Spinal Surgery in Patients Aged 80 Years and Older: Risk Stratification Using the Modified Frailty Index

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Abstract

Study Design: This was an ambispective clinical quality registry study.

Objective: To evaluate utility of 11-variable modified Frailty Index (mFI) in predicting postoperative outcomes among patients ≥80 years undergoing spinal surgery.

Methods: Consecutive patients ≥80 years who underwent spinal surgery between January 1, 2013, and June 30, 2018, were included. Primary outcome measure was rate of major complication. Secondary outcome measures were (1) overall complication rate, (2) surgical site infection, and (3) 6-month mortality.

Results: A total of 121 operations were performed. Demographic metrics were (1) age (mean ± SD) = 83.1 ± 2.8 years and (2) mFI (mean ± SD) = 2.1 ± 1.4 variables. As mFI increased from 0 to ≥4 variables, risk of major complication increased from 18.2% to 40.0% ($P = .014$); overall complication increased from 45.5% to 70.0% ($P = .032$); surgical site infection increased from 0.0% to 25.0% ($P = .007$). There were no significant changes in risk of 6-month mortality across mFIs ($P = .115$). Multivariate analysis showed that a higher mFI score of ≥3 variables was associated with a significantly higher risk of (1) major complication ($P = .025$); (2) overall complication ($P = .015$); (3) surgical site infection ($P = .007$); and (4) mortality ($P = .044$).

Conclusions: mFI scores of ≥3/11 variables were associated with a higher risk of postoperative morbidity in patients aged ≥80 years undergoing spinal surgery. The mFI-associated risk stratification provides a valuable adjunct in surgical decision making for this rapidly growing subpopulation of patients.

Keywords

elderly, frailty, modified Frailty Index, spinal surgery, spine trauma, predictors, risk stratification, mortality, postoperative complications, infection

Introduction

Frailty is a universal risk factor for recurrent falls, delirium, institutionalization, and poor postoperative outcome.[1] It is estimated to affect 7% to 11% of individuals older than 65 years, and 25% to 40% of individuals aged 80 years or older.[1]

Numerous criteria, including the Fried Frailty Index and the Rockwood Frailty Index, have attempted to classify frailty.[1,2] More recently, the Canadian Study of Health and Aging Frailty Index (CSHA-FI) validated 70 variables as markers of frailty.[3]

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This has been further refined to form the Modified Frailty Index (mFI), which comprises 11 variables. An individual's mFI is denoted as n/11, wherein n is the number of the 11 variables satisfied.[3]

Various frailty indices have been previously validated as predictors of postoperative complication rates.[4] Farhat et al[5] examined a cohort of 35 334 patients undergoing general surgery and found that an increase in the 11-variable mFI from 0 to 8 variables (0 to 0.73) was associated with a rise in 30-day mortality rate from 3.6% to 51%. The wound infection rate also increased from 9.0% to 12.1% when the mFI rose from 0 to 3 variables (0 to 0.27) in the same cohort of patients.[5] The mFI has also been effective in predicting 30-day mortality and morbidity in patients undergoing spinal surgery,[5-9] although not in patients aged 80 years or older.

The United Nations defines people aged 60 years and older as *older people*, and people aged 80 years and older are further classified as the *oldest-old* population.[10] Frailty is becoming increasingly relevant given that global life expectancy is projected to rise from 71 years in 2010-2015 to 77 years in 2045-2050, and the population aged 80 years or greater in 2017 (137 million) is projected to triple to 425 million in 2050, before further expanding to 909 million in 2100.[10] Consistent with this, there is an increasing number of patients aged 80 years and older who are being considered for, or undergoing, elective or emergency surgery.[11-14] Although many studies have associated this with increased rates of morbidity and mortality,[15,16] others have demonstrated low complication rates with appropriate patient selection.[17] Therefore, it is timely to validate an accurate tool to assist with preoperative risk stratification in patients 80 years and older who are being considered for surgery. This article aimed to evaluate the utility of the 11-variable modified Frailty Index (mFI) in predicting postoperative outcomes among patients 80 years and older undergoing spinal surgery.

