$), adverse hospital discharge (OR: 1.87 [1.62 − 2.14], $P < .001$), and any complication (OR: 1.60 [1.34 − 1.92], $P < .001$). Of the complications, a higher mFI score was associated with a significantly higher rate of renal (OR: 3.68 [1.58 − 8.59], $P = .003$) and hematological (OR: 1.60 [1.31 − 1.94], $P < .001$) complications.

Table II
Complications by mFI scores (univariate)

Complication	Total		0		1		2+		*P* value	Odds ratio	*P* value	95% CI
Readmission	86	4.3%	21	2.8%	34	4.3%	31	6.7%	**.005**	1.611	**.000**	1.28-2.02
Reoperation	53	2.6%	21	2.8%	21	2.7%	11	2.4%	.903	1.043	.793	0.76-1.43
Mortality	13	0.6%	2	0.3%	4	0.5%	7	1.5%	**.027**	2.387	**.001**	1.42-4.00
Discharge	297	14.8%	54	7.1%	125	16.0%	118	25.3%	**.000**	1.866	**.000**	1.62-2.14
Any complication	185	9.2%	49	6.5%	71	9.1%	65	13.9%	**.000**	1.551	**.000**	1.32-1.83
Clavien-Dindo 4	19	0.9%	7	0.9%	8	1.0%	4	0.9%	.956	0.929	.789	0.54-1.60
Total	2,004		756		782		466					

mFI, modified Fragility Index; *95% CI*, 95% confidence interval.
P-values <.05 (bold) were considered statistically significant.

Table III
Complications vs mFI score components (univariate)

mFI components	Readmission			Reoperation			Mortality		
	OR	*P* value	95% CI	OR	*P* value	95% CI	OR	*P* value	95% CI
Diabetes	1.74	**.022**	1.08-2.79	0.90	.778	0.45-1.82	1.74	.358	0.53-5.68
COPD	2.02	**.036**	1.05-3.89	1.72	.222	0.72-4.09	1.10	.926	0.14-8.53
CHF	6.17	**.000**	2.25-16.94	3.44	.101	0.79-15.01	43.80	**.000**	12.46-154.02
Hypertension	1.50	.078	0.95-2.36	0.82	.468	0.47-1.41	2.65	.140	0.73-9.66
Functional status	3.05	**.001**	1.56-5.95	1.59	.379	0.56-4.51	5.92	**.008**	1.6-21.87
mFI components	**Adverse discharge**			**Any complication**			**Clavien-Dindo IV**		
	OR	*P* value	95% CI	OR	*P* value	95% CI	OR	*P* value	95% CI
Diabetes	1.61	**.001**	1.21-2.13	1.36	.126	0.92-2	0.46	.295	0.1-1.98
COPD	2.28	**.000**	1.54-3.39	2.28	**.001**	1.37-3.78	—	—	—
CHF	4.21	**.001**	1.85-9.58	5.45	**.000**	2.22-13.37	4.74	.138	0.61-37.01
Hypertension	2.33	**.000**	1.78-3.06	1.73	**.003**	1.21-2.48	1.09	.856	0.44-2.72
Functional status	5.22	**.000**	3.44-7.93	3.33	**.000**	1.95-5.66	2.29	.272	0.52-10.05

mFI, modified Fragility Index; *OR*, odds ratio; *COPD*, chronic obstructive pulmonary disease; *CHF*, congestive heart failure; *95% CI*, 95% confidence interval.
P-values <.05 (bold) were considered statistically significant.

Table IV
Complications by mFI (multivariate)

mFI	Readmission			Reoperation			Mortality		
	OR	*P* value	95% CI	OR	*P* value	95% CI	OR	*P* value	95% CI
mFI									
0	—	—	—	—	—	—	—	—	—
1	1.366	.291	0.77-2.44	1.000	.999	0.52-1.92	1.123	.898	0.19-6.65
2 +	2.024	**.026**	1.09-3.76	0.894	.784	0.4-1.99	3.673	.131	0.68-19.89
	Any complication			**Clavien-Dindo IV**			**Discharge**		
	OR	*P* value	95% CI	OR	*P* value	95% CI	OR	*P* value	95% CI
mFI									
0	—	—	—	—	—	—	—	—	—
1	.853	.464	0.56-1.3	0.572	.309	0.19-1.68	1.386	.095	0.95-2.03
2 +	1.450	.106	0.92-2.27	0.393	.169	0.10-1.49	2.289	**.000**	1.53-3.43

mFI, modified Fragility Index; *OR*, odds ratio; *95% CI*, 95% confidence interval.
P-values <.05 (bold) were considered statistically significant.

