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A simplified preoperative risk assessment tool as a predictor of complications in the surgical management of forearm fractures

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ABSTRACT

Purpose: Frailty is a well-known predictor of adverse postoperative outcomes and is often considered in the preoperative planning stage of surgery. In recent years, the modified frailty index (mFI), a novel metric used to quantify frailty, has become increasingly used in the orthopedic literature as a risk assessment tool. In this study, we analyze the utility of the mFI in predicting unplanned repeat operations and morbidity in the surgical treatment forearm fractures.

Methods: We used the American College of Surgeons National Surgical Quality Improvement Program 2006–2014 dataset to identify patients undergoing open fixation of forearm fractures. The mFI was calculated based on 5 possible comorbid conditions. Demographic and predictor variables were analyzed for associations with each outcome. In order to assess frailty in both the general and elderly population, two analyses were completed: one for the entire population and one for a population of age 65 or older. The primary outcome of interest was unplanned repeat operation. Secondary outcomes included discharge destination and major post-operative complications. Chi square and logistic regression analyses were used to identify associations.

Results: A total of 4641 patients were included in our final analysis. There was a higher prevalence of females and patients between the ages of 61 and 80 compared to other age groups. An mFI score $\geq$2 was a positively associated with unplanned repeat operation in the general population. An mFI score $\geq$2 was also positively associated with a discharge destination other than home and major post-operative complications. In the elderly population, mFI $\geq$2 was similarly associated with a discharge destination other than the patient's home.

Conclusions: Patients undergoing open treatment of forearm fractures were at an increased likelihood of having an unplanned repeat operation and having major complications as frailty score increased, demonstrating that the mFI may be clinically applicable risk assessment tool for these patients.

1. Introduction

Forearm fractures constitute up to 28.9% of all orthopedic fractures.[1–3] Incidence of open surgical management is common, ranging from 6.7%[4] to 20%,[5] depending on factors such as alignment, rotation, angulation, displacement, concomitant trauma, open vs. closed injuries, and patient age. While many fractures in the young and pediatric populations can be managed conservatively due to physiologic differences from adult populations, such as thicker periosteum and substantial remodeling potential,[6–9] fractures in the elderly population are more prone to nonunion, displacement, and morbidity, often necessitating surgical intervention.[10–12] Indeed, it has been well established that predictors of adverse outcomes in this population include advanced age, decreased activity level, bone loss, and presence of concurrent disease.[10,13–15] Though independently associated with complications, grouping comorbid conditions into a composite risk assessment tool may provide a more complete understanding of a patient's functional status and risk for surgery.

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Currently, the elderly population is the fastest growing age group in the United States.[16] Unsurprisingly, patients over the age of 65 experience a larger host of comorbidities and pathology that makes them susceptible to higher rates of unplanned reoperation compared to younger populations in orthopedic surgery.[15,17,18] Unplanned adverse events contribute to the $414.3 billion of total health care expense for the elderly[19] and serve as a potential source of errors in transitions of care[20] and penalization for hospitals under new laws.[21] Developing a comprehensive understanding of perioperative risk factors at the time of surgery is therefore crucial to optimizing patient care and reducing hospital costs.

Frailty, defined as a decrease of physiologic capacity apart from normal aging,[22] is becoming increasingly recognized as a significant predictor of outcomes in the surgical literature, orthopedic surgery.[15,18,23] It is a term typically used in regard to elderly patients, but advanced age is only one contributing factor that fails to take into account many clinically relevant variables. Adapted from the Canadian Study of Health and Aging Frailty Index, the modified frailty index (mFI) is a novel, validated measure of an individual's medical, psychological, and functional status.[24] It has been adapted by Velanovich et al.[25] to be used effectively with large databases by providing a simplified, 11-point scale of patient comorbidities. It offers the advantage of giving surgeons the capability to evaluate risk based off of the medical history of patients without delay. Since its inception, modifications to the index have been made, including the 5-item mFI, which has a powerful predictive ability similar to the 11-point scale.[26] Recently, Wilson et al. used a derivation of the mFI to show its predictive value of adverse outcomes after distal radius fractures.[15] Forearm fractures, however, have not been separately investigated.

