RESEARCH ARTICLE

Higher Modified Frailty Index Score is Associated with Increased 30-Day Postoperative Complications Following Surgical Treatment of Tibial Shaft Fractures

Mitchell S. Mologne, BS; Theodore Quan, BS; Jacob D. Mikula, MD; Alexander R. Garcia, BS; Matthew J. Best, MD; Savyasachi C. Thakkar, MD

Research performed at Johns Hopkins University in Baltimore, MD, USA

Received: 6 October 2023 *Accepted: 15 June 2024*

Abstract

Objectives: This study was conducted to determine if factors comprising the mFI were correlated with adverse outcomes following surgical intervention of tibial shaft fractures.

Methods: We identified patients 50 years or older with tibial shaft fractures that were managed surgically from a national database from 2007-2019. The 5-item mFI score, which comprised of diabetes, hypertension, congestive heart failure, dependent functional status, and chronic obstructive pulmonary disease, was calculated for each patient. Regression analysis was used to evaluate the association of different mFI scores with thirty-day postoperative outcomes.

Results: 1,159 total patients (mean age of 65 years) were included in this study. After controlling for confounding variables on multivariate analysis, compared to patients with a mFI of 0, those with a score of 1 had an increased risk of major complications (OR 5.11; p=0.038), minor complications (OR 3.11; p=0.004), readmission (OR 2.75; p=0.020), postoperative transfusion (OR 2.22; p=0.037), prolonged hospital stay (OR 1.88; p<0.001), and non-home discharge (OR 1.52; p=0.014). Similar increased risk of complications was seen for patients with a mFI of 2 compared to those with a score of 0: major complications (OR 9.49; p=0.004), readmission (OR 3.73; p=0.003), postoperative transfusion (OR 4.07; p<0.001), prolonged hospital stay (OR 2.50; p<0.001), and non-home discharge (OR 2.32; p<0.001).

Conclusion: Higher scores on the mFI were associated with higher complication rates in patients following surgical treatment of tibial shaft fractures. The modified frailty index is a useful tool for surgeons to assess risk before operation.

Level of evidence: III

Keywords: Complications, Frailty, Internal fixation, mFI, NSQIP, Tibia

Introduction

Tibial shaft fractures account for nearly 2% of all adult fractures and have been reported to have a one-year mortality rate up to 42% in patients older than 75.[1-3] Most closed tibial shaft fractures in adults are managed surgically with open reduction and internal fixation (ORIF) or intramedullary nail (IMN) fixation.[4-6] There have been numerous factors reported to lead to varied outcomes following surgical treatment of tibial shaft fractures.

The modified frailty index is a 5-factor index includes five medical comorbidities that are equally weighted to predict risks, outcomes, and complications and includes the following factors: diabetes mellitus, chronic obstructive pulmonary disease (COPD) or recent pneumonia diagnosis, hypertension requiring medication, congestive heart failure (CHF), and functional status.[7] Previous studies have shown that the modified frailty index is associated with poor outcomes across a wide breadth of surgeries.[8] Phen et al. recently reported that frailty, defined using the modified frailty index, and malnutrition were risk factors for

Corresponding Author: Savyasachi C. Thakkar, Department of Orthopaedic Surgery, Johns Hopkins University, MD, USA

Email: mmologne@gmail.com

THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

complications following tibial shaft fractures. Notably, the patient population only featured patients under the age of 65.[9] With frailty primarily impacting older populations, there is currently a gap in literature looking at the combined effects of various comorbidities on outcomes following surgical fixation of tibial shaft fractures in these older groups. Additionally, there appears to be some conflicting evidence regarding whether the factors that comprise the mFI affect outcomes following tibial shaft fracture. A recent systematic review showed that smoking had a detrimental effect on healing of tibial shaft fractures, while a cohort study found that diabetes, age, sex, and smoking status did not influence union time for open tibial shaft fractures.[4,10]

Therefore, this study was conducted to determine if factors comprising the mFI were correlated with adverse outcomes following surgical intervention of tibial shaft fractures. We hypothesized that patients with higher mFI scores would have higher rates of both major and minor complications.