mFI components and 30-day postoperative outcomes and complications

Table III portrays the association between the five components of the mFI score and 30-day postoperative complications. On univariate analysis, each of the five mFI variables was independently associated with higher rates of readmission with the exception of HTN. All of the mFI variables were independently associated with higher rates of adverse hospital discharge. Each of the mFI variables was independently associated with higher rates of any complications with the exception of diabetes. CHF and nonindependent functional status were independently associated with increased mortality. On multivariate analysis, higher rates of readmission were associated with CHF and nonfunctional status. Higher rates of adverse discharge were associated with patients who had chronic obstructive pulmonary disease, HTN, and nonfunctional status. Furthermore, patients with CHF had an increased risk of mortality and any complication.

Multivariate analysis of the mFI score and 30-day postoperative outcomes and complications

Table IV portrays the results of the multivariate analysis when controlling for age, sex, BMI, race, smoking status, LOS, and operative time. After controlling for these variables, patients with an mFI score of 2 or greater had an increased rate of readmission (OR: 2.02 [1.09 − 3.76], $P = .026$) and adverse hospital discharge (OR: 2.29 [1.53 − 3.43], $P < .001$).

Discussion

This analysis confirmed our hypothesis that the 5-item mFI predicts complications after PHFs. In a sample size of 2,025 patients, 76.2% of patients who had received operative intervention for PHFs were female. This finding is in congruence with previously reported data, indicating a 70:30 predilection for female populations.[54] A high mFI score was a strong predictor for adverse outcomes across a variety of complication categories. When all complications were grouped together, rates of any complication increased from 5% to 13% as the mFI score increased from 0 to 2 or greater. The rates of renal and hematologic complications were particularly affected by a higher mFI score. In the chronic kidney disease population, a variety of markers of frailty including depression and low testosterone levels were found to be independent contributors to increased healthcare utilization and mortality.[72] Regarding hematologic complications, it is well documented that elderly patients are at a particularly high risk of hemorrhage-related issues, given generalized degradation of the coagulation cascade and high likelihood of concomitant use of anticoagulation for acute coronary syndrome, atrial fibrillation, and a variety of other comorbidities.[1,9,14,22,25,29,32,33,49,68] These data taken together may indicate that particular attention should be given to renal and hematologic status of patients with high levels of fragility.

Predictive modeling indicates that the number of people older than 60 years will increase to more than two billion by the year 2050.[53] Thus, fracture management in the geriatric population will remain of chief importance in the orthopedic community. The incidence of PHFs is increasing, and PHFs have become the third most common fracture type observed in elderly populations.[26] PHFs have been found to carry similar morbidity and mortality as compared with the hip fracture population.[8] Optimal treatment for these fractures is the topic of much continued debate, with hundreds of studies comparing various surgical and nonoperative methodologies.[24,27,28,31,46–48,52,55,56,60,65,67,69]

Emerging literature has demonstrated favorable outcomes for both surgical and nonsurgical management of PHFs.[10,15,20,35,37,50,61,62,75,76] The Proximal Fracture of the Humerus Evaluation by Randomization (PROFHER) trial evaluated 249 patients with PHFs who underwent fracture fixation, humeral head replacement, or sling immobilization. This study found no significant difference in the Oxford Shoulder Score between groups, with 39.07 points for the surgical group and 38.32 for the nonsurgical group, suggesting that the increase in operative management of these fractures is possibly unwarranted.[50] A 2018 study evaluating 70 patients who underwent ORIF with locking plates found satisfactory results with low complication rates at any age.[75] However, another study focused on patients older than 60 years and concluded that ORIF with locking plates resulted in a 44% complication rate and a 34% failure rate.[4] In a randomized control trial comparing reverse total shoulder arthroplasty with ORIF, there was a significant mean difference of 13.4 points in the Constant outcome score at 2-year follow-up in favor of reverse total shoulder arthroplasty.[20] There is also evidence of low implant survival and low patient-reported outcomes in patients who fail nonoperative treatment and subsequently undergo RSA, highlighting the importance of providing optimal treatment during the initial intervention.[36]

Despite the large body of literature describing operative fixation techniques for PHFs, emerging evidence suggests that nonoperative management is adequate for geriatric patients or those with high comorbidity burden.[23,27] A recent randomized control trial evaluating clinical outcomes at 2 years between surgery and nonoperative treatment in patients older than 60 years with displaced 2-part fractures of the proximal humerus found no difference in outcomes.[27] A systematic review concluded that nonoperative treatment of PHFs demonstrates high rates of radiographic healing, good functional outcomes, and a modest complication rate.[23] Notably, this review demonstrated a low rate of avascular necrosis of the humeral head, affecting only 13 of 650 patients. Radiographic union was 98%, and the overall complication rate was 13%.[23]

With mounting evidence in favor of nonoperative management of PHFs, attention should be placed on optimal patient selection for surgical intervention. Specific fracture patterns such as degree of comminution and displacement guide treatment considerations, but patient-specific health factors, must also factor into the decision to pursue nonoperative vs. surgical management. Consequently, evidence-based risk factor assessment scores can have particular importance in stratifying appropriate management of PHFs, especially for geriatric patients and those with high comorbidity burden.

