North American Spine Society Journal (NASSJ) 13 (2023) 100189

Contents lists available at ScienceDirect

North American Spine Society Journal (NASSJ)

journal homepage: www.elsevier.com/locate/xnsj

Clinical Studies

The 5-factor modified Frailty Index (mFI-5) predicts adverse outcomes after elective Anterior Lumbar Interbody Fusion (ALIF)

Neil P. Patel[a,b], Faisal Elali[b], Daniel Coban[a], Stuart Changoor[a], Neil V. Shah[b], Kumar Sinha[a], Ki Hwang[a], Michael Faloon[a], Carl B. Paulino[b,c], Arash Emami[a,*]

[a] St. Joseph's University Medical Center, Department of Orthopaedic Surgery, 703 Main Street, Paterson, NJ 07503, USA
[b] The State University of New York (SUNY) Downstate Health Sciences University, Department of Orthopaedic Surgery and Rehabilitation Medicine, 450 Clarkson Avenue, Brooklyn, NY 11203, USA
[c] New York Presbyterian Brooklyn Methodist Hospital, Department of Orthopaedic Surgery, 38 6th Ave, Brooklyn, NY 11217, USA

ARTICLE INFO

Keywords:
Anterior lumbar interbody fusion
ALIF
Frailty
Modified frailty index
Complications
Lumbar

ABSTRACT

Background: The 5-factor modified frailty index (mFI-5) has been shown to be a concise and effective tool for predicting adverse events following various spine procedures. However, there have been no studies assessing its utility in patients undergoing anterior lumbar interbody fusion (ALIF). Therefore, the aim of this study was to analyze the predictive capabilities of the mFI-5 for 30-day postoperative adverse events following elective ALIF.
Methods: The National Surgical Quality Improvement Program (NSQIP) database was queried from 2010 through 2019 to identify patients who underwent elective ALIF using Current Procedural Terminology (CPT) codes in patients over the age of 50. The mFI-5 score was calculated using variables for hypertension, congestive heart failure, comorbid diabetes, chronic obstructive pulmonary disease, and partially or fully dependent functional status which were each assigned 1 point. Univariate analysis and multivariate logistic regression models were utilized to identify the associations between mFI-5 scores, and 30-day rates of overall complications, readmissions, reoperations, and mortality.
Results: 11,711 patients were included (mFI-5=0: 4,026 patients, mFI-5=1: 5,392, mFI-5=2: 2,102, mFI-5=3+: 187. Multivariate logistic regression revealed that mFI-5 scores of 1 (OR: 2.2, CI: 1.2–4.2, p=0.02), 2 (OR: 3.6, CI: 1.8–7.3, p<0.001), and 3+ (OR: 7.0, CI: 2.5–19.3, p<0.001) versus a score of 0 were significant predictors of pneumonia. An mFI-5 score of 2 (OR: 1.3; CI: 1.01–1.6, p=0.04), and 3+ (OR: 1.9; CI: 1.1–3.1; p=0.01) were both independent predictors of related readmissions. An mFI score of 3+ was an independent predictor of any complication (OR: 1.5, CI: 1.01–2.2, p=0.004), UTI (OR: 2.4, CI: 1.1–5.2, p=0.02), and unplanned intubation (OR: 4.5, CI: 1.3–16.1, p=0.02).
Conclusions: The mFI-5 is an independent predictor for 30-day postoperative complications, readmissions, UTI, pneumonia, and unplanned intubations following elective ALIF surgery in adults over the age of 50.

Introduction

The increasing lifespan of average Americans has serious implications for the orthopaedic management of the adult population. The proportion of the population over the age of 65 in the United States is projected to increase from 12% in 2000 to over 20% in 2030 [1]. This shift is associated with an increase in the prevalence of degenerative spinal disorders requiring operative management. Older patients experience higher rates of complications following spine surgery, however, there is limited literature showing age to be an independent predictor of adverse outcomes [2].

Frailty is defined by an age-associated decline in functioning and reserve of multiple organ systems, leading to increased vulnerability to detrimental postoperative sequalae, such as infection, reoperation and death [3]. Recently, studies have suggested that frailty may be an effective predictor of adverse events in an older patient population [4–6]. Several frailty indices have been developed to assist surgeons in risk stratification following lumbar fusion [7–10]. One such frailty index is

FDA device/drug status: Not applicable.
Author disclosures: ***NPP***: Nothing to disclose. ***FE:*** Nothing to disclose. ***DC:*** Nothing to disclose. ***SC***: Nothing to disclose. ***NVS***: Nothing to disclose. ***KS***: Nothing to disclose. ***KH***: Consulting fee or honorarium: Stryker Spine (A). ***MF***: Grant: Centinel (B). Consulting fee or honorarium: Stryker Spine (A). ***CBP***: Nothing to disclose. ***AE***: Grant: Nuvasive (B).

* Corresponding author at: 504 Valley Road, Suite 203, Wayne, NJ 07470, USA.
E-mail address: emamiresearch@gmail.com (A. Emami).

https://doi.org/10.1016/j.xnsj.2022.100189
Received 11 November 2022; Received in revised form 29 November 2022; Accepted 30 November 2022
Available online 5 December 2022

the 11-factor modified frailty index (mFI-11), which has shown predictive capabilities for adverse events following various forms of thoracolumbar surgery [11–14]. The mFI-11 is based on 11 comorbidities and functional status that can be obtained from any patient's chart. More recently, the 5-factor modified frailty index (mFI-5) has emerged as a simpler modification of the mFI-11 and has shown to be equally effective at predicting complications, mortality and reoperations after various orthopaedic procedures [11,15–17].