Better understanding the impact of frailty can elucidate the specific risks associated with fracture fixation. Due to the high incidence of forearm fractures and the increased risk of complications in elderly patients, we apply the new, 5-item mFI to the surgical treatment of forearm fractures and assess its predictive ability for unplanned repeat operation.

2. Materials and methods

2.1. Study population

The American College of Surgeons National Quality Improvement Program (ACS-NSQIP) 2005–2014 dataset was used for patient selection. ACS-NSQIP is a nationally-representative database that reports de-identified patient data from participating hospitals throughout the United States. Data is collected by a trained surgical clinical reviewer from the preoperative through 30-day postoperative period using a HIPAA-complaint methodology. It reports information on over 130 clinical variables, including preoperative comorbidities and postoperative outcomes.

A retrospective analysis of the NSQIP 2006–2014 dataset was performed by first selecting adult patients who underwent open surgical fixation of forearm fractures based on Current Procedural Terminology codes 24635, 24665, 24666, 24685, 25515, 25525, 25526, 25545, 25574, and 25575. In order to mitigate the effect of other concurrent surgeries performed in the patient's record, patients were included only if operative fixation was listed as the primary procedure. Patients were excluded from analysis if there were missing demographic or predictor information (i.e., data needed to calculate the mFI). We then repeated this methodology on a subset of patients aged ≥65 to assess predictability in the elderly population. No human subjects were used in this study and Institutional Review Board (IRB) exemption was obtained.

2.2. Modified frailty index (mFI)

The mFI was calculated according to previously validated methodology.[26] A binary system of patient conditions was created, in which each variable was assigned a value of "1," if present, or "0," if absent. The mFI score was then calculated by adding the value of all concurrent conditions together (Table 1). This was performed for two populations: one that included all patients age 19–100, defined as the "general population," and one that included only patients age 65 and older, defined as the "elderly population." In the general population, patients were organized into four cohorts, from 0 to ≥2. Only 70 patients with mFI = 3, 5 patients with mFI = 4, and 1 patient with mFI = 5 were identified. Comparatively, there were 2813 patients with mFI = 0 and 1311 patients with mFI = 1. In order to make sizes more comparable for analysis, mFI cohorts 2 through 5 were grouped into one cohort (mFI ≥2).

In the elderly population, we similarly combined mFI cohorts to make comparable sizes. In this age cohort, there were 458 patients with mFI = 0, 734 patients with mFI = 1, 292 patients with mFI = 2, and 57 patients with mFI ≥3. Therefore, the same cohorts were used in this elderly population: mFI = 0, 1, or ≥2.

2.3. Outcomes

The primary outcome in this study was unplanned repeat operation. An "unplanned repeat operation" is defined as a procedure performed within the 30-day postoperative period at any hospital or surgical facility participating in NSQIP related to the index or concurrent procedure.[27] Secondary outcomes included major complications, discharge destination, sepsis, pneumonia, and postoperative bleeding. For the purposes of this study, a "major complication" was defined as the presence of a deep surgical site infection, sepsis, ventilator dependence >48 h, re-intubation, acute renal failure, deep vein thrombosis, pulmonary embolism, myocardial infarction, cardiac arrest, or cerebrovascular accident. These complications were grouped into one composite variable as they generally requiring acute intervention and monitoring. NSQIP records "discharge destination" as 1 of 8 possibilities: home, skilled care facility, unskilled care facility, separate acute care, rehab, expired, or unknown. In our study, "discharge destination" was divided into two variables: "home" or "other than home," which included all known possibilities other than "home."

2.4. Statistics

Pearson's chi square test was used to identify preoperative factors associated with each outcome. The Kendall-tau test was used to assess the relationship between mFI and age cohorts. Binary logistic regression was then performed to identify any relationships between frailty and each outcome, while accounting for patient demographics and comorbidities. To be included in the regression model, a variable must have been significantly associated with the outcome in the bivariate analysis. To assess the same associations in the elderly population, a second set of analyses was performed for the "elderly" cohort, defined as patients of age ≥65 years. The threshold for significance was set at $p < 0.05$. All data were analyzed using Statistical Package for the Social Science (SPSS) version 23 (International Business Machines, Corp., Armonk, NY).