In treatment planning, there are two main categories of adverse outcomes that warrant consideration: Surgical procedure–specific complications and 2. general medical complications. In addition, providers should be aware of the likelihood of greatly increased hospital resource utilization parameters in the decision between operative and nonoperative management. The United States health system spends roughly twice as much as other high-income countries on medical care.[44] While optimal management of the patient in question must always trump cost consideration, when two equally efficacious treatments are available, the lower cost option is the responsible choice. In treatment planning, orthopedic surgeons are likely to consider surgical procedure–specific complications but may be less adept at predicting markers of fragility which are correlated with the likelihood of development of adverse medical complications postoperatively.[3] Rates of medical and surgical complications as well as healthcare resource utilization metrics are all higher in patients with high markers of fragility across multiple surgical fields.[12,21] In patients with high frailty status as measured by the Frailty Phenotype and Frailty Index scores, outcomes were significantly worse after elective orthopedic surgical procedures.[12] Furthermore, poor outcomes in a geriatric population with a variety of fracture types were noted in patients with a high FRAIL scale (a short 5-question assessment of fatigue, resistance, aerobic capacity, illnesses, and loss of weight).[21]

From a hospital resource utilization standpoint, 30-day readmission rate increased from 3% to 7% and the rate of discharge to rehabilitation facility increased from 8% to 33% as the mFI score increased from 0 to 2 or greater. We add to the literature another risk factor metric which can be utilized for treatment stratification for PHFs. The Elixhauser measure for mortality prediction has been shown to effectively predict mortality as well as likelihood for development of postoperative complications after fixation of these fractures.[38] Furthermore, a recent study indicated that factors such as insurance status, geographic region, timing of emergency department visit, Charlson Comorbidity Index, and hospital type are associated with inpatient admission for PHFs, lengthening the hospital stay and increasing the total cost.[39] While a variety of risk factor scoring systems exists, we intentionally utilized the 5-item mFI in this analysis for several reasons. First, to increase orthopedic surgeon consideration of patient fragility in the surgical decision-making process for PHFs, a simple yet effective tool is optimal. The 5-item mFI takes less time to administer than the 11-item mFI and other risk factor assessment tools and is also easily amenable to memorization. In addition, the 5-item mFI when compared with the 11-item mFI appears equally efficacious, and it has been utilized already to describe complication risk after fractures of the distal radius.[64,71]

Any large database study has several inherent limitations, and the NSQIP database is not immune from restrictions in application of data obtained within. First, there is ongoing debate about clinical significance of findings that achieve statistical significance despite a small effect size given a very large sample pool.[34] We demonstrate sizeable differences between cohorts (for example, the rate of discharge to rehabilitation facility increasing from 8% to 33% as the mFI score increased from 0 to 2 or greater) that would likely remain statistically significant even in smaller sample sizes. These findings are very likely to be clinically significant in the assessment of patients with high degree of fragility. As another limitation, the NSQIP is not an orthopedic surgery–specific database. Thus, it does not allow for inclusion of many outcomes of special interest, such as specific neurovascular compromise, malunion and nonunion rates, radiographic alignment parameters, hardware-specific complication rates, postoperative range of motion, and patient-reported postoperative functionality metrics. It is reasonable to assume that several of these outcomes would be adversely affected by a higher mFI score, and future work should aim to quantify these effect sizes.

A third limitation is the NSQIP database documents complications only if they occurred within a 30-day window after surgery and only patients undergoing surgery in the hospital setting are included. For this reason, complications occurring more than 30 days after surgery and patients who received their surgery at an ambulatory surgery center were not included in our multivariate regression model. As a final limitation, the NSQIP database does not allow for stratification between various forms of operative intervention for PHFs (for example, whether a patient received ORIF or RSA). The intention of our study was not to directly compare these treatment modalities but rather to quantify the effect of high mFI scores on patients undergoing operative treatment of PHFs, encompassing all fixation strategies as well as RSA. Furthermore, the database does not allow for stratification within RSA undertaken for treating either osteoarthritis or PHF, ultimatley resulting in an unknown number of PHFs treated by RSA not being included in the analysis.