Materials and Methods

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2007-2019 was used for this retrospective analysis. All patient data is deidentified, and previous research has described in depth the various variables that were collected from the database.[11,12]

Patient Selection

Using International Classification of Diseases (ICD), Ninth Revision and Tenth Revision, diagnosis codes, we identified patients with tibial shaft fractures. Current Procedural Terminology codes were then used to identify patients who were treated with ORIF or IMN. Patients with missing baseline demographics data, such as gender or race, were excluded from the study. Patients less than 50 years old were also excluded, as frailty is mainly associated with aging and it is less clinically relevant in younger patients.[13] Patients with missing data for variables included in the mFI score calculation were further excluded.

Patient Characteristics

Various patient characteristics were collected, including age, gender, race, body mass index (BMI), and American Society of Anesthesiologists (ASA) score. BMI was further sub-categorized into different weight classes: underweight (<18.5 kg/m^2), normal weight (18.5-24.9), overweight (25.0-29.9), obese (30.0-34.9), severely obese (35.0-39.9), and morbidly obese (≥40.0).

The 5-item mFI score was calculated for each patient by matching the variables in NSQIP to the original frailty index as described by Velanovich et al.[8,14] The 5-item mFI is a validated index that has been used widely in surgical fields.[13,15] One point was assigned to each of the 5 conditions listed as part of the mFI and mFI scores were calculated by taking the sum of points for each individual. These comorbid variables included diabetes mellitus, CHF, hypertension, COPD or pneumonia, and dependent functional status [Table 1]. Patients who had a dependent functional status were defined as those needing the help of another individual for everyday living activities, such as feeding, bathing, and dressing.

Table 1. The Five Items Included in the 5-item mFI

Items
1. Diabetes mellitus: non-insulin or insulin dependent
2. CHF within 30 days before surgery
3. Hypertension requiring medication
4. History of COPD or pneumonia
5. Partially or totally dependent functional health status before surgery

mFI, modified frailty index; CHF, congestive heart failure; COPD; chronic obstructive pulmonary disease.

Postoperative Outcomes

The thirty-day outcomes analyzed included major and minor complications. Based on past literature, major complications included cardiac arrest, pulmonary embolism, unplanned reintubation, myocardial infarction, sepsis, septic shock, renal failure, or mortality; minor complications included urinary tract infection, deep vein thrombosis, pneumonia, or superficial/deep surgical site infection.[16] Other outcomes assessed included readmission, revisit to the surgical suite, postoperative bleeding requiring transfusion, prolonged hospital stay, and discharge to a non-home location. Extended length of hospital stay was specified as more than three days.[17]

Statistical Analysis

Baseline patient characteristics were analyzed using descriptive analyses. Multiple regression models were then used to further analyze the differences in postoperative outcomes among the varying mFI scores. The multiple regression analyses controlled for gender, age, race, BMI, and total operation time, and these results were reported as odds ratios with 95% confidence intervals. Statistical significance was determined by a p-value less than 0.05 and all analyses were done utilizing the Statistical Package for the Social Sciences Version 28 software.

Results

Characteristics

Overall, 1,159 patients undergoing operative treatment for tibial shaft fracture were included in the study [Table 2]. The mean patient age was 65 years, and 58.0% were female. The mean patient BMI was 29.2 kg/m^2, with 32.7% being overweight, 23.0% being normal weight, and 20.8% being obese. The most common race for the patients was White (79.6%) and most of the patients had an ASA score of III (54.3%). Since the majority of the patients had an mFI score of 0 (35.5%), 1 (34.7%) or 2 (22.4%), patients with an mFI score of 3 (6.6%), 4 (0.7%), or 5 (0.2%) were combined with the patients who had a score of 2, which is consistent with prior studies [Table 2].[18]

Postoperative Complications

After conducting a bivariate analysis, when compared to patients with an mFI of 0, those with an mFI of 1 were more likely to develop major complications (p=0.006), minor complications (p=0.002), require readmission (p=0.005), postoperative transfusion (p=0.003), prolonged hospital stay (p<0.001), and be discharged to a destination other than

home (p<0.001). Also relative to patients with an mFI of 0, those with an mFI of 2 or greater had increased likelihood of experiencing major complications (p<0.001), readmission (p<0.001), postoperative transfusion (p<0.001), extended length of hospital stay (p<0.001), and non-home discharge (p<0.001). In comparison to an mFI of 1, an mFI of 2 or greater were more likely to develop major complications (p=0.041), postoperative transfusion (p=0.022), prolonged hospital stay (p=0.008), and discharge to a non-home location (p<0.001) [Table 3].