3. Results

Of the 6560 forearm fractures treated with open fixation identified in the database, 4641 (70.7%) were included in our final analysis of the general population (Table 2). Notably, 67.5% of patients with mFI scores ≥2 were 65 or older, and 22.7% were 80 or

Table 1
NSQIP[†] Variables to Calculate mFI.[a].

5-[a]tem Frailty Index Variables
COPD[b] or recent pneumonia
Congestive heart failure
Diabetes mellitus
Hypertension requiring medication
Functional status (totally or partially dependent)
Variables Included in 11-Item Frailty Index, not Included in 5-Item Index
PCI,[*] PCS,[c] or angina
Myocardial[c]Infarction
Transient ischemic attack or cerebrovascular accident
Cerebrovascular accident with neurological deficit
Impaired sensorium
Peripheral vascular disease or ischemic rest pain

[†] National Surgical Quality Improvement Program.
[a] Modified frailty index.
[b] Chronic obstructive pulmonary disease.
[*] Percutaneous coronary intervention.
[c] Prior cardiac surgery.

Table 2
Demographic and descriptive data for total and elderly study populations[a].

Total Study Population		Elderly Population, Age ≥65	
Variable	Frequency (%)	Variable	Frequency (%)
Age		Age	
≤ 40	1393 (30.0)	**65–69**	414 (26.9)
41–60	1346 (29.0)	**70–79**	589 (38.2)
61–80	1428 (30.8)	**80–89**	452 (29.3)
≥80	474 (10.2)	**≥90**	86 (5.6)
Race			
Caucasian	3725 (80.3)	**Caucasian**	1335 (86.6)
African American	359 (7.7)	**African American**	51 (3.3)
Hispanic	283 (6.1)	**Hispanic**	84 (5.5)
Other	274 (5.9)	**Other**	71 (4.6)
Female	2688 (57.9)	**Female**	1256 (81.5)
mFI[b]		**mFI**[b]	
0	2813 (60.6)	**0**	458 (29.7)
1	1311 (28.2)	**1**	734 (47.6)
≥2	517 (11.1)	**≥2**	349 (22.6)
Complications			
Unplanned Reoperation	102 (2.2%)	**Unplanned Reoperation**	40 (2.6)
Discharge Destination Other than Home	3641 (78.5)	**Discharge Destination Other than Home**	276 (17.9)
Major Complication	60 (1.3)	**Major Complication**	35 (2.3)
Sepsis	14 (0.3)	**Sepsis**	9 (0.6)
Pneumonia	10 (0.2)		
Bleeding	49 (1.1)		

[a] These variables were significantly associated with at least one outcome at $p < 0.05$.
[b] Modified Frailty Index.

older. Unplanned repeat operation occurred in 2.2% of patients in the general population. In the elderly population, the majority of patients were also female and Caucasian. Unplanned repeat operation occurred in 1.9% of these patients. There was a significant association between mFI score and age (<65 and ≥ 65) by Kendall's test (correlation coefficient 0.433, $p < 0.01$).

Regression analysis revealed that mFI ≥2 and bleeding disorders were positive predictors of unplanned repeat operation in the general population (OR = 2.09 and 2.66, respectively) (Table 3). An mFI score of 1 and ≥ 2 resulted in increased likelihood of being discharged to a destination other than the patient's home (OR = 1.73 and 3.36, respectively), while mFI ≥2 was predictive of having a major complication (OR = 3.17) in the general population (Table 4). In the elderly population aged 65 or greater, mFI ≥2 resulted in increased likelihood of discharge to a location other than home (Table 4).