Regardless of these limitations, we demonstrate markedly worse outcomes with high mFI scores, indicating that caution should be taken in choosing any form of operative intervention in patients with a high comorbidity burden. Future research should aim to perform a subgroup analysis on various surgical interventions for PHFs to delineate mFI efficacy in predicting risk for specific procedures.

Conclusion

Nonoperative vs. surgical management stratification of PHFs remains a topic of much debate within the orthopedic community. Given a significantly higher risk of adverse outcomes after surgical treatment for these fractures in patients with a high mFI score, comorbidity burden should contribute to treatment planning. The 5-item mFI is a simple, easily memorizable tool orthopedic surgeons can use to help risk stratify their patients. Future research should elaborate on mFI contribution to orthopedic-specific complications after PHFs not contained within the NSQIP and to elaborate on complications occurring outside of the 30-day postoperative window.

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References

1. Abraham NS, Hartman C, Richardson P, Castillo D, Street RL Jr, Naik AD. Risk of lower and upper gastrointestinal bleeding, transfusions, and hospitalizations with complex antithrombotic therapy in elderly patients. Circulation 2013;128:1869-77. https://doi.org/10.1161/CIRCULATIONAHA.113.004747.
2. Ali R, Schwalb JM, Nerenz DR, Antoine HJ, Rubinfeld I. Use of the modified frailty index to predict 30-day morbidity and mortality from spine surgery. J Neurosurg Spine 2016;25:537-41. https://doi.org/10.3171/2015.10.SPINE14582.
3. Archibald MM, Lawless M, Gill TK, Chehade MJ. Orthopaedic surgeons' perceptions of frailty and frailty screening. BMC Geriatr 2020;20:17. https://doi.org/10.1186/s12877-019-1404-8.
4. Barlow JD, Logli AL, Steinmann SP, Sems SA, Cross WW, Yuan BJ, et al. Locking plate fixation of proximal humerus fractures in patients older than 60 years continues to be associated with a high complication rate. J Shoulder Elbow Surg 2020;29:1689-94. https://doi.org/10.1016/j.jse.2019.11.026.
5. Bateni SB, Bold RJ, Meyers FJ, Canter DJ, Canter RJ. Comparison of common risk stratification indices to predict outcomes among stage IV cancer patients with bowel obstruction undergoing surgery. J Surg Oncol 2018;117:479-87. https://doi.org/10.1002/jso.24866.
6. Bell JE, Leung BC, Spratt KF, Koval KJ, Weinstein JD, Goodman DC, et al. Trends and variation in incidence, surgical treatment, and repeat surgery of proximal humeral fractures in the elderly. J Bone Joint Surg Am 2011;93:121-31. https://doi.org/10.2106/JBJS.I.01505.
7. Bellamy JL, Runner RP, Vu CCL, Schenker ML, Bradbury TL, Roberson JR. Modified Frailty Index Is an Effective Risk Assessment Tool in Primary Total Hip Arthroplasty. J Arthroplasty 2017;32:2963-8. https://doi.org/10.1016/j.arth.2017.04.056.
8. van Eck CF, Klein CM, Rahmi H, Scheidt KB, Schultzel M, Lee BK, Itamura JM. Morbidity, mortality and cost of osteoporotic fractures—should proximal humerus fractures be taken as seriously as hip fractures? Annals of Joint 2019;4. https://doi.org/10.21037/aoj.2019.01.01.
9. Chen TY, Lin CE, Chen LF, Tzeng NS. Enhanced bleeding risk in an elderly dementia patient treated with warfarin and quetiapine. J Neuropsychiatry Clin Neurosci 2013;25:E25. https://doi.org/10.1176/appi.neuropsych.12090232.
10. Chen X, Yu ZX, Wang HY, Shen F, Lin GB, Wang S, et al. Proximal humeral internal locking plate combined with a custom neutral-position shoulder and elbow sling for proximal humerus fractures: A randomized study. Medicine (Baltimore) 2019;98:e15271. https://doi.org/10.1097/MD.0000000000015271.
11. Chimukangara M, Helm MC, Frelich MJ, Bosler ME, Rein LE, Szabo A, et al. A 5-item frailty index based on NSQIP data correlates with outcomes following paraesophageal hernia repair. Surg Endosc 2017;31:2509-19. https://doi.org/10.1007/s00464-016-5253-7.
12. Cooper Z, Rogers SO Jr, Ngo L, Guess J, Schmitt E, Jones RN, et al. Comparison of Frailty Measures as Predictors of Outcomes After Orthopedic Surgery. J Am Geriatr Soc 2016;64:2464-71. https://doi.org/10.1111/jgs.14387.
13. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. Acta Orthop Scand 2001;72:365-71.
14. Darnell SW, Davis SC, Whitcomb JJ, Manfredi JA, McLaurin BT. Bleeding risk factors affecting warfarin therapy in the elderly with atrial fibrillation. Dimens Crit Care Nurs 2014;33:57-63. https://doi.org/10.1097/DCC.0000000000000022.
15. Dixit A, Cautela FS, Cooper CS, Beyer GA, Messina JC, Mait JE, et al. ORIF versus arthroplasty for open proximal humerus fractures: Nationwide Inpatient Sample data between 1998 and 2013. J Orthop Traumatol 2018;19:12. https://doi.org/10.1186/s10195-018-0503-1.
16. Ehlert BA, Najafian A, Orion KC, Malas MB, Black JH 3rd, Abularrage CJ. Validation of a modified Frailty Index to predict mortality in vascular surgery patients. J Vasc Surg 2016;63:1595-1601.e1592. https://doi.org/10.1016/j.jvs.2015.12.023.
17. Ferrel JR, Trinh TQ, Fischer RA. Reverse total shoulder arthroplasty versus hemiarthroplasty for proximal humeral fractures: a systematic review. J Orthop Trauma 2015;29:60-8. https://doi.org/10.1097/BOT.0000000000000224.
18. Fisher C, Tee J. Editorial: The utility of the modified frailty index for risk stratification in patients undergoing spine surgery. J Neurosurg Spine 2016;25:535-6. https://doi.org/10.3171/2016.1.SPINE151261.
19. Flexman AM, Charest-Morin R, Stobart L, Street J, Ryerson CJ. Frailty and postoperative outcomes in patients undergoing surgery for degenerative spine disease. Spine J 2016;16:1315-23. https://doi.org/10.1016/j.spinee.2016.06.017.
20. Fraser AN, Bjordal J, Wagle TM, Karlberg AC, Lien OA, Eilertsen L, et al. Reverse Shoulder Arthroplasty Is Superior to Plate Fixation at 2 Years for Displaced Proximal Humeral Fractures in the Elderly: A Multicenter Randomized Controlled Trial. J Bone Joint Surg Am 2020;102:477-85. https://doi.org/10.2106/JBJS.19.01071.
21. Gleason LJ, Benton EA, Alvarez-Nebreda ML, Weaver MJ, Harris MB, Javedan H. FRAIL Questionnaire Screening Tool and Short-Term Outcomes in Geriatric