Table 2. Baseline Characteristics for Tibial Shaft Fracture Patients

Variable	Overall
Total patients, n	1,159
Gender, %	
Female	58.0
Male	42.0
Age, mean (SD), years	64.81 (10.59)
BMI, mean (SD), kg/m²	29.17 (7.56)
BMI Category, %	
Underweight (<18.5)	4.2
Normal Weight (18.5-24.9)	23.0
Overweight (25.0-29.9)	32.7
Obese (30.0-34.9)	20.8
Severely Obese (35.0-39.9)	10.2
Morbidly Obese (≥40.0)	7.2
Race, %	
White	79.6
Black or African American	9.7
Hispanic	7.8
American Indian	0.6
Asian	2.1
Native Hawaiian or Pacific Islander	0.3
ASA Class, %	
I	3.0
II	34.9
III	54.3
IV	7.8
mFI Score, %	
0	35.5
1	34.7
2	22.4
3	6.6
4	0.7
5	0.2

SD, standard deviation; BMI, body mass index; ASA, American Society of Anesthesiologists; mFI, modified frailty index.

Table 3. Bivariate Analysis of Complications for Tibial Shaft Fracture Patients

Complications	mFI 0	mFI 1	p-value: mFI 1 vs mFI 0¶	mFI > 2	p-value: mFI > 2 vs mFI 0¶	p-value: mFI > 2 vs mFI 1¶
Total patients, n	411	402		346		
*Major complication, n (%) ** *	2 (0.5)	12 (3.0)	0.006	21 (6.1)	< 0.001	0.041
Minor complication, n (%) ††	10 (2.4)	28 (7.0)	0.002	17 (4.9)	0.067	0.239
Readmission, n (%)	8 (2.6)	22 (7.6)	0.005	30 (11.1)	< 0.001	0.155
Reoperation, n (%)	4 (1.0)	8 (2.0)	0.231	8 (2.3)	0.143	0.761

Table 3. Continued						
Postoperative transfusion, n (%)	11 (2.7)	29 (7.2)	0.003	42 (12.1)	< 0.001	0.022
Extended length of stay (> 3 days), n (%)	134 (32.6)	211 (52.5)	< 0.001	215 (62.1)	< 0.001	0.008
Non-home discharge, n (%)	114 (28.9)	182 (47.6)	< 0.001	211 (63.2)	< 0.001	< 0.001

¶Pearson's chi-squared test
**Includes cardiac arrest, pulmonary embolism, myocardial infarction, unplanned intubation, sepsis, septic shock, acute renal failure, or mortality.
††Includes urinary tract infection, pneumonia, deep venous thrombosis, superficial surgical site infection, or deep surgical site infection.
Bolding equals significance p<0.05
mFI, modified frailty index.

After controlling for patient demographics on multivariate analysis, compared to an mFI of 0, an mFI of 1 had an increased risk of major complications (OR 5.11; 95% CI 1.09 to 23.95; p=0.038), minor complications (OR 3.11; 95% CI 1.43 to 6.77; p=0.004), readmission (OR 2.75; 95% CI 1.17 to 6.48; p=0.020), postoperative transfusion (OR 2.22; 95% CI 1.05 to 4.71; p=0.037), prolonged hospital stay (OR 1.88; 95% CI 1.38 to 2.55; p<0.001), and non-home discharge (OR 1.52; 95% CI 1.09 to 2.12; p=0.014). Similar increased risk of complications were seen for patients with a mFI of 2 compared to those with a score of 0: major complications (OR 9.49; 95% CI 2.02 to 44.54; p=0.004), readmission (OR 3.73; 95% CI 1.56 to 8.91; p=0.003), postoperative transfusion (OR 4.07; 95% CI 1.90 to 8.69; p<0.001), prolonged hospital stay (OR 2.50; 95% CI 1.78 to 3.52; p<0.001), and non-home discharge (OR 2.32; 95% CI 1.61 to 3.35; p<0.001). Compared to an mFI of 1, an mFI of 2 or greater had a heightened risk of postoperative transfusion (OR 1.74; 95% CI 1.02 to 2.95; p=0.041) and discharge to a location other than home (OR 1.63; 95% CI 1.17 to 2.28; p=0.004) [Table 4].