4. Discussion

Our data quantify the effect of frailty on outcomes after the surgical management of forearm fractures as assessed by the 5-item mFI. The mFI specifically demonstrated a predictive value for rates of unplanned repeat operation, discharge destination to locations other than home, and major complications in the general population. For the purposes of this study, a major complication included the presence of a deep surgical site infection, sepsis, ventilator dependence >48 h, re-intubation, acute renal failure, deep vein thrombosis, pulmonary embolism, myocardial infarction, cardiac arrest, or cerebrovascular accident. These complications typically require acute intervention and monitoring. Therefore, the mFI may provide a useful way to increase awareness of risk factors associated with life-threatening problems and may better inform physicians in preoperative planning.

Table 3
Predictors of unplanned reoperation after surgical treatment of forearm fractures.

Total Study Population		Elderly Population, Age ≥65	
Variable	**Logistic Regression OR[*] (95%CI[a])**	**Variable**	**Logistic Regression OR[*] (95%CI[a])**
Age		**Age**	
16–40	Reference	**65–69**	Reference
41–60	1.24 (0.63–2.46)	**70–79**	0.90 (0.39–2.04)
61–80	1.75 (0.85–3.58)	**80–89**	1.26 (0.56–2.87)
≥81	1.67 (0.68–4.10)	**≥90**	0 (N/A)
Female (vs. male)	0.72 (0.45–1.14)	**Female (vs. male)**	0.57 (0.28–1.16)
Race		**Race**	
Caucasian	Reference	**Caucasian**	Reference
African American	0.60 (0.22–1.68)	**African American**	0 (N/A)
Hispanic	0.76 (0.30–1.91)	**Hispanic**	0.80 (0.18–3.69)
Other	0.61 (0.19–1.97)	**Other**	2.07 (0.61–7.06)
mFI[¥]		**mFI[b]**	
0	Reference	**0**	Reference
1	1.29 (0.74–2.25)	**1**	1.22 (0.54–2.79)
≥2	2.09 (1.11–3.96)[d]	**≥2**	1.59 (0.64–3.94)
Open Wound/Wound Infection	1.06 (0.47–2.41)	**Open Wound/Wound Infection**	0.69 (0.20–2.39)
Bleeding Disorder	2.66 (1.26–5.62)[d]	**Bleeding Disorder**	3.53 (1.53–8.15)[d]
Systemic Sepsis	2.38 (0.99–5.75)	**Corticosteroid Use**	1.72 (0.47–6.26)
Obesity	1.17 (0.73–1.88)	**Preoperative Blood Transfusion**	3.68 (0.41–32.93)
		On Dialysis	5.09 (0.91–28.45)

[*] Odds Ratio.
[a] Confidence interval.
[b] Modified frailty index.
[d] Significance defined as $p < 0.05$.

Table 4
Multivariate Regression Analysis for mFI ≥2 as an Independent Risk Factor for Postoperative Adverse Outcomes in the Study Population[#].

	Total Study Population		Elderly Population, Age ≥65	
Complication	OR[$], 95% CI[a]	P Value	OR,[$] 95% CI[a]	P[b]Value
Discharge Destination other than Home	3.36 (2.34–4.82)	<0.001[*]	2.45 (1.62–3.72)	<0.01[*]
Any Major Complication	3.17 (1.48–6.78)	0.003[*]	2.82 (0.97–8.19)	0.07
Sepsis	3.74 (0.47–29.7)	0.212	15.6E6 (0-Infinity)	0.992
Pneumonia	2.56 (0.18–36.72)	0.490		
Bleeding	2.08 (0.34–12.09)	0.413		

[#] All covariables from Table 2 were controlled for as appropriate.
[$] Odds Ratio.
[a] Confidence interval.
[b] Modified frailty index, - not included in regression due to insignificance in chi square analysis.
[*] Significance defined as <0.01.

Interestingly, higher mFI scores were only predictive of non-home discharge destinations in the elderly population, but not repeat operation. This contributes to existing evidence that the benefit of measuring frailty in the preoperative period provides invaluable information that may be used to predict patient outcomes in the general population, not strictly among the elderly.[28] These data may better inform medical as well as social work decisions regarding treatment, continuity of care, and patient disposition.