Fracture Patients. J Am Med Dir Assoc 2017;18:1082-6. https://doi.org/10.1016/j.jamda.2017.07.005.
22. Harper P, Young L, Merriman E. Bleeding risk with dabigatran in the frail elderly. N Engl J Med 2012;366:864-6. https://doi.org/10.1056/NEJMc1112874.
23. Iyengar JJ, Devcic Z, Sproul RC, Feeley BT. Nonoperative treatment of proximal humerus fractures: a systematic review. J Orthop Trauma 2011;25:612-7. https://doi.org/10.1097/BOT.0b013e3182008df8.
24. Johnson NA, Pandey R. Proximal humerus fracture-dislocation managed by mini-open reduction and percutaneous screw fixation. Shoulder Elbow 2019;11:353-8. https://doi.org/10.1177/1758573218791815.
25. Kampfen P, Mean M, Limacher A, Righini M, Jaeger K, Beer HJ, et al. Risk of falls and bleeding in elderly patients with acute venous thromboembolism. J Intern Med 2014;276:378-86. https://doi.org/10.1111/joim.12236.
26. Launonen AP, Lepola V, Saranko A, Flinkkila T, Laitinen M, Mattila VM. Epidemiology of proximal humerus fractures. Arch Osteoporos 2015;10:209. https://doi.org/10.1007/s11657-015-0209-4.
27. Launonen AP, Sumrein BO, Reito A, Lepola V, Paloneva J, Jonsson KB, et al. Operative versus non-operative treatment for 2-part proximal humerus fracture: A multicenter randomized controlled trial. PLoS Med 2019;16:e1002855. https://doi.org/10.1371/journal.pmed.1002855.
28. Law TY, Rosas S, George F, Kurowicki J, Formaini N, Levy J. Short-Term Projected Use of Reverse Total Shoulder Arthroplasty in Proximal Humerus Fracture Cases Recorded in Humana's National Private-Payer Database. Am J Orthop (Belle Mead NJ) 2017;46:E28-31.
29. Leiss W, Mean M, Limacher A, Righini M, Jaeger K, Beer HJ, et al. Polypharmacy is associated with an increased risk of bleeding in elderly patients with venous thromboembolism. J Gen Intern Med 2015;30:17-24. https://doi.org/10.1007/s11606-014-2993-8.
30. Leven DM, Lee NJ, Kothari P, Steinberger J, Guzman J, Skovrlj B, et al. Frailty Index Is a Significant Predictor of Complications and Mortality After Surgery for Adult Spinal Deformity. Spine (Phila Pa 1976) 2016;41:E1394-401. https://doi.org/10.1097/BRS.0000000000001886.
31. Lim TE, Ochsner PE, Marti RK, Holscher AA. The results of treatment of comminuted fractures and fracture dislocations of the proximal humerus. Neth J Surg 1983;35:139-43.
32. Lip GY, Clementy N, Pericart L, Banerjee A, Fauchier L. Stroke and major bleeding risk in elderly patients aged >/=75 years with atrial fibrillation: the Loire Valley atrial fibrillation project. Stroke 2015;46:143-50. https://doi.org/10.1161/STROKEAHA.114.007199.
33. Lip GY, Frison L, Halperin JL, Lane DA. Comparative validation of a novel risk score for predicting bleeding risk in anticoagulated patients with atrial fibrillation: the HAS-BLED (Hypertension, Abnormal Renal/Liver Function, Stroke, Bleeding History or Predisposition, Labile INR, Elderly, Drugs/Alcohol Concomitantly) score. J Am Coll Cardiol 2011;57:173-80. https://doi.org/10.1016/j.jacc.2010.09.024.
34. Maltenfort MG. Understanding Large Database Studies. J Spinal Disord Tech 2015;28:221. https://doi.org/10.1097/BSD.0000000000000296.
35. Maugendre E, Gadisseux B, Chantelot C, Clavert P, Ramdane N, Werthel JD, et al. Epidemiology and mortality in older patients treated by reverse shoulder arthroplasty for displaced proximal humerus fractures. Orthop Traumatol Surg Res 2019;105:1509-13. https://doi.org/10.1016/j.otsr.2019.07.026.
36. Mechlenburg I, Rasmussen S, Unbehaun D, Amundsen A, Rasmussen JV. Patients undergoing shoulder arthroplasty for failed nonoperative treatment of proximal humerus fracture have low implant survival and low patient-reported outcomes: 837 cases from the Danish Shoulder Arthroplasty Registry. Acta Orthop 2020;91:319-25. https://doi.org/10.1080/17453674.2020.1730660.