As the aging population continues to expand, so too will the demand for procedures necessary to address degenerative changes of the spine. Anterior lumbar interbody fusion (ALIF) is a reliable procedure commonly performed to treat older populations with degenerative lumbar spine disease. ALIF offers several advantages over alternative approaches including faster recovery and superior restoration of disc height and segmental lordosis [18]. There has been extensive literature demonstrating that increased age is associated with various adverse clinical and radiological outcomes following ALIF [14,19–21]. However, there is a paucity of studies analyzing the utility of frailty indices in identifying patients at high risk of adverse postoperative outcomes following ALIF. Phan et al. [22] found that high levels of frailty using the mFI-11 was a significant predictor of overall and pulmonary complications following elective ALIF. However, there have been no large studies analyzing the utility of the mFI-5 as a risk stratification tool in this patient population. Therefore, the purpose of this study was to determine the predictive capability between mFI-5 score and 30-day adverse outcomes following elective ALIF.

Methods

Data source and patient population

The American College of Surgeons' National Surgical Quality Improvement Program (ACS NSQIP) (Chicago, Illinois, United States) is a surgical outcomes database that was designed by the ACS to provide nationally validated information regarding postoperative patient outcomes. NSQIP patient profiles were queried from 2010 to 2019 to identify patients undergoing ALIF utilizing Current Procedural Terminology (CPT codes) 22558 and 22585. Exclusion criteria included patients undergoing spinal deformity surgery (CPT 22800, 22802, 22804, 22808, 22810). Patients were excluded if they were missing data for any of the outcome variables evaluated, underwent emergency surgery, underwent concomitant traumatic spine surgery, were under the age of 50, or had sepsis, disseminated cancer, a prior operation in the last 30 days, ascites, or wound infections. The application of the inclusion and exclusion criteria is illustrated in **Fig. 1**.

Outcomes

The mFI-5 score, ranging from 0 to 5, was calculated for each patient using variables that already existed in the NSQIP database. Each patient received one point towards their score for the following within 30 days preceding the index procedure: 1) congestive heart failure (CHF); 2) history of chronic obstructive pulmonary disease (COPD); 3) hypertension requiring medication; 4) insulin-dependent or non-insulin dependent diabetes mellitus; 5) totally- or partially- dependent preoperative functional status (**Table 1**). Fewer than 25 patients had an mFI-5 score of either 4 or 5. Therefore, those with an mFI-5 score of 4 or 5 were grouped with patients with a score of 3 to create a group with a collective score of 3 or more (3+). Patient demographics including sex, age, and body mass index (BMI) and preoperative conditions were also obtained.

Data regarding 30-day postoperative complications, readmissions, reoperations, and mortality were compiled using NSQIP outcome data. Both minor and major complications were analyzed including postoperative superficial, deep and organ/deep space surgical site infections (SSIs), pneumonia, unplanned intubations, pulmonary embolism (PE), ventilator use greater than 48 hours, progressive renal insufficiency, acute renal failure (ARF), urinary tract infections (UTI), stroke/cerebrovascular accident (CVA), cardia arrest, myocardial infarction (MI), bleeding requiring transfusion, deep vein thrombosis (DVT), sepsis, and septic shock. American Society of Anesthesiologists Classification (ASA) was collected for each patient as well.

Statistical analysis

Four patient cohorts were constructed based on frailty: not frail (mFI=0), mild frailty (mFI=1), moderate frailty (mFI=2), and severe frailty (mFI=3+). Percentages were calculated for all dichotomous variables and means values with standard deviations were generated for continuous variables. Univariate analysis was conducted to compare demographics, comorbidities, and postoperative complications across the varying cohorts based on mFI-5 scores. Categorical or dichotomous variables were compared using chi-squared tests or Fisher exact tests. Continuous variables were assessed using one-way analysis of variance (ANOVA) tests.

Multivariate logistic regression was performed to evaluate the impact of mFI-5 scores on the odds of 30-day postoperative mortality, readmissions, reoperations, any complications, and specific complications, as mentioned above, as compared to an mFI-5 score of 0. Preoperative variables including age, race, BMI, sex, ASA score, obesity, operative time >4 hours, dyspnea, alcohol use, steroid use, bleeding disorder, preoperative transfusions and recent weight loss were included in the regression model to assess if mFI scores were independent predictors for developing adverse events. Odds ratios, 95% confidence intervals, and p-values for each variable were calculated from the regression. All statistical analyses were performed using SPSS version 24.0 (IBM Corp., Amonk, NY, USA). P-values less than 0.05 were considered statistically significant.

Results

11,711 patients with complete data who had undergone elective ALIF were included. These patients were grouped based on their mFI-5 score: 0 (n=4,026), 1 (n=5,396), 2 (n=2,102), and 3+ (n=187). The proportions of evaluated complications are illustrated in **Table 2**. As the mFI-5 score increased from 0 (no frailty) to 3+ (severe frailty), a stepwise increase in the rates of total complications (15.5% to 33.7%), pneumonia (0.3% to 3.7%), unplanned intubation (0.25% to 2.1%), ventilator requirement > 48 hours (0.3% to 2.14%), acute renal failure (0.1% to 0.5%), UTI (1.4% to 4.8%), MI (0.3% to 1.1%), postoperative bleeding requiring transfusion (1.4% to 4.8%), and related readmissions (5.0% to 11.2%) was observed.