Materials and Methods

Study Design

The Alfred Hospital is a tertiary spine referral center and a state-service level 1 trauma center. The Alfred Hospital Spine Service is a combined neurosurgery and orthopaedic service. The Alfred Hospital has established clinical quality trauma registry and department surgical databases, which contain minimal data sets on patient demographic, details of the diagnosis, the surgery received, and postoperative complications. With approval from the institutional Human Research Ethics Committee, we conducted an ambispective review of consecutive patients, aged 80 years and older, who underwent elective or emergency spinal surgery from January 2013 to June 2018 (inclusive). Medical records of patients who satisfied the inclusion criteria were assessed retrospectively to collect data on body mass index (BMI), smoking status, albumin level, preoperative residence, discharge destination, length of surgery, requirement for blood transfusion, American Society of

Anesthesiologists (ASA) classification[18], and mFI. Primary outcome measures, including complications during hospital admission, surgical site infection, mortality within 6 months, and readmission within 30 days, were recorded. Other outcome measures consist of length of surgery, requirement for blood transfusion, discharge destination, and readmission within 30 days.

Modified Frailty Index

The mFI consists of 11 variables, including the following: (1) nonindependent functional status; (2) history of diabetes mellitus; (3) history of chronic obstructive pulmonary disease; (4) history of congestive cardiac failure; (5) history of myocardial infarction; (6) history of percutaneous coronary intervention, cardiac surgery, or angina; (7) history of hypertension requiring medication; (8) history of peripheral vascular disease; (9) history of impaired sensorium; (10) history of transient ischemic attack or cerebrovascular accident without deficit; and (11) cerebrovascular accident with deficit.[3,4] The mFI score was calculated as n/11 (where n is the positive number of the 11 variables identified).

Clavien-Dindo Complication Classification

The Clavien-Dindo complication system classifies adverse events during the postoperative course into 5 categories: (1) Class 1 represents any deviation from the normal postoperative course without the need for pharmacological, surgical, endoscopic, or radiological interventions; (2) class 2 complications require pharmacological treatment; (3) class 3 complications encompass those requiring surgical, endoscopic, or radiological intervention; (4) class 4 incorporates life-threatening complications of single or multiorgan failure requiring intensive care unit management; and (5) class 5 constitutes patient death.[19] Major complication is defined as a Clavien-Dindo score of 3 or greater.[20]

Statistical Analysis

Univariate and bivariate descriptive and inferential statistical methods were used to investigate demographics, ASA score, surgical metrics, complications, and outcomes between the mFI cohorts. The Fisher exact test was used to analyze univariate categorical data. The sample size was determined to be adequate for the number of predictive variables utilized in the multivariate models using previously described methods.[21] Binary logistic regression analysis was performed for identification of independent predictors of adverse surgical outcomes. Best-fit models were constructed with the dependent variables being as follows: (1) major complications (Clavien-Dindo Classification $\geq$3), (2) all complications, (3) surgical site infection, and (4) mortality. Selection of baseline covariates as independent variables in the model was based on the univariate *P* value (<.20). The backward elimination method was utilized in the creation of models. Goodness-of-fit analysis was

Table 1. Preoperative Patient Demographics.