37. Mellstrand Navarro C, Brolund A, Ekholm C, Heintz E, Hoxha Ekstrom E, Josefsson PO, et al. Treatment of humerus fractures in the elderly: A systematic review covering effectiveness, safety, economic aspects and evolution of practice. PLoS One 2018;13:e0207815. https://doi.org/10.1371/journal.pone.0207815.
38. Menendez ME, Ring D. A Comparison of the Charlson and Elixhauser Comorbidity Measures to Predict Inpatient Mortality After Proximal Humerus Fracture. J Orthop Trauma 2015;29:488-93. https://doi.org/10.1097/BOT.0000000000000380.
39. Menendez ME, Ring D. Factors associated with hospital admission for proximal humerus fracture. Am J Emerg Med 2015;33:155-8. https://doi.org/10.1016/j.ajem.2014.10.045.
40. Nowak LL, Hall J, McKee MD, Schemitsch EH. A higher reoperation rate following arthroplasty for failed fixation versus primary arthroplasty for the treatment of proximal humeral fractures: a retrospective population-based study. Bone Joint J 2019;101-B:1272-9. https://doi.org/10.1302/0301-620X.101B10.BJJ-2019-0142.R2.
41. Ondeck NT, Bohl DD, Bovonratwet P, McLynn RP, Cui JJ, Shultz BN, et al. Discriminative ability of commonly used indices to predict adverse outcomes after poster lumbar fusion: a comparison of demographics, ASA, the modified Charlson Comorbidity Index, and the modified Frailty Index. Spine J 2018;18:44-52. https://doi.org/10.1016/j.spinee.2017.05.028.
42. Padegimas EM, Maltenfort M, Lazarus MD, Ramsey ML, Williams GR, Namdari S. Future patient demand for shoulder arthroplasty by younger patients: national projections. Clin Orthop Relat Res 2015;473:1860-7. https://doi.org/10.1007/s11999-015-4231-z.
43. Palvanen M, Kannus P, Niemi S, Parkkari J. Update in the epidemiology of proximal humeral fractures. Clin Orthop Relat Res 2006;442:87-92. https://doi.org/10.1097/01.blo.0000194672.79634.78.
44. Papanicolas I, Woskie LR, Jha AK. Health Care Spending in the United States and Other High-Income Countries. JAMA 2018;319:1024-39. https://doi.org/10.1001/jama.2018.1150.
45. Patel KV, Brennan KL, Brennan ML, Jupiter DC, Shar A, Davis ML. Association of a modified frailty index with mortality after femoral neck fracture in patients aged 60 years and older. Clin Orthop Relat Res 2014;472:1010-7. https://doi.org/10.1007/s11999-013-3334-7.
46. Petros RSB, Ribeiro FR, Tenor AC, Brasil R, Filardi CS, Molin DCD. Proximal Humerus Fracture with Locking Plate: Functional and Radiographic Results. Acta Ortop Bras 2019;27:164-8. https://doi.org/10.1590/1413-785220192703142049.
47. Piatkowski K, Kwiatkowski K, Piekarczyk P, Przybycien M, Zaborowski D. Outcome of comminuted proximal humerus fracture treatment with locking compression plate. Pol Orthop Traumatol 2013;78:239-46.
48. Postacchini R, Castagna A, Borroni M, Cinotti G, Postacchini F, Gumina S. Total shoulder arthroplasty for the treatment of failed hemiarthroplasty in patients with fracture of the proximal humerus. J Shoulder Elbow Surg 2012;21:1542-9. https://doi.org/10.1016/j.jse.2011.12.007.
49. Quilliam BJ, Lapane KL, Eaton CB, Mor V. Effect of antiplatelet and anticoagulant agents on risk of hospitalization for bleeding among a population of elderly nursing home stroke survivors. Stroke 2001;32:2299-304.
50. Rangan A, Handoll H, Brealey S, Jefferson L, Keding A, Martin BC, et al. Surgical vs nonsurgical treatment of adults with displaced fractures of the proximal humerus: the PROFHER randomized clinical trial. JAMA 2015;313:1037-47. https://doi.org/10.1001/jama.2015.1629.
51. Runner RP, Bellamy JL, Vu CCL, Erens GA, Schenker ML, Guild GN 3rd. Modified Frailty Index Is an Effective Risk Assessment Tool in Primary Total Knee Arthroplasty. J Arthroplasty 2017;32:S177-82. https://doi.org/10.1016/j.arth.2017.03.046.