Multivariable logistic regression models were utilized to identify the odds ratios and 95% confidence intervals for mFI-5 scores and covariates in predicting 30-day readmissions, reoperations, mortality, general complications, and each previously mentioned complication (**Table 3**). Multivariate logistic regression revealed that mFI-5 scores of 1 (OR: 2.2, CI: 1.2 – 4.2, p=0.02), 2 (OR: 3.6, CI: 1.8 – 7.3, p<0.001), and 3+ (OR: 7.0, CI: 2.5 – 19.3, p<0.001) versus a score of 0 were significant predictors of pneumonia. An mFI-5 score of 2 (OR: 1.3; CI: 1.01 – 1.6, p=0.04), and 3+ (OR: 1.9; CI: 1.1 – 3.1; p=0.01), as compared to a score of 0, were both independent predictors of related readmissions. An mFI score of 3+ was an independent predictor of any major or minor complication (OR: 1.5, CI: 1.01 – 2.2, p=0.004), UTI (OR: 2.4, CI: 1.1 – 5.2, p=0.02), and unplanned intubation (OR: 4.5, CI: 1.3 – 16.1, p=0.02). High frailty scores, defined as 3+, were not found to be predictive of surgical site infections, wound disruption, unplanned intubation, pulmonary embolism, ventilator requirements greater than 48 hours, renal insufficiency, acute renal failure, stroke/CVA, MI, bleeding requiring transfusion, DVT, sepsis, septic shock, reoperation, or mortality.

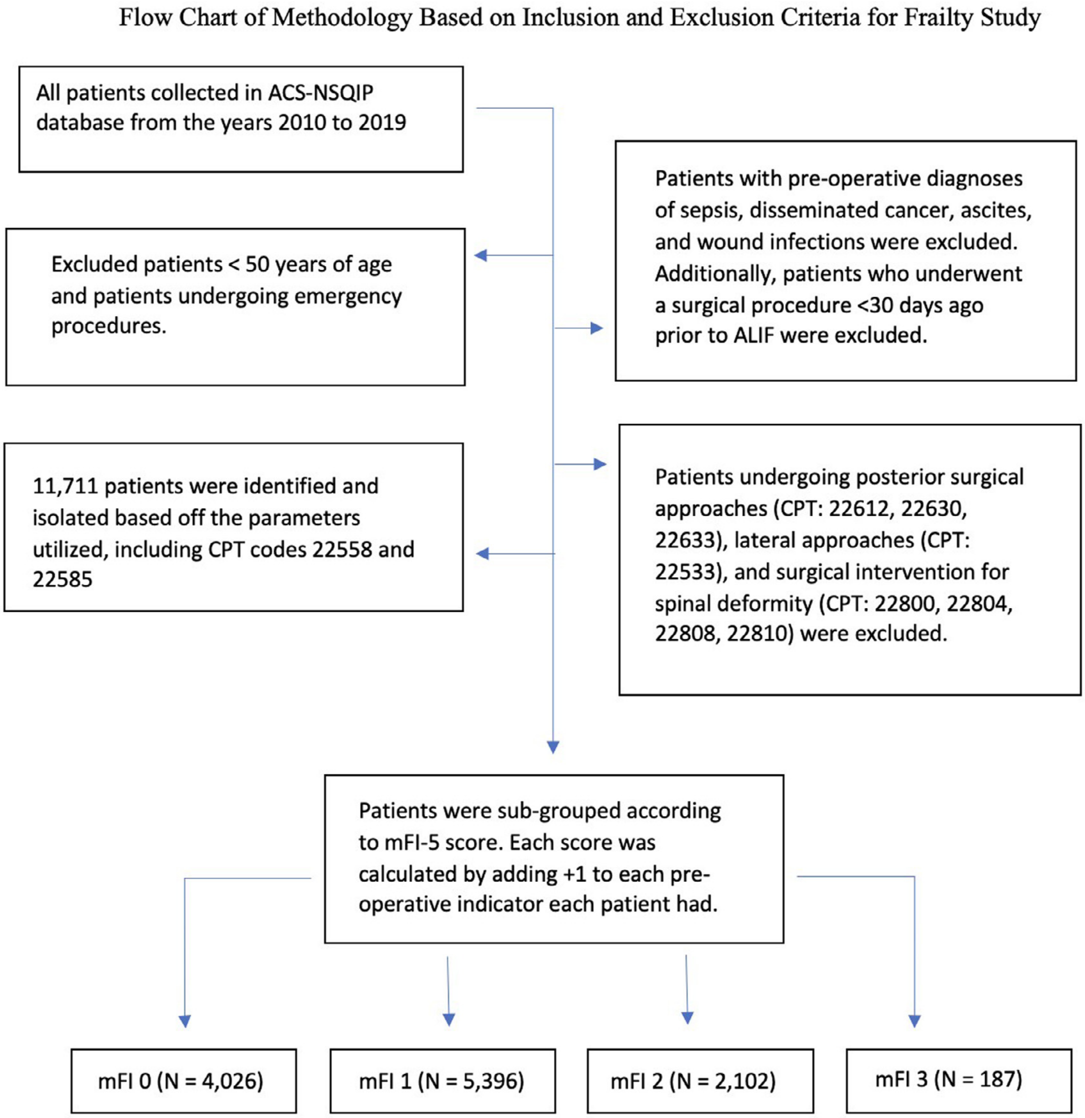

Fig. 1. Flow chart of methodology based on inclusion and exclusion criteria for frailty study.