	Modified Frailty Index										
	0 Variables (0.00), n = 11		1 Variable (0.09), n = 35		2 Variables (0.18), n = 31		3 Variables (0.27), n = 24		≥4 Variables (≥0.36), n = 20		
Demographic	n	Percentage	n	Percentage	n	Percentage	n	Percentage	n	Percentage	P Value
Age (years)											.895
<85	9	82	26	74	23	74	17	71	13	65	
≥85	2	18	9	26	8	26	7	29	7	35	
Sex											.834
Male	6	55	20	57	17	55	15	63	14	70	
Female	5	45	15	43	14	45	9	38	6	30	
Smoker (current)	1	9	1	3	1	3	1	4	0	0	.724
BMI (kg/m^2)											.735
<25	6	55	9	26	9	29	10	42	6	30	
25-30	4	36	17	49	12	39	8	33	9	45	
≥30	1	9	9	26	10	32	6	25	5	25	
Albumin level											.511
<28 g/L	3	27	10	29	6	19	10	42	6	30	
≥28 g/L	8	73	25	71	25	81	14	58	14	70	
Preoperative residence											.132
Home	11	100	34	97	30	97	24	100	16	80	
Nursing home	0	0	0	0	1	3	0	0	3	15	
Other	0	0	1	3	0	0	0	0	1	5	
Diagnosis											.132
Degenerative	4	36	24	69	21	68	13	54	17	85	
Trauma	5	45	8	23	8	26	9	38	2	10	
Other (infection, tumor)	2	18	3	9	2	6	2	8	1	5	
Admission type											.783
Elective	5	45	20	57	17	55	10	42	11	55	
Emergency	6	55	15	43	14	45	14	58	9	45	
ASA											.006
1	1	9	0	0	0	0	0	0	0	0	
2	4	36	13	37	4	13	1	4	1	5	
3	5	45	16	46	26	84	16	67	19	95	
4	1	9	6	17	1	3	7	29	0	0	

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index.

conducted using the Hosmer-Lemeshow Test and Omnibus Test of Model Coefficients.

Sensitivity analysis of mFI was conducted by evaluating the correlation of a graduated increase in mFI from ≥1 variable (≥0.09) to ≥5 variables (≥0.45) in predicting (1) major complications; (2) all complications; (3) surgical site infections, and (4) mortality. The association between graduated increases in ASA score and complications was also analyzed. Statistical significance was defined as a P value of less than .05. All statistical analyses were performed using STATA/IC version 14.2 (StataCorp, College Station, TX).

Results

Demographics

From January 2016 to June 2018, there were 115 patients who underwent 121 cases of spinal surgery (Table 1). The mean (±SD) age was 83.1 years (±2.8), with the oldest patient

being 93 years. More than half (59.5%, n = 72) of the surgeries were performed in male patients. The mean mFI was 2.1 (±1.4) out of the 11 variables (mFI scores of 0.19 ± 0.13), whereas the median was 2 out of the 11 variables (0.18). The mean ASA grade was 2.9 (±0.6).

A total of 11 (9.1%) patients had a mFI of 0 variables, 35 (28.9%) had a mFI of 1 variable (0.09), 31 (25.6%) had a mFI of 2 variables (0.18), 24 (19.8%) had a mFI of 3 variables (0.27), and 20 (16.5%) had a mFI of ≥4 variables (≥0.36). There was no statistically significant difference across mFIs with respect to age, sex, smoking status, BMI, albumin level, preoperative residence, diagnosis type, or admission type. Those patients with higher mFI scores registered higher ASA scores (P = .006) than their less frail counterparts.

Surgical Metrics

There was no significant difference in the number of surgical levels per operation (P = .516), type of procedure performed

Table 2. Surgical Metrics.

	Modified Frailty Index									
	0 Variables (0.00), n = 11		1 Variable (0.09), n = 35		2 Variables (0.18), n = 31		3 Variables (0.27), n = 24		≥4 Variables (≥0.36), n = 20	
Surgical Metrics	n	Percentage	n	Percentage	n	Percentage	n	Percentage	n	Percentage	P Value
Number of levels											.516
1	2	18	17	49	13	42	8	33	6	30	
2	4	36	9	26	12	39	4	17	7	35	
≥3	5	45	6	26	6	19	12	50	7	35	
Type of procedure											.059
Anterior fusion	2	18	3	9	8	27	4	17	3	15	
Postdecompression	5	45	22	63	18	60	7	29	10	50	
Post–instrumented fusion	4	36	10	29	4	13	13	54	7	35	
Location											.495
Cervical	6	55	11	31	14	45	7	29	7	35	
Thoracolumbar	5	45	24	69	17	55	17	71	13	65	
Length of surgery											.793
<3 Hours	8	73	25	71	19	61	14	58	14	70	
≥3 Hours	3	27	10	29	12	39	10	42	6	30	

Table 3. Postoperative Outcome With Correlation to Modified Frailty Index.