Table 4. Multivariate Analysis of Complications for Tibial Shaft Fracture Patients

Complications	mFI 1 (reference group is mFI 0)		mFI > 2 (reference group is mFI 0)		mFI > 2 (reference group is mFI 1)	
	p-value	***Odds ratio (95% CI)***	***p-value***	***Odds ratio (95% CI)***	***p-value***	***Odds ratio (95% CI)***
*Major complication***	0.038	5.114 (1.092 to 23.952)	0.004	9.488 (2.021 to 44.542)	0.075	1.993 (0.934 to 4.256)
Minor complication††	0.004	3.107 (1.425 to 6.772)	0.175	1.869 (0.757 to 4.611)	0.219	0.668 (0.351 to 1.271)
Readmission	0.020	2.754 (1.170 to 6.478)	0.003	3.725 (1.558 to 8.910)	0.321	1.358 (0.742 to 2.484)
Postoperative transfusion	0.037	2.221 (1.048 to 4.705)	< 0.001	4.066 (1.904 to 8.686)	0.041	1.736 (1.022 to 2.947)
Extended length of stay (> 3 days)	< 0.001	1.875 (1.381 to 2.545)	< 0.001	2.503 (1.782 to 3.517)	0.091	1.308 (0.958 to 1.785)
Non-home discharge	0.014	1.517 (1.087 to 2.117)	< 0.001	2.321 (1.607 to 3.352)	0.004	1.632 (1.166 to 2.283)

**Includes cardiac arrest, pulmonary embolism, myocardial infarction, unplanned intubation, sepsis, septic shock, acute renal failure, or mortality.
††Includes urinary tract infection, pneumonia, deep venous thrombosis, superficial surgical site infection, or deep surgical site infection.
Bolding equals significance p<0.05
mFI, modified frailty index; CI, confidence interval.

We did a further stratified analysis looking at only patients with an mFI score of 2 (not including 3, 4, 5) and comparing them to an mFI score of 0 and 1 [Supplemental Table 1]. This new stratified analysis continued to show that mFI scores of 2 were more likely experience major complications (p<0.001), readmission (p=0.019), postoperative transfusion (p<0.001), extended length of stay (p<0.001), and non-home discharge (p<0.001) when compared to patients with an mFI score of 0. When compared to mFI scores of 1, mFI scores of 2 only had significantly higher rates of postoperative non-home discharge (p<0.001) [Supplemental Table 2].

Supplemental Table *1*. Baseline Characteristics for Tibial Shaft Fracture Patients

Variable	Overall
Total patients, n	1,073
Gender, %	
Female	58.1
Male	41.9
Age, mean (SD), years	64.81 (10.59)

Supplemental Table *1*. Continued	
BMI, mean (SD), kg/m2	29.17 (7.56)
BMI Category, %	
Underweight (<18.5)	4.4
Normal Weight (18.5-24.9)	24.4
Overweight (25.0-29.9)	32.3
Obese (30.0-34.9)	20.8
Severely Obese (35.0-39.9)	9.8
Morbidly Obese (>40.0)	6.4
Race, %	
White	79.7
Black or African American	10.1
Hispanic	7.5
American Indian	0.5
Asian	2.1
Native Hawaiian or Pacific Islander	0.3
ASA Class, %	
I	3.3
II	37.7
III	52.9
IV	6.2
mFI Score, %	
0	38.3
1	37.5
2	24.2

SD, standard deviation; BMI, body mass index; ASA, American Society of Anesthesiologists; mFI, modified frailty index.

Supplemental Table *2*. Bivariate Analysis of Complications for Tibial Shaft Fracture Patients

Complications	mFI 0	mFI 1	p-value: mFI 1 vs mFI 0¶	mFI 2	p-value: mFI 2 vs mFI 0¶	p-value: mFI 2 vs mFI 1¶
Total patients, n	411	402		260		
*Major complication, n (%) ** *	2 (0.5)	12 (3.0)	0.006	13 (5.0)	< 0.001	0.184
Minor complication, n (%) ††	10 (2.4)	28 (7.0)	0.002	9 (3.5)	0.434	0.055
Readmission, n (%)	8 (2.6)	22 (7.6)	0.005	14 (6.8)	0.019	0.749
Reoperation, n (%)	4 (1.0)	8 (2.0)	0.231	6 (2.3)	0.166	0.781
Postoperative transfusion, n (%)	11 (2.7)	29 (7.2)	0.003	30 (11.5)	< 0.001	0.057
Extended length of stay (> 3 days), n (%)	134 (32.6)	211 (52.5)	< 0.001	150 (57.7)	< 0.001	0.189
Non-home discharge, n (%)	114 (28.9)	182 (47.6)	< 0.001	158 (62.0)	< 0.001	< 0.001

¶Pearson's chi-squared test
**Includes cardiac arrest, pulmonary embolism, myocardial infarction, unplanned intubation, sepsis, septic shock, acute renal failure, or mortality.
††Includes urinary tract infection, pneumonia, deep venous thrombosis, superficial surgical site infection, or deep surgical site infection.
Bolding equals significance p<0.05
mFI, modified frailty index.