Table 1
MFI-5 variables mapped to NSQIP variables for score calculations.

mFI-5	NSQIP
Diabetes Mellitus (+1)	History of diabetes mellitus
Increased blood pressure requiring medication (+1)	Hypertension requiring medication
Functional Status (+1)	Functional status (non-independent)
COPD (+1)	History of COPD
Heart Failure (+1)	History of congestive heart failure

mFI-5 = 5-Item Modified Frailty Index; NSQIP = National Surgical Quality Improvement Program; COPD = Chronic Obstructive Pulmonary Disease

Discussion

ALIF remains a commonly utilized procedure to address degenerative changes of the lumbar spine that require operative treatment. ALIF offers several advantages over alternative techniques for lumbar arthrodesis, including extensive access to the anterior disc space, allowing for placement of larger interbody cages and superior correction of disc height and lordosis [18,23]. Despite these advantages, ALIF is associated with a variety of approach-related complications, including vascular or nerve injury, and ileus, especially in older populations. Therefore, frailty indices, such as the mFI-5 score, may assist surgeons in reliably identifying high risk patients for surgery. Although several studies have highlighted the predictive capabilities of the mFI-5 index across various spine procedures, none have used it to assess adverse outcomes following ALIF [17,24,25]. Therefore, the purpose of this retrospective analysis was to determine the utility of mFI-5 scores for predicting adverse events following elective ALIF using a large database. This study found that mFI-5 scores were independent predictors for related readmissions, overall complications, pneumonia, unplanned intubation, and UTI.

This study found that high levels of frailty were associated with the development of 30-day postoperative complications. Our analysis revealed that an mFI-5 score of 3 or more was an independent predictor

Table 2
Proportion of complications across frailty levels.

	Modified Frailty Index, n				
	0	1	2	3+	p-value
N = 11,711	4,026	5,396	2,102	187	
Total Complications	15.5%	18.8%	21.7%	33.7%	**<0.001**
SSI	0.7%	1.0%	1.1%	1.1%	0.163
Deep Incisional SSI	0.4%	0.4%	0.9%	1.1%	**0.028**
Organ/Space SSI	0.2%	0.4%	0.3%	0.5%	0.280
Wound Disruption	0.3%	0.3%	0.4%	0.0%	0.843
Pneumonia	0.3%	0.8%	1.6%	3.7%	**<0.001**
Unplanned Intubation	0.3%	0.4%	0.4%	2.1%	**<0.001**
Pulmonary Embolism	0.7%	0.6%	0.9%	0.0%	0.413
Ventilator > 48 hours	0.3%	0.3%	0.8%	2.1%	**<0.001**
Renal Insufficiency	0.1%	0.2%	0.1%	0.0%	0.580
Acute Renal Failure	0.1%	0.2%	0.4%	0.5%	**0.035**
Urinary Tract Infection	1.4%	1.5%	2.0%	4.8%	**<0.001**
Stroke/CVA	0.1%	0.1%	0.3%	0.0%	0.299
Cardiac Arrest Requiring CPR	0.2%	0.2%	0.2%	0.5%	0.614
Myocardial Infarction	0.3%	0.3%	0.7%	1.1%	**0.022**
Bleeding Transfusions	8.9%	10.1%	9.4%	14.4%	**0.033**
DVT/Thrombophlebitis	0.8%	1.2%	1.1%	0.5%	0.184
Sepsis	0.5%	0.6%	0.9%	1.07%	0.211
Septic Shock	0.1%	0.2%	0.3%	0.0%	0.224
Other Outcomes					
Reoperation	2.2%	2.6%	3.1%	2.7%	0.139
Readmission	5.0%	6.0%	7.3%	11.2%	**< 0.001**
Death	0.2%	0.3%	0.2%	1.1%	0.123

SSI= Superficial Site Infection; CVA= Cerebrovascular Accident; CPR= Cardiopulmonary Resuscitation; DVT= Deep Vein Thrombosis
Note: p-values < 0.05 were bolded

for the development of any major or minor complications (mFI 3+ vs. 0: OR= 1.5, p=0.004). Phan et al. [22] using the NSQIP database to isolate patients undergoing ALIF from the years 2010 to 2014, found high levels of frailty, based on the mFI-11 index, to be independently predictive of 30-day complications (mFI 0.27+ vs. 0: OR= 2.4, p=0.04). Weaver et al. [26] performed an analysis on the NSQIP database, isolating patients undergoing 1- to 2-level posterior lumbar fusion between the years 2012 to 2016. They used the mFI-5 index to predict postoperative outcomes and found that increasing mFI-5 score was correlated with increased risk for experiencing complications (1 vs. 0: OR= 1.22, p<0.001; 2 vs 0: OR= 1.45, p<0.001). Elsamadicy et al. [27] found that mFI-5 scores were not independently predictive of complications in patients undergoing posterior lumbar fusion for spondylolisthesis. However, these differences are likely attributable to the inclusion of all patients over the age of 18 in the aforementioned study [27]. There is limited literature validating the use of frailty indices in younger patient populations which may account for the discrepancies observed [28].