	Modified Frailty Index									
	0 Variables (0.00), n = 11		1 Variable (0.09), n = 35		2 Variables (0.18), n = 31		3 Variables (0.27), n = 24		≥4 Variables (≥0.36), n = 20	
Postoperative Outcome	n	Percentage	n	Percentage	n	Percentage	n	Percentage	n	Percentage	P Value
Blood transfusion	1	9	3	9	3	10	10	42	3	15	.054
Length of stay >5 days	6	55	17	49	16	52	17	71	16	80	.019
Discharge destination											.498
Home	3	27	13	37	9	29	6	25	6	32	
Subacute care	7	64	20	57	19	61	17	71	13	68	
Palliative care	1	9	2	6	3	10	1	4	0	0	
Readmission within 30 days	1	9	3	9	1	3	4	17	3	15	.291
Major complications (Clavien-Dindo classification score ≥3)	2	18	4	11	3	10	7	29	8	40	.014
All complications	5	45	15	43	9	29	15	63	14	70	.032
Surgical site infection	0	0	2	6	0	0	4	17	5	25	.007
Mortality within 6 months	1	9	2	6	3	10	6	25	3	15	.115

($P = .059$), location of surgery ($P = .495$), or duration of surgery ($P = .793$) between cohorts (Table 2).

Postoperative Surgical Outcome Metrics

A significant difference in postoperative outcomes was observed between the mFI cohorts. As the mFI increased from 0 to ≥4 variables (≥0.36), the attendant risk of major complications, all complications, and surgical site infection increased from 18.2% to 40.0% ($P = .014$), 45.5% to 70.0% ($P = .032$), and 0% to 25.0% ($P = .007$), respectively. Additionally, lengthy acute hospital admission of >5 days was also increased as mFI increased from 0 to ≥4 variables (≥0.36; 54.5% vs 80.0%, $P = .019$). However, mortality

within 6 months was indifferent between the cohorts ($P = .115$). There was no significant difference in requirement for blood transfusion ($P = .054$), discharge destination ($P = .498$), or readmission within 30 days (.291) observed between cohorts (Table 3).

Independent Predictors of Surgical Outcomes

As shown in Figure 1, the rates of mortality and morbidity were considerably increased in the mFI ≥3 variables (≥0.27) cohort when compared with the mFI <3 variables (<0.27) cohort. Binary multivariate analysis was conducted with mFI stratified into 2 categories: (1) low-frailty cohort, with mFI <3 variables (<0.27), and (2) high-frailty cohort, mFI ≥3 variables (≥0.27).
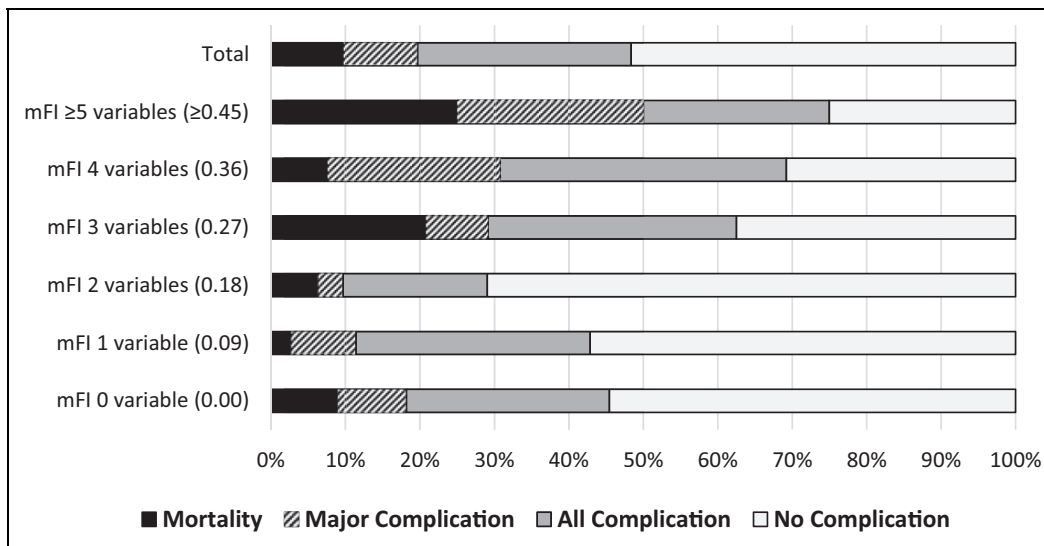
Figure 1. Stacked bar chart of mortality and morbidity with increasing modified Frailty Index (mFI).