When conducting a multivariate analysis with this new stratified cohort, patients with a score of 2 had significantly higher odds of major complications (OR 9.34, 95% CI 1.83 to 47.77; p=0.007), postoperative transfusion (OR 4.77, 95% CI 2.12 to 10.72, p<0.001), extended length of stay (OR 2.06, 95% CI 1.43 to 2.96; p<0.001), and non-home discharge (OR 2.40, 95% CI 1.61 to 3.56; p<0.001), but no longer had significantly increased odds of readmission (OR

2.48, 95% CI 0.92 to 6.72; p=0.073) as seen in the initial analysis. When compared to mFI scores of 1, patients with an mFI score of 2 had significantly higher odds of postoperative transfusion (OR 1.78, 95% CI 1.00 to 3.17; p=0.050), and non-home discharge (OR 1.62, 95% CI 1.13 to 2.32; p=0.009) [Supplemental Table 3].

Supplemental Table *3*. Multivariate Analysis of Complications for Tibial Shaft Fracture Patients

Complications	mFI 1 (reference group is mFI 0)		mFI 2 (reference group is mFI 0)		mFI 2 (reference group is mFI 1)	
	p-value	***Odds ratio (95% CI)***	***p-value***	***Odds ratio (95% CI)***	***p-value***	***Odds ratio (95% CI)***
*Major complication***	0.038	5.114 (1.092 to 23.952)	0.007	9.344 (1.828 to 47.767)	0.223	1.680 (0.730 to 3.867)
Minor complication††	0.004	3.107 (1.425 to 6.772)	0.381	1.594 (0.562 to 4.525)	0.062	0.473 (0.216 to 1.039)
Readmission	0.020	2.754 (1.170 to 6.478)	0.073	2.484 (0.918 to 6.726)	0.667	0.853 (0.414 to 1.759)
Postoperative transfusion	0.037	2.221 (1.048 to 4.705)	< 0.001	4.766 (2.119 to 10.718)	0.050	1.780 (1.001 to 3.166)
Extended length of stay (> 3 days)	< 0.001	1.875 (1.381 to 2.545)	< 0.001	2.057 (1.428 to 2.963)	0.587	1.097 (0.785 to 1.533)
Non-home discharge	0.014	1.517 (1.087 to 2.117)	< 0.001	2.398 (1.614 to 3.562)	0.009	1.619 (1.129 to 2.321)

**Includes cardiac arrest, pulmonary embolism, myocardial infarction, unplanned intubation, sepsis, septic shock, acute renal failure, or mortality.
††Includes urinary tract infection, pneumonia, deep venous thrombosis, superficial surgical site infection, or deep surgical site infection.
Bolding equals significance p<0.05
mFI, modified frailty index; CI, confidence interval.

Discussion

The primary finding of this study revealed that mFI scores of 1 exhibited significantly higher rates of both major and minor complications when compared to mFI scores of 0. The same results were also seen when comparing an mFI of 2 to an mFI of 0. A higher rate of major complications such as cardiac arrest, pulmonary embolism, or sepsis, was seen in patients with an mFI score of 2 or above compared to those with a score of 1; however, this was not seen when only comparing patients with an mFI of 2 and patients with an mFI of 1.

Comorbidity indexes are commonly utilized to risk stratify certain patient groups, especially the elderly. Historically, the Charlson Comorbidity Index (CCI) as well as the Elixhauser Comorbidity Measure (ECM) have been used to predict the risk of adverse outcomes from surgical intervention; higher scores on both the CCI and ECM have been linked with negative outcomes including complications or mortality.[19-23] However, the CCI and ECM take into account 17 and 30 comorbidities in their indices, which can be time-consuming to calculate.