52. Sabesan VJ, Lombardo D, Petersen-Fitts G, Weisman M, Ramthun K, Whaley J. National trends in proximal humerus fracture treatment patterns. Aging Clin Exp Res 2017;29:1277-83. https://doi.org/10.1007/s40520-016-0695-2.
53. Sander M, Oxlund B, Jespersen A, Krasnik A, Mortensen EL, Westendorp RG, et al. The challenges of human population ageing. Age Ageing 2015;44:185-7. https://doi.org/10.1093/ageing/afu189.
54. Schumaier A, Grawe B. Proximal Humerus Fractures: Evaluation and Management in the Elderly Patient. Geriatr Orthop Surg Rehabil 2018;9:2151458517750516. https://doi.org/10.1177/2151458517750516.
55. Shah N, Iqbal HJ, Brookes-Fazakerley S, Sinopidis C. Shoulder hemiarthroplasty for the treatment of three and four part fractures of the proximal humerus using Comprehensive(R) Fracture stem. Int Orthop 2011;35:861-7. https://doi.org/10.1007/s00264-010-1083-8.
56. Shi X, Liu H, Xing R, Mei W, Zhang L, Ding L, et al. Effect of intramedullary nail and locking plate in the treatment of proximal humerus fracture: an update systematic review and meta-analysis. J Orthop Surg Res 2019;14:285. https://doi.org/10.1186/s13018-019-1345-0.
57. Shin JI, Keswani A, Lovy AJ, Moucha CS. Simplified Frailty Index as a Predictor of Adverse Outcomes in Total Hip and Knee Arthroplasty. J Arthroplasty 2016;31:2389-94. https://doi.org/10.1016/j.arth.2016.04.020.
58. Shin JI, Kothari P, Phan K, Kim JS, Leven D, Lee NJ, et al. Frailty Index as a Predictor of Adverse Postoperative Outcomes in Patients Undergoing Cervical Spinal Fusion. Spine (Phila Pa 1976) 2017;42:304-10. https://doi.org/10.1097/BRS.0000000000001755.
59. Slobogean GP, Johal H, Lefaivre KA, MacIntyre NJ, Sprague S, Scott T, et al. A scoping review of the proximal humerus fracture literature. BMC Musculoskelet Disord 2015;16:112. https://doi.org/10.1186/s12891-015-0564-8.
60. Sobel AD, Shah KN, Paxton ES. Fixation of a Proximal Humerus Fracture With an Intramedullary Nail. J Orthop Trauma 2017;31(Suppl 3):S47-9. https://doi.org/10.1097/BOT.0000000000000909.
61. Sproul RC, Iyengar JJ, Devcic Z, Feeley BT. A systematic review of locking plate fixation of proximal humerus fractures. Injury 2011;42:408-13. https://doi.org/10.1016/j.injury.2010.11.058.
62. Steinhaus ME, Dare DM, Gulotta LV. Displaced Proximal Humerus Fractures: is a Sling as Good as a Plate? HSS J 2016;12:287-90. https://doi.org/10.1007/s11420-015-9479-z.
63. Stone MA, Namdari S. Surgical Considerations in the Treatment of Osteoporotic Proximal Humerus Fractures. Orthop Clin North Am 2019;50:223-31. https://doi.org/10.1016/j.ocl.2018.10.005.
64. Subramaniam S, Aalberg JJ, Soriano RP, Divino CM. New 5-Factor Modified Frailty Index Using American College of Surgeons NSQIP Data. J Am Coll Surg 2018;226:173-81.e78. https://doi.org/10.1016/j.jamcollsurg.2017.11.005.
65. Tilton M, Armstrong A, Wee H, Hast MW, Manogharan G, Lewis GS. Finite Element-Predicted Effects of Screw Configuration in Proximal Humerus Fracture Fixation. J Biomech Eng 2020. https://doi.org/10.1115/1.4045907.
66. Velanovich V, Antoine H, Swartz A, Peters D, Rubinfeld I. Accumulating deficits model of frailty and postoperative mortality and morbidity: its application to a national database. J Surg Res 2013;183:104-10. https://doi.org/10.1016/j.jss.2013.01.021.
67. Vijayvargiya M, Pathak A, Gaur S. Outcome Analysis of Locking Plate Fixation in Proximal Humerus Fracture. J Clin Diagn Res 2016;10:RC01-05. https://doi.org/10.7860/JCDR/2016/18122.8281.
68. Vitry AI, Roughead EE, Ramsay EN, Preiss AK, Ryan P, Gilbert AL, et al. Major bleeding risk associated with warfarin and co-medications in the elderly