By virtue of their univariate *P* values, gender, BMI, type of admission (elective or emergency), presence of instrumentation, type of approach (anterior or posterior), location of surgery (cervical spine or thoracolumbar spine), etiology of pathology (degenerative or nondegenerative), number of spinal levels (<3 or ≥3), albumin level, and mFI or ASA score were incorporated into the multivariable model.

Binary logistic regression analyses revealed that mFI ≥3 variables (≥0.27) conferred higher risk of (1) major complications (OR = 3.23; 95% CI = 1.16-8.99; *P* = .025), (2) all complications (OR = 3.46; 95% CI = 1.27-9.42; *P* = .015), (3) surgical site infection (OR = 12.82; 95% CI = 2.00-81.87; *P* = .007), and (4) mortality (OR = 4.04; 95% CI = 1.04-15.71; *P* = .044). Instrumented surgery (OR = 3.19; 95% CI = 1.01-10.04; *P* = .048) and surgery involving 3 or more spinal levels (OR = 2.96; 95% CI = 1.04-8.39; *P* = .041) increased the risk of major complications. Instrumented surgery (OR = 6.70; 95% CI = 1.98-22.73; *P* = .002), nondegenerative diagnosis (OR = 5.44; 95% CI = 1.51-19.59; *P* = .010), and posterior approach (OR = 6.86; 95% CI = 1.40-33.62; *P* = .018) also predicted postoperative complications. Surgical site infection was positively associated with cervical spine surgical site (OR = 5.58, 95% CI = 1.07-28.96, *P* = .041; Table 4). The Hosmer-Lemeshow Test and Omnibus Test of Model Coefficients confirmed satisfactory goodness of fit.

Dose-Response Relationship of the mFI in Rate of Complications

Analysis involving a graduated increase in mFI demonstrated a positive relationship between increasing mFI and the risk of (1) major complications, (2) all complications, and (3) surgical site infections. The odds ratio of major complication increased from 3.23 (95% CI = 1.16-8.99; *P* = .025) in patients with a mFI of ≥3 variables (≥0.27) to 11.85 (95%

Table 4. Independent Predictors of Surgical Outcomes Identified With Multivariate Logistic Regression Analysis.

Independent Predictors	OR	95% CI	P Value
Major complications (Clavien-Dindo complication score ≥ 3)			
mFI ≥3 variables (≥0.27)	3.23	1.16-8.99	.025
Instrumented surgery	3.19	1.01-10.04	.048
Level of surgery ≥ 3	2.96	1.04-8.39	.041
All complications			
mFI ≥3 variables (≥0.27)	3.46	1.27-9.42	.015
Instrumented surgery	6.70	1.98-22.73	.002
Nondegenerative diagnosis	5.44	1.51-19.59	.010
Posterior approach	6.86	1.40-33.62	.018
Surgical site infection			
mFI ≥3 variables (≥0.27)	12.82	2.00-81.87	.007
Cervical spine surgery	5.58	1.07-28.96	.041
Mortality within 6 months			
mFI ≥3 variables (≥0.27)	4.04	1.04-15.71	.044

Abbreviation: mFI, modified Frailty Index.