This present study found that both moderate (mFI 2 vs 0: OR=1.3, p=0.041) and severe (mFI 3 vs 0: OR= 1.9, p=0.01) levels of frailty were predictors for related 30-day readmission. The risk for readmission based off mFI-5 score was scarce in the literature, specifically within patients undergoing ALIF. However, there are studies which looked at the predictability of mFI-5 on readmission rates in other spine-related orthopaedic interventions [26,27]. Weaver et al. [26] found that patients with increased mFI-5 scores had a greater incidence of readmission within 30 days (0: 3.7%; 1: 5.3%; 2+: 7.2%; p < 0.001). Though these studies relate to different approaches to the lumbar spine, they provide additional insight and support for the usage of the mFI-5 index to predict risk for readmissions. This study is the first to analyze changes in readmission rates in patients undergoing ALIF and may bridge this gap in the literature.

The mFI-5 index was also found to be an independent predictor of specific complications including pneumonia, unplanned intubation, and UTI. Only severe levels of frailty were associated with unplanned intubation (3+ vs 0: OR=4.5, p=0.02) and UTI (3+ vs 0: OR=2.4, p=0.02). However, mFI-5 scores were predictive of postoperative pneumonia at

Table 3
Multivariate logistic regression utilized to determine impact of mFI-5 score on adverse post-operative outcomes.

Effect	Odds Ratio	95% Confidence Interval	p-value
Total Complications			
mFI-5: 1 vs. 0	1.1	0.9 – 1.2	0.406
mFI-5: 2 vs. 0	1.1	0.9 – 1.3	0.283
mFI-5: 3+ vs. 0	1.5	1.1 – 2.2	**0.041**
SSI			
mFI-5: 1 vs. 0	1.5	0.9 – 2.4	0.127
mFI-5: 2 vs. 0	1.7	0.9 – 3.2	0.085
mFI-5: 3+ vs. 0	1.6	0.4 – 7.2	0.522
Deep Incisional SSI			
mFI-5: 1 vs. 0	0.7	0.4 – 1.4	0.369
mFI-5: 2 vs. 0	1.6	0.8 – 3.4	0.205
mFI-5: 3+ vs. 0	2.0	0.4 – 9.5	0.364
Organ/Space SSI			
mFI-5: 1 vs. 0	1.5	0.7 – 3.5	0.339
mFI-5: 2 vs. 0	0.9	0.3 – 2.8	0.920
mFI-5: 3+ vs. 0	1.7	0.2 – 14.6	0.629
Wound Disruption			
mFI-5: 1 vs. 0	0.8	0.4 – 1.8	0.607
mFI-5: 2 vs. 0	0.9	0.3 – 2.3	0.801
mFI-5: 3+ vs. 0	-	-	-
Pneumonia			
mFI-5: 1 vs. 0	2.2	1.1 – 4.2	**< 0.001**
mFI-5: 2 vs. 0	3.6	1.8 – 7.3	**0.015**
mFI-5: 3+ vs. 0	7.0	2.5 – 19.3	**< 0.001**
Unplanned Intubation			
mFI-5: 1 vs. 0	1.1	0.5 – 2.4	0.865
mFI-5: 2 vs. 0	1.1	0.4 – 2.9	0.849
mFI-5: 3+ vs. 0	4.5	1.3 – 16.1	**0.020**
Pulmonary Embolism			
mFI-5: 1 vs. 0	0.8	0.5 – 1.4	0.420
mFI-5: 2 vs. 0	1.1	0.6 – 2.1	0.785
mFI-5: 3+ vs. 0	-	-	-
Ventilator ≥ 48 hours			
mFI-5: 1 vs. 0	0.8	0.4 – 1.8	0.634
mFI-5: 2 vs. 0	1.6	0.7 – 3.8	0.237
mFI-5: 3+ vs. 0	3.4	1.0 – 11.5	0.053
Renal Insufficiency			
mFI-5: 1 vs. 0	1.3	0.4 – 4.2	0.696
mFI-5: 2 vs. 0	0.7	0.1 – 3.4	0.653
mFI-5: 3+ vs. 0	-	-	-
Acute Renal Failure			
mFI-5: 1 vs. 0	1.6	0.4 – 6.1	0.501
mFI-5: 2 vs. 0	3.0	0.7 – 12.4	0.137
mFI-5: 3+ vs. 0	3.1	0.3 – 33.6	0.348
UTI			
mFI-5: 1 vs. 0	0.9	0.6 – 1.3	0.612
mFI-5: 2 vs. 0	1.2	0.4 – 1.8	0.525
mFI-5: 3+ vs. 0	2.4	1.1 – 5.2	**0.024**
Stroke/CVA			
mFI-5: 1 vs. 0	0.8	0.2 – 2.8	0.759
mFI-5: 2 vs. 0	2.4	0.6 – 9.0	0.201
mFI-5: 3+ vs. 0	-	-	-
Myocardial Infarction			
mFI-5: 1 vs. 0	1.0	0.4 – 2.1	0.949
mFI-5: 2 vs. 0	2.1	0.9 – 4.8	0.096
mFI-5: 3+ vs. 0	3.3	0.7 – 16.3	0.140
Bleeding Transfusions			
mFI-5: 1 vs. 0	1.1	0.9 – 1.2	0.551
mFI-5: 2 vs. 0	0.9	0.7 – 1.1	0.372
mFI-5: 3+ vs. 0	1.3	0.8 – 2.0	0.243
DVT			
mFI-5: 1 vs. 0	1.5	1.0 – 2.4	0.067
mFI-5: 2 vs. 0	1.4	0.8 – 2.5	0.305
mFI-5: 3+ vs. 0	0.6	0.1 – 4.7	0.648
Sepsis			
mFI-5: 1 vs. 0	1.0	0.5 – 1.8	0.971
mFI-5: 2 vs. 0	1.1	0.5 – 2.2	0.808
mFI-5: 3+ vs. 0	1.2	0.3 – 5.6	0.795
Septic Shock			
mFI-5: 1 vs. 0	1.5	0.4 – 6.0	0.529
mFI-5: 2 vs. 0	2.0	0.4 – 9.0	0.366