The 5-factor modified frailty index was created as a more efficient method of risk stratifying patients, and has performed similarly to other indices.[24,25] It has been widely studied within the realm of orthopedics and previous literature has shown its strength in predicting unfavorable outcomes, readmission, and mortality especially within trauma.[9, 26-30] Phen and colleagues observed that patients under 65 who were either frail (defined as mFI of 2 or above and albumin levels of over 3.5 g/dL) and/or malnourished (mFI of 1 or lower and albumin levels below 3.5 g/dL) had significantly elevated rates of postoperative complications and mortality following lower extremity trauma surgeries when compared with their healthy counterparts.[8] Similarly, Tracy et al. reported that trauma patients with elevated mFI scores exhibited increased frequency of unplanned intubations, admission to an intensive care unit, complications, and mortality.[31] Our study yields similar conclusions, as patients with higher scores on the mFI had higher rates of both major and minor complications.

Comorbidities included in the modified frailty index have previously been studied in isolation in tibial fractures.[7,21,32] Saiz Jr. and colleagues investigated several patient comorbidities following open tibial fractures and found that that COPD, hypertension, diabetes, and congestive heart failure were all independently associated with higher infection rates.[33] Similarly, when managing open tibial shaft fractures, Upfill-Brown et al. reported that diabetes and COPD were both linked with higher likelihood of postoperative blood transfusions in patients treated operatively for open tibial shaft fractures and that CHF and hypertension were both independently associated with higher complication rates.[34] While these comorbidities within the mFI have been studied as independent risk factors, as a whole, our study shows that a higher mFI score is also associated with higher transfusion and complication rates. The mFI-5 incorporates these established risk factors and can more effectively identify at-risk patients than looking at these factors individually.

This study is not without limitations. Similar to other database studies, these results are limited by inaccurate reporting or coding errors that may come with retrospective analysis. Also, our study only observed complications that occurred within a 30-day post-operative window, and therefore did not account for complications after 30 days. Future studies should be conducted to evaluate longer-term outcomes. Tibial shaft fractures often occur in polytrauma patients, but these concomitant injuries were not included in

the analysis. In addition, we did not categorize the severity of the complications seen with increased mFI. Future investigation should focus on the severity of different complications seen with increased mFI scores. Lastly, while frailty index scores are simple to calculate, they may miss the nuance that comes from a formal clinical examination performed by a geriatrician. Despite these limitations, our findings suggest that the mFI is quick and useful to help identify risk within certain patient populations for surgical intervention for tibial shaft fractures.

Conclusion

Higher scores on the mFI were associated with higher complication rates in patients following surgical treatment of tibial shaft fractures. The modified frailty index is valuable for surgeons to assess risk before operation.

Acknowledgement

N/A

Authors Contribution:

Mitchell S Mologne: Conceptualization, Writing - original draft, Writing review and editing,

Theodore Quan: Conceptualization, Data Curation, Formal Analysis, Writing- review and editing

Jacob D. Mikula - Conceptualization, Writing - review and editing

Alex Garcia - Conceptualization, Writing - original draft, Writing - review and editing

Matthew J Best - Conceptualization, Methodology, Supervision, Writing - review and editing

Savyasachi C Thakkar - Conceptualization, Methodology, Supervision, Writing - review and editing

Declaration of Conflict of Interest: The authors do NOT have any potential conflicts of interest for this manuscript.

Declaration of Funding: The authors of this study received NO financial support for the preparation, research, authorship, and publication of this manuscript.

Declaration of Ethical Approval for Study: Approval was not necessary for this study as data from a national database was used.

Declaration of Informed Consent: Informed Consent was not necessary for this study as data from a national database was used.

Mitchell S. Mologne BS [1]
Theodore Quan BS [2]
Jacob D. Mikula MD [3]
Alexander R. Garcia BS [4]
Matthew J. Best MD [3]
Savyasachi C. Thakkar MD [4]