CI = 1.68-83.61) in those with an mFI of ≥5 variables (≥0.45; *P* = .013). An mFI of ≥3 variables (≥0.27) carried an all-complication odds ratio of 3.46 (95% CI = 1.27-9.42; *P* = .015), which rose to 8.92 in patients with an mFI of ≥5 variables (≥0.45; 95% CI = 1.13-70.47, *P* = .038). A higher mFI was also associated with a greater likelihood of surgical site infection, with an odds ratio of 12.82 (95% CI = 2.01-81.87; *P* = .007) increasing to 48.93 (95% CI = 3.13-765.27) in those with an mFI of ≥3 variables (≥0.27) compared with patients with an mFI of ≥5 variables (≥0.45; *P* = .004). An increase in mFI from ≥3 to ≥5 variables (≥0.27 to ≥0.45) was also associated with a commensurate increase in mortality, from an odds ratio of 4.04 (95% CI = 1.04-15.71; *P* = .044) to 14.51 (95% CI = 1.49-140.94; *P* = .021). However, risk of mortality was not increased in the cohort with mFI ≥4 variables (≥0.36).

Table 5. Dose-Response Relationship of mFI and ASA Scores in Surgical Outcomes.

	Major Complications			All Complications		
	OR	95% CI	P Value	OR	95% CI	P Value
mFI ≥1 variable (≥0.09)	1.61	0.28-9.20	.590	3.26	0.52-20.65	.209
mFI ≥2 variables (≥0.18)	1.73	0.55-5.40	.348	1.56	0.59-4.11	.367
mFI ≥3 variables (≥0.27)	3.23	1.16-8.99	.025	3.46	1.27-9.42	.015
mFI ≥4 variables (≥0.36)	4.62	1.40-15.26	.012	7.03	1.91-25.78	.003
mFI ≥5 variables (≥0.45)	11.85	1.68-83.61	.013	8.92	1.13-70.47	.038
ASA ≥ 3	3.64	0.43-31.03	.238	1.47	0.45-4.83	.528
ASA ≥ 4	0.57	0.14-2.27	.425	1.27	0.26-7.15	.788

	Surgical Site Infection			Mortality Within 6 Months		
	OR	95% CI	P Value	OR	95% CI	P Value
mFI ≥1 variable (≥0.09)	—	—	—	1.89	0.19-18.48	.583
mFI ≥2 variables (≥0.18)	6.03	0.94-38.50	.058	3.84	0.88-17.20	.078
mFI ≥3 variables (≥0.27)	12.82	2.01-81.87	.007	4.04	1.04-15.71	.044
mFI ≥4 variables (≥0.36)	9.48	1.65-54.47	.012	1.37	0.28-6.77	.697
mFI ≥5 variables (≥0.45)	48.93	3.13-765.27	.006	14.51	1.49-140.94	.021
ASA ≥ 3	0.85	0.08-8.97	.893	1.61	0.18-14.71	.671
ASA ≥ 4	0.66	0.11-3.92	.648	2.38	0.56-10.13	.241

Abbreviation: ASA, American Society of Anesthesiologists; mFI, modified Frailty Index.

mFI Score Versus ASA Score

ASA scores did not predict major complications, all complications, surgical site infection, or mortality (*P* > .20; Table 5). The Spearman rank correlation coefficient between mFI and ASA was 0.2572, indicating a weak concordance.

Discussion

The mFI has been previously associated with postoperative complications and mortality in a mixed spinal surgery cohort by Ali et al,[7] an adult spinal deformity surgery population by Leven et al,[3,9] and surgical complications in patients undergoing lumbar and cervical fusion surgery.[3,6-9] However, no previous studies have specifically addressed the utility of mFI in elderly patients undergoing spine surgery. This study is unique because it examines the ability of the mFI, once dichotomized, to prognosticate the outcome of spinal surgery in patients 80 years and older.