(*continued on next page*)

Table 3 (*continued*)

Effect	Odds Ratio	95% Confidence Interval	p-value
mFI-5: 3+ vs. 0	-	-	-
Reoperation			
mFI-5: 1 vs. 0	1.1	0.8 – 1.4	0.628
mFI-5: 2 vs. 0	1.2	0.8 – 1.7	0.305
mFI-5: 3+ vs. 0	1.0	0.4 – 2.5	0.952
Readmission			
mFI-5: 1 vs. 0	1.1	0.9 – 1.4	0.200
mFI-5: 2 vs. 0	1.3	1.0 – 1.6	**0.041**
mFI-5: 3+ vs. 0	1.9	1.1 – 3.1	**0.011**
Death			
mFI-5: 1 vs. 0	1.3	0.5 – 3.0	0.608
mFI-5: 2 vs. 0	0.7	0.2 – 2.3	0.543
mFI-5: 3+ vs. 0	1.8	0.3 – 11.2	0.531

SSI = Superficial Site Infection; CVA = Cerebrovascular Accident; DVT = Deep Vein Thrombosis; UTI= Urinary Tract Infection
Note: p-values < 0.05 were bolded

all levels of frailty and demonstrated a stepwise increase in odds ratios (1 vs 0: OR= 2.2, p=0.02; 2 vs 0: OR=3.6, p<0.001; 3 vs 0: OR= 7.0, p<0.001). Phan et al. [22] did find severe levels of frailty to be predictive of pulmonary complications (0.27 vs 0: OR=7.5, p=0.001). However, they analyzed the odds of developing pulmonary complications collectively, whereas our analysis focused on specific complications. Additionally, mFI-5 scores have been shown to be predictive of pulmonary complications following other non-orthopaedic procedures as well [29,30].

Results from other studies suggest that the predictive capability of mFI-5 regarding postoperative complications may be influenced by surgical approaches and types of spine procedures being performed. For example, Weaver et al. [26] found that an mFI score of 2 or more independently predicted pneumonia, UTI, and unplanned intubations. However, their study also demonstrated that the mFI-5 index was also able to stratify patients at high risk for other complications including cardiac complications, renal failure, stroke, and sepsis among others [26]. Frailty is associated with impairment in of multiple organ systems, including the immune system, which may leave patients at increased susceptibility to infection [31]. Furthermore, the association of mFI-5 scores with risk of UTI and pneumonia may be explained by diabetes mellitus being a component of the index. Diabetes has been shown to increase the risk of infections through various physiologic mechanisms [29].

In their study evaluating the association of frailty with morbidity in patients undergoing elective ALIF, Phan et al. [22] found high levels of frailty to be independent predictors of overall postsurgical and pulmonary complications. Our study incorporated the same wide range of preoperative variables into the logistic regression to ensure that frailty was an independent predictor of adverse events. The findings of this present study demonstrate that mFI-5 is comparable to the mFI-11 index at predicting overall and pulmonary complications. Additionally, mFI-5 may offer advantages of being used as a risk stratification tool for predicting 30-day related readmissions and specific complications including UTI, pneumonia and unplanned intubation although these findings were not directly analyzed in the aforementioned study. However, the mFI-5 index is a much more concise screening tool that is comprised of variables that are easily ascertainable. Nonetheless, both studies further solidify the capabilities of frailty as a preoperative risk stratification tool.

The modified frailty index is one of many frailty indices that have been developed over the years. It remains the most frequently cited frailty index in the literature and is the most adaptable to all spine pathologies [32]. Unlike other frailty scales, such as the FRIED criteria or FRAIL scale, the mFI-5 index utilizes objective data based on patient comorbidities as opposed to subjective questionnaires. Additionally, the mFI-5 index is comprised of a concise number of components with information that can be readily obtained from patients or their medical records. This makes it an easily accessible and quick tool for spine surgeons to stratify patients at high risk for postoperative adverse events. Our findings add to the growing body of literature that the mFI-5 score is a simple and effective risk stratification tool for patients undergoing various types of spine surgery including elective ALIF.