1 Washington University School of Medicine, St. Louis, MO, USA

2 George Washington School of Medicine and Health Sciences, Washington, DC, USA

3 Renaissance School of Medicine at Stony Brook University, Stony Brook, NY, USA

4 Department of Orthopaedic Surgery, Johns Hopkins Hospital, Baltimore, BA, USA

References

1. Connelly CL, Bucknall V, Jenkins PJ, Court-Brown CM, McQueen MM, Biant LC. Outcome at 12 to 22 years of 1502 tibial shaft fractures. Bone Joint J. 2014; 96-B (10):1370-1377. doi:10.1302/0301-620X.96B10.32914.
2. Larsen P, Elsoe R, Graven-Nielsen T, Laessoe U, Rasmussen S. Decreased muscle strength is associated with impaired long-term functional outcome after intramedullary nailing of femoral shaft fracture. Eur J Trauma Emerg Surg. 2015; 41(6):673-681. doi:10.1007/s00068-014-0488-2.
3. Laurila J, Huttunen TT, Kannus P, Kääriäinen M, Mattila VM. Tibial shaft fractures in Finland between 1997 and 2014. Injury. 2019; 50(4):973-977. doi:10.1016/j.injury.2019.03.034.
4. Patel KH, Logan K, Krkovic M. Strategies and outcomes in severe open tibial shaft fractures at a major trauma center: A large retrospective case-series. World J Orthop. 2021; 12(7):495-504. 2021; 12(7):495-504. doi:10.5312/wjo.v12.i7.495.
5. Lin CA, Swiontkowski M, Bhandari M, et al. Reaming Does Not Affect Functional Outcomes after Open and Closed Tibial Shaft Fractures: The Results of a Randomized Controlled Trial. J Orthop Trauma.2016; 30(3):142-8. doi: 10.1097/BOT.0000000000000497.
6. Smith C, Ades R, Lo Y, Stallone S, Khokhar S, Gruson K. Predictors of Return to Emergency Department and Readmission Following Primary Elective Total Shoulder Arthroplasty. Arch Bone Jt Surg. 2024; 12(7).
7. Aderinto J, Keating JF. Intramedullary nailing of fractures of the tibia in diabetics. J Bone Joint Surg Br. 2008; 90(5):638-642. doi:10.1302/0301-620X.90B5.19854.
8. Wahl TS, Graham LA, Hawn MT, et al. Association of the Modified Frailty Index with 30-Day Surgical Readmission. JAMA Surg. 2017; 152(8):749-757. doi:10.1001/jamasurg.2017.1025.
9. Phen HM, Jones C, Kravets VG, et al. Impact of Frailty and Malnutrition on Outcomes after Surgical Fixation of Lower Extremity Fractures in Young Patients. J Orthop Trauma. 2021; 35(4):e126-e133. doi:10.1097/BOT.0000000000001952.
10. Mahajan A, Kumar N, Gupta B. Delayed Tibial Shaft Fracture Healing Associated with Smoking: A Systematic Review and Meta-Analysis of Observational Studies Conducted Worldwide. Int J Environ Res Public Health. 2021; 18(19):10228. doi:10.3390/ijerph181910228.
11. Malik AT, Kim J, Yu E, Khan SN. Discharge to Inpatient Care Facility After Anterior Lumbar Interbody Fusion: Incidence,