The mFI provides an objective measurement of frailty, which is easily applicable in the clinical setting and is associated with less interassessor variability than previously utilized indices.[7,22] As a relatively concise score, it strikes a balance between being both practical and valid compared with more unwieldy indexes, such as the 70-variable CSHA-FI.[6] Beyond this, the mFI has been further abbreviated to the 5-variable mFI and has been shown to predict postoperative morbidity following posterior lumbar fusion surgery.[23]

Consistent with a number of previously reported studies,[3,6-8] our findings suggest that the 11-variable mFI has utility in stratifying the 80 years and older subpopulation into low and high risk according to a threshold score of 3 variables (0.27). We observed that the mFI of ≥3 variables (≥0.27) was strongly

associated with an increased risk of complications, surgical site infection, and mortality. We also observed a substantial increase in morbidity and mortality as the mFI increases from ≥3 variables (≥0.27) to ≥4 variables (≥0.36) and ≥5 variables (≥0.45). This is congruent with prior studies in spinal surgery, which have also showed comparable stepwise increases in morbidity and mortality as mFI increases.[3,6-9]

The ability of the mFI to risk stratify patients 80 years and older undergoing spinal surgery carries even greater significance because the ASA score, in an identical population, did not correlate with any of the postoperative outcome measures.[17,24,25] Previous studies evaluating the ASA score have shown varying results. Fu et al[26] and Somani et al[27] contended that a higher ASA score predicted higher morbidity rates compared with lower ASA grades in a spinal surgery population, whereas Whitmore et al[28] contested that the ASA score was not predictive of complications. Importantly, these studies were performed in the general, rather than the 80 years and older population. We posit that at this extreme of age, the mFI proves superior to the ASA because of its unique combination of variables, which accurately captures the patient's frailty status.

The mFI is increasingly relevant in light of an ageing population and improved surgical techniques, which potentially leads to an increased likelihood of operative management in elderly patients.[29] Interestingly, when the elderly undergo spinal surgery, it appears that the overall outcome remains favorable in a majority of patients.[30,31] Gerhardt et al[31] reviewed the outcome of patients who underwent lumbar decompression surgery aged 80 years or older and reported that 63.2% of these patients experienced an improvement in preexisting neurological deficits. Most of the patients (91%) also had improvement in neurogenic claudication and/or sciatica by the

time of hospital discharge.[31] Similarly, Bouloussa et al[30] found a high rate of self-reported satisfaction after undergoing lumbar spine surgery in patients older than 85 years.[30] We propose that, among carefully selected patients, advanced age should not be a contraindication to spinal surgery. The mFI score can play a valuable role in risk stratifying and selecting suitable surgical candidates in the elderly population.

The utility of the Frailty Index for prediction of surgical risk will enable the surgeon to have a more informed discussion with patients aged 80 years and older and will assist the patient and their family in balancing the risks, benefits, and expected outcomes of spine surgery in this patient population.

The primary limitation of this study is the inability to further stratify the cohort and perform detailed subgroup analysis. This relates to the relative infrequency of patients 80 years and older requiring elective or emergency spine surgery. Moreover, this data is derived from a single center, although the center is the state-designated level 1 trauma center and receives a high volume of patients requiring spine surgery and is, therefore, likely to represent contemporary treatment for patients with spinal disease. Future studies in this domain should incorporate multiple centers and their registries, with propensity cohort matching, to further identify independent predictors of outcome of the individual mFI variable as well as other comorbidity indices in this expanding population of patients.

Conclusion

Presence of ≥ 3 out of 11 mFI variables (a score of ≥ 0.27) was associated with significantly higher risk of postoperative morbidity in patients 80 years and older undergoing spinal surgery. The mFI-associated risk stratification provides a valuable adjunct in surgical decision making for this rapidly growing subpopulation.

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