population. Pharmacoepidemiol Drug Saf 2011;20:1057-63. https://doi.org/10.1002/pds.2219.

69. Wachtl SW, Marti CB, Hoogewoud HM, Jakob RP, Gautier E. Treatment of proximal humerus fracture using multiple intramedullary flexible nails. Arch Orthop Trauma Surg 2000;120:171-5.
70. Wahl TS, Graham LA, Hawn MT, Richman J, Hollis RH, Jones CE, et al. Association of the Modified Frailty Index With 30-Day Surgical Readmission. JAMA Surg 2017;152:749-57. https://doi.org/10.1001/jamasurg.2017.1025.
71. Wilson JM, Holzgrefe RE, Staley CA, Schenker ML, Meals CG. Use of a 5-Item Modified Frailty Index for Risk Stratification in Patients Undergoing Surgical Management of Distal Radius Fractures. J Hand Surg Am 2018;43:701-9. https://doi.org/10.1016/j.jhsa.2018.05.029.
72. Wu PY, Chao CT, Chan DC, Huang JW, Hung KY. Contributors, risk associates, and complications of frailty in patients with chronic kidney disease: a scoping review. Ther Adv Chronic Dis 2019;10:2040622319880382. https://doi.org/10.1177/2040622319880382.
73. Xue QL. The frailty syndrome: definition and natural history. Clin Geriatr Med 2011;27:1-15. https://doi.org/10.1016/j.cger.2010.08.009.
74. Yagi M, Michikawa T, Hosogane N, Fujita N, Okada E, Suzuki S, et al. The 5-Item Modified Frailty Index Is Predictive of Severe Adverse Events in Patients Undergoing Surgery for Adult Spinal Deformity. Spine (Phila Pa 1976) 2019;44:E1083-91. https://doi.org/10.1097/BRS.0000000000003063.
75. Yang TC, Su YP, Chang MC. The elderly have similar outcomes compared to younger patients after ORIF with locking plate for comminuted proximal humerus fracture. Acta Orthop Traumatol Turc 2019;53:1-5. https://doi.org/10.1016/j.aott.2018.12.001.
76. Zyto K. Non-operative treatment of comminuted fractures of the proximal humerus in elderly patients. Injury 1998;29:349-52.