The limitations of this study may be associated with the database used, sample size, the study's retrospective nature, and its follow-up time. NSQIP uses the ALIF surgical procedure to isolate the cohort this study utilized for subsequent analysis. In cases where ALIF was not properly defined or incorrectly assigned to a patient, the database and sample size would be affected, potentially underpowering the results found in this study. Additionally, due to the retrospective nature of this study, there was an inability to analyze future trends of risk for complications, readmissions, reoperations, and mortality. A larger, prospective cohort study should be utilized in the future to bridge this gap to further evaluate how the mFI-5 index may be utilized in a prospective sense. Similarly, the follow-up time was another limitation pertaining to this study. The NSQIP database only allows for a 30-day follow-up period, which may not quantify the outcomes to a greater extent. Also, the database possesses a lack of clinical or objective frailty related data, such as bone densitometry, CT or qCT bone density studies, or lab values. Future studies should choose databases with follow-up times of 180-days or 365-days to better understand how mFI-5 scores may be used in a retrospective sense.

Despite these limitations, there is a relative scarcity of literature evaluating the impact of pre-operative mFI-5 scores on the prediction of post-surgical outcomes in patients undergoing spine surgery. Specifically, this study is the first to detail the significance of the mFI-5 index in patients undergoing elective ALIF in a retrospective sense. This study may be used as a point of reference by orthopaedic spine surgeons to better educate patients of potential postoperative expectations based on their mFI-5 score and associated risk profiles. Additionally, our findings may guide surgeons in attempting to optimize patients preoperatively to mitigate adverse outcomes during the postoperative course.

Conclusion

The mFI-5 was an independent predictor for 30-day postoperative major or minor complications, readmissions, UTI, pneumonia, and unplanned intubation following elective ALIF surgery in adults over the age of 50. The mFI-5 is a quick and concise risk assessment tool that may be used by spine surgeons to optimize high risk patients for surgery in an effort to prevent postsurgical adverse events.

Declarations of Competing Interests

One or more of the authors declare financial or professional relationships on ICMJE-NASSJ disclosure forms. None of these are applicable to the current study. For the remaining authors, none were declared.

Source of funding

IRB approval was not needed for this study.

No funding was received for conduction or administration of this study.

There are no acknowledgements.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2022.100189.

References

[1] O'Lynnger TM, Zuckerman SL, Morone PJ, Dewan MC, Vasquez-Castellanos RA, Cheng JS. Trends for spine surgery for the elderly: implications for ac-

cess to healthcare in North America. Neurosurgery 2015;77(Suppl 4):S136–41. doi:10.1227/NEU.0000000000000945.

[2] Bydon M, Abt NB, De la Garza-Ramos R, Olorundare IO, McGovern K, Sciubba DM, et al. Impact of age on short-term outcomes after lumbar fusion: an analysis of 1395 patients stratified by decade cohorts. Neurosurgery 2015;77:344–7. doi:10.1227/NEU.0000000000000852.

[3] Chen X, Mao G, Leng SX. Frailty syndrome: an overview. Clin Interv Aging 2014;9:433–41. doi:10.2147/CIA.S45300.

[4] Shahrestani S, Bakhsheshian J, Solaru S, Ton A, Ballatori AM, Chen XT, et al. Inclusion of frailty improves predictive modeling for postoperative outcomes in surgical management of primary and secondary lumbar spine tumors. World Neurosurg 2021;153:e454–63. doi:10.1016/j.wneu.2021.06.143.

[5] 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. doi:10.1016/j.spinee.2016.06.017.

[6] Wilson JRF, Badhiwala JH, Moghaddamjou A, Yee A, Wilson JR, Fehlings MG. Frailty is a better predictor than age of mortality and perioperative complications after surgery for degenerative cervical myelopathy: an analysis of 41,369 patients from the NSQIP database 2010-2018. J Clin Med 2020;9. doi:10.3390/jcm9113491.

[7] Jenkins NW, Parrish JM, Nolte MT, Jadczak CN, Geoghegan CE, Mohan S, et al. Charlson comorbidity index: an inaccurate predictor of minimally invasive lumbar spinal fusion outcomes. Int J Spine Surg 2021;15:770–9. doi:10.14444/8099.

[8] Kang T, Park SY, Lee JS, Lee SH, Park JH, Suh SW. Predicting postoperative complications in patients undergoing lumbar spinal fusion by using the modified five-item frailty index and nutritional status. Bone Joint J 2020;102-B:1717–22. doi:10.1302/0301-620X.102B12.BJJ-2020-0874.R1.

[9] Baron RB, Neifert SN, Ranson WA, Schupper AJ, Gal JS, Cho SK, et al. A comparison of the Elixhauser and Charlson comorbidity indices: predicting in-hospital complications following anterior lumbar interbody fusions. World Neurosurg 2020;144:e353–60. doi:10.1016/j.wneu.2020.08.138.

[10] Moskven E, Charest-Morin R, Flexman AM, Street JT. The measurements of frailty and their possible application to spinal conditions: a systematic review. Spine J 2022. doi:10.1016/j.spinee.2022.03.014.

[11] 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 2019;44:E1083–91. doi:10.1097/BRS.0000000000003063.

[12] Jung J-M, Chung CK, Kim CH, Yang SH, Ko YS. The modified 11-item frailty index and postoperative outcomes in patients undergoing lateral lumbar interbody fusion. Spine 2022;47:396–404. doi:10.1097/BRS.0000000000004260.

[13] Sun W, Lu S, Kong C, Li Z, Wang P, Zhang S. Frailty and post-operative outcomes in the older patients undergoing elective posterior thoracolumbar fusion surgery. Clin Interv Aging 2020;15:1141–50. doi:10.2147/CIA.S245419.