Predictors, and Postdischarge Outcomes. World Neurosurg. 2019; 122:e584-e590. doi:10.1016/j.wneu.2018.10.108.
12. Otero J, Arnold MR, Kao AM, et al. Short-term Outcomes of Esophagectomies in Octogenarians-An Analysis of ACS-NSQIP. J Surg Res. 2019; 235:432-439. doi:10.1016/j.jss.2018.07.044.
13. Holzgrefe RE, Wilson JM, Staley CA, Anderson TL, Wagner ER, database. J Surg Res. 2013; 183(1):104-110. doi:10.1016/j.jss.2013.01.021.
15. Amer KM, Congiusta DV, Suri P, Merchant AM, Vosbikian MM, Ahmed IH. Patient frailty as a risk assessment tool in surgical management of long bone fractures. J Clin Orthop Trauma. 2020; 11(Suppl 4):S591-S595. doi:10.1016/j.jcot.2020.01.007.
16. Liodakis E, Bergeron SG, Zukor DJ, Huk OL, Epure LM, Antoniou J. Perioperative Complications and Length of Stay After Revision Total Hip and Knee Arthroplasties: An Analysis of the NSQIP Database. J Arthroplasty. 2015; 30(11):1868-1871. doi:10.1016/j.arth.2015.05.029.
17. Smith EJ, Kuang X, Pandarinath R. Comparing hospital outcomes between open and closed tibia fractures treated with intramedullary fixation. Injury. 2017; 48(7):1609-1612. doi:10.1016/j.injury.2017.03.038.
18. Chimukangara M, Helm MC, Frelich MJ, et al. A 5-item frailty index based on NSQIP data correlates with outcomes following paraesophageal hernia repair. Surg Endosc. 2017; 31(6):2509-2519. doi:10.1007/s00464-016-5253-7.
19. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987; 40(5):373-383. doi:10.1016/0021-9681(87)90171-8.
20. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. Med Care. 1998; 36(1):8-27. doi:10.1097/00005650-199801000-00004.
21. Lakomkin N, Kothari P, Dodd AC, et al. Higher Charlson Comorbidity Index Scores Are Associated With Increased Hospital Length of Stay After Lower Extremity Orthopaedic Trauma. J Orthop Trauma. 2017; 31(1):21-26. doi:10.1097/BOT.0000000000000701.
22. Menendez ME, Neuhaus V, van Dijk CN, Ring D. The Elixhauser comorbidity method outperforms the Charlson index in predicting inpatient death after orthopaedic surgery. Clin Orthop Relat Res. 2014; 472(9):2878-2886. doi:10.1007/s11999-014-3686-7.
23. Sinclair ST, Emara AK, Orr MN, McConaghy KM, Klika AK, Piuzzi NS. Comorbidity indices in orthopaedic surgery: a narrative review focused on hip and knee arthroplasty. EFORT Open Rev. 2021; 6(8):629-640. doi:10.1302/2058-5241.6.200124.
24. Ondeck NT, Bohl DD, Bovonratwet P, 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 Gottschalk MB. Modified frailty index is an effective risk-stratification tool for patients undergoing total shoulder arthroplasty. J Shoulder Elbow Surg. 2019; 28(7):1232-1240. doi:10.1016/j.jse.2018.12.004.
14. 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 modified Frailty Index. Spine J. 2018; 18(1):44-52. doi:10.1016/j.spinee.2017.05.028.
25. 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(2):173-181.e8. doi:10.1016/j.jamcollsurg.2017.11.005.
26. Lee J, Alfonso AR, Kantar RS, et al. Modified Frailty Index Predicts Postoperative Complications following Panniculectomy in the Elderly. Plast Reconstr Surg Glob Open. 2020; 8(7):e2987. doi:10.1097/GOX.0000000000002987.
27. Patel NP, Elali F, Coban D, et al. The 5-factor modified Frailty Index (mFI-5) predicts adverse outcomes after elective Anterior Lumbar Interbody Fusion (ALIF). N Am Spine Soc J. 2022; 13:100189. doi:10.1016/j.xnsj.2022.100189.
28. Pean CA, Thomas HM, Singh UM, DeBaun MR, Weaver MJ, von Keudell AG. Use of a Six-Item Modified Frailty Index to Predict 30-day Adverse Events, Readmission, and Mortality in Older Patients Undergoing Surgical Fixation of Lower Extremity, Pelvic, and Acetabular Fractures. J Am Acad Orthop Surg Glob Res Rev. 2023; 7(1):e22.00286. doi:10.5435/JAAOSGlobal-D-22-00286.
29. Traven SA, Reeves RA, Althoff AD, Slone HS, Walton ZJ. New Five-Factor Modified Frailty Index Predicts Morbidity and Mortality in Geriatric Hip Fractures. J Orthop Trauma. 2019; 33(7):319-323. doi:10.1097/BOT.0000000000001455.
30. Abboud A, Masrouha K, Hanna T, Saghieh S. Union Following Biological and Rigid Fixations of Distal Tibia Extra-articular Fractures. Arch Bone Jt Surg. 2020; 8(2):162-167. doi:10.22038/abjs.2019.36760.1972.
31. Tracy BM, Wilson JM, Smith RN, Schenker ML, Gelbard RB. The 5-Item Modified Frailty Index Predicts Adverse Outcomes in Trauma. J Surg Res. 2020; 253:167-172. doi:10.1016/j.jss.2020.03.052.
32. Yong PH, Weinberg L, Torkamani N, et al. The Presence of Diabetes and Higher HbA1c Are Independently Associated With Adverse Outcomes After Surgery. Diabetes Care. 2018; 41(6):1172-1179. doi:10.2337/dc17-2304.
33. Saiz AM Jr, Stwalley D, Wolinsky P, Miller AN. Patient Comorbidities Associated With Acute Infection after Open Tibial Fractures. J Am Acad Orthop Surg Glob Res Rev. 2022; 6(9):e22.00196. doi:10.5435/JAAOSGlobal-D-22-00196.
34. Upfill-Brown A, Hwang R, Clarkson S, et al. Rates and timing of short-term complications following operative treatment of tibial shaft fractures. OTA Int. 2021; 4(4):e158. doi:10.1097/OI9.0000000000000158.