These data corroborate with the results of other studies in orthopedic surgery. Using the same mFI to assess risk in patients with distal radius fractures undergoing surgery, a study found that patients with elevated mFI scores were 2.5 times as likely to suffer a postoperative complication.[15] In a similar analysis, Segal et al. reported nearly 3 times increased likelihood of suffering postoperative complications in frail patients undergoing spine surgery.[18,29] There are numerous studies investigating mFI in other specialties, lending to its ubiquity across many disciplines, particularly with elderly patients.[30–32]

Currently, elderly patients represent the fastest growing age population in the United States.[33] In this population, identification of frail patients is a crucial component of the pre-operative risk assessment that may help mitigate complications and mortality by informing crucial conversations with patients perioperatively. In the current analysis, there was a significant association between mFI score and age <65 and ≥ 65. Over 30% of patients in our general population were aged 65 or over, and nearly 10% were aged 80 or older. When compared to adults under age 40, these advanced age groups were more frequently discharged to destinations other than home ($p < 0.01$).

The 5-item mFI had similar results in elderly patients. Among the most frail patients, we identified a significant increase in discharge destination to a location other than home. Elderly patients with an mFI score of ≥2 had a 2.45 times increased likelihood for each of these complications, similar to the aforementioned increased risk reported by others.[15,18,29] These results support the notion that the mFI is a strong and consistent predictor of postoperative outcomes. Importantly, it effectively measures preoperative risks in populations who are at higher risk with more comorbid diseases at baseline. As mentioned previously, however, it is erroneous to consider frailty a uniquely elderly condition. These data show that the mFI is clinically useful in the general population as well as in the elderly.

The mFI may be suitable for use in planning of forearm fracture surgery. Our study is consistent and in concert with many large,

administrative database studies on traumatic orthopedic procedures. It is calculated rapidly through readily available elements in the patient's history, which can be provided to clinicians at the bedside. This may also help in the allocation of appropriate hospital resources and services to frail patients from the onset of presentation. The 5-item mFI also allows for greater power in statistical analyses compared to the formerly used 11-item index, and has nearly identical predictive value.[26] As a result, clinicians may be just as confident in using the 5-item index as the 11-item index. This can allow for greater utility among patients in the clinical setting and in future research, as there is less potential for missing data to interfere with results. If we applied the same exclusion criteria for those who had missing data for the 11-item index, for example, we would only have 871 cases (an 81% loss of sample size).

There are several important limitations to this study. Due to the retrospective nature of our analysis, we cannot unequivocally establish a causal relationship between mFI and our outcome variables. This can only be done through a prospective, randomized study constructed to specifically address cause and effect. Furthermore, the database has inherent selection bias, since data only comes from patients who have undergone surgery. Therefore, patients who were not offered surgery due to the perceived high risks of comorbidities and prior complications are not included. NSQIP also only reports outcomes up to 30-days post-surgery. Extrapolation of data to outcomes beyond this period must be done cautiously, particularly when considering malunion or nonunion rates, as they are often reported beyond 30-days postoperatively.

While our study demonstrates the potential utility of mFI in identifying high risk patients undergoing forearm fracture fixation, it does not offer clinical recommendations beyond risk assessment. Many of the factors involved in calculating mFI are often not addressable in acute care settings. Despite this fact, awareness of patients who are more likely do poorly after surgery is information that can benefit patients, their families, and their surgeons.

5. Conclusions

The 5-item mFI is predictive of unplanned repeat operation, discharge to location other than home, and postoperative complications. These data demonstrate that frailty is a significant indicator of poor surgical outcomes in both the elderly and general population. Our results may help further inform conversations with patients about risks of surgery. Identifying frail patients in this way may allow for appropriate preoperative counseling and allocation of resources to minimize complications.

CRediT authorship contribution statement

Dominick Congiusta: Data curation, Formal analysis, Writing - original draft, Conceptualization. **Kamil Amer:** Conceptualization, Writing - original draft. **Aziz M. Merchant:** Conceptualization, Writing - original draft, Data curation. **Irfan H. Ahmed:** Conceptualization, Writing - original draft, Data curation. **Michael M. Vosbikian:** Conceptualization, Writing - original draft.

Declaration of competing interest

All authors have declared that they have no conflicts of interest for this project. This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue. The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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