[14] Phan K, Ramachandran V, Tran T, Phan S, Rao PJ, Mobbs RJ. Impact of elderly age on complications and clinical outcomes following anterior lumbar interbody fusion surgery. World Neurosurg 2017;105:503–9. doi:10.1016/j.wneu.2017.05.056.

[15] Traven SA, Reeves RA, Sekar MG, Slone HS, Walton ZJ. New 5-factor modified frailty index predicts morbidity and mortality in primary hip and knee arthroplasty. J Arthroplasty 2019;34:140–4. doi:10.1016/j.arth.2018.09.040.

[16] 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;226 173-181.e8. doi:10.1016/j.jamcollsurg.2017.11.005.

[17] Shah N V, Kim DJ, Patel N, Beyer GA, Hollern DA, Wolfert AJ, et al. The 5-factor modified frailty index (mFI-5) is predictive of 30-day postoperative complications and readmission in patients with adult spinal deformity (ASD). J Clin Neurosci Off J Neurosurg Soc Australas 2022;104:69–73. doi:10.1016/j.jocn.2022.07.020.

[18] Teng I, Han J, Phan K, Mobbs R. A meta-analysis comparing ALIF, PLIF, TLIF and LLIF. J Clin Neurosci Off J Neurosurg Soc Australas 2017;44:11–17. doi:10.1016/j.jocn.2017.06.013.

[19] Elia CJ, Arvind V, Brazdzionis J, von Glinski A, Schell BA, Pierre CA, et al. 90-day Readmission rates for single level anterior lumbosacral interbody fusion: a nationwide readmissions database analysis. Spine 2020;45:E864–70. doi:10.1097/BRS.0000000000003443.

[20] Lee D, Lee R, Cross MT, Iweala U, Weinreb JH, Falk DP, et al. Risk factors for postoperative urinary tract infections following anterior lumbar interbody fusion. Int J Spine Surg 2020;14:493–501. doi:10.14444/7065.

[21] Kuo CC, Hess RM, Khan A, Pollina J, Mullin JP. Factors affecting postoperative length of stay in patients undergoing anterior lumbar interbody fusion. World Neurosurg 2021;155:e538–47. doi:10.1016/j.wneu.2021.08.093.

[22] Phan K, Kim JS, Lee NJ, Somani S, Di Capua J, Kothari P, et al. Frailty is associated with morbidity in adults undergoing elective anterior lumbar interbody fusion (ALIF) surgery. Spine J 2017;17:538–44. doi:10.1016/j.spinee.2016.10.023.

[23] Richter M, Weidenfeld M, Uckmann FP. [Anterior lumbar interbody fusion. Indications, technique, advantages and disadvantages]. Orthopade 2015;44:154–61. doi:10.1007/s00132-014-3056-x.

[24] Pierce KE, Naessig S, Kummer N, Larsen K, Ahmad W, Passfall L, et al. The five-item modified frailty index is predictive of 30-day postoperative complications in patients undergoing spine surgery. Spine 2021;46:939–43. doi:10.1097/BRS.0000000000003936.

[25] Wert WGJ, Sellers W, Mariner D, Obmann M, Song B, Ryer EJ, et al. Identifying risk factors for complications during exposure for anterior lumbar interbody fusion. Cureus 2021;13:e16792. doi:10.7759/cureus.16792.

[26] Weaver DJ, Malik AT, Jain N, Yu E, Kim J, Khan SN. The modified 5-item frailty index: a concise and useful tool for assessing the impact of frailty on postoperative morbidity following elective posterior lumbar fusions. World Neurosurg 2019. doi:10.1016/j.wneu.2018.12.168.

[27] Elsamadicy AA, Freedman IG, Koo AB, David WB, Reeves BC, Havlik J, et al. Modified-frailty index does not independently predict complications, hospital length of stay or 30-day readmission rates following posterior lumbar decompression and fusion for spondylolisthesis. Spine J 2021;21:1812–21. doi:10.1016/J.SPINEE.2021.05.011.

[28] Spiers GF, Kunonga TP, Hall A, Beyer F, Boulton E, Parker S, et al. Measuring frailty in younger populations: a rapid review of evidence. BMJ Open 2021;11:e047051. doi:10.1136/bmjopen-2020-047051.

[29] Meng Y, Zhao P, Yong R. Modified frailty index independently predicts postoperative pulmonary infection in elderly patients undergoing radical gastrectomy for gastric cancer. Cancer Manag Res 2021;13:9117–26. doi:10.2147/CMAR.S336023.

[30] Aceto P, Perilli V, Luca E, Schipa C, Calabrese C, Fortunato G, et al. Predictive power of modified frailty index score for pulmonary complications after major abdominal surgery in the elderly: a single centre prospective cohort study. Eur Rev Med Pharmacol Sci 2021;25:3798–802. doi:10.26355/eurrev_202105_25947.

[31] Bellumkonda L, Tyrrell D, Hummel SL, Goldstein DR. Pathophysiology of heart failure and frailty: a common inflammatory origin? Aging Cell 2017;16:444–50. doi:10.1111/acel.12581.

[32] Veronesi F, Borsari V, Martini L, Visani A, Gasbarrini A, Brodano GB, et al. The impact of frailty on spine surgery: systematic review on 10 years clinical studies. Aging Dis 2021;12:625–45. doi:10.14336/AD.2020.0904.