

The 8-item Modified Frailty Index Is an Effective Risk Assessment Tool in Anterior Cervical Decompression and Fusion

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Abstract

Study Design: Case-control study; Level of evidence, 3.

Objective: Anterior cervical discectomy and fusion (ACDF) is one of the most common procedures for cervical diseases often with reliable outcomes. However, morbidity rates can be as high as 19.3% so appropriate patient selection and risk stratification is imperative. Our modified frailty index (MFI) predicts postoperative complications after other orthopaedic procedures. We hypothesized that this index would predict complications in a large cohort of ACDF patients.

Methods: We reviewed the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database, including patients who underwent ACDF from 2015–2020. An 8-item MFI score was calculated for each patient. We recorded 30-days postoperative complications, readmission, and reoperation rates, adjusting for baseline features using standard multivariate regression. This project was approved of by the University of Texas Health Science Center Institutional Review Board and an IRB exception was granted.

Results: We identified 17 662 ACDF cases. Patients with MFI of 5 or greater had a 37.53 times increased odds of incurring postoperative complications compared to patients with MFI of 0 ($P < .001$) even when age, sex, race, and ethnicity were controlled for. Specifically, life-threatening Clavien-Dindo IV complications, as well as wound, cardiac, renal, and pulmonary complications were significantly increased in patients with an MFI of 5 or greater. Also, as MFI increased from 1–2 to 3–4 to 5 or greater, the odds of readmission increased from 1.36 to 2.31 to 5.42 times ($P < .001$) and odds of reoperation from 1.19 ($P = .185$) to 2.3 to 6.54 times ($P < .001$). Frailty was still associated with increased complications, readmission, and reoperation after controlling for demographic data, including age, as well as operative time and length of stay.

Conclusion: Frailty is highly predictive of postoperative complications, readmission, and reoperation following ACDF. Employing a simple frailty evaluation can guide surgical decision-making and patient counseling for cervical disease.

Keywords

anterior cervical discectomy and fusion, cervical spine, myelopathy, radiculopathy, ACDF, Risk Assessment

Introduction

Anterior cervical discectomy and fusion (ACDF) is typically used to treat cervical arthritis, radiculopathy, myelopathy, degenerative disc disease, malignancy, and other causes of cervical instability.^{1,2} While patients generally experience pain relief and restoration of function, morbidity rates have been reported to be as high as 19.3%.^{3,4} The most common

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complication of this operation is postoperative dysphagia, but patients can also experience post-operative hematoma, wound infection, myelopathy, laryngeal nerve palsy, malunion, respiratory insufficiency, or esophageal rupture.^{4,5} Anterior cervical discectomy and fusion has recently been performed in both inpatient or outpatient settings, with lower rates of complications reported when performing this operation as an outpatient procedure.⁶

As the population ages and grows, the number of ACDFs performed will significantly increase to treat the concomitant degenerative spine conditions.⁷ It is critical that effective preoperative risk stratification tools are available for physicians to determine ideal candidates to undergo this surgery to reduce the risk of complications. Frailty is a marker of physiological decline, often tied to increased age, and has been used for risk stratification via the Fried physical frailty phenotype (FPFP).⁸ The FPFP characterizes frailty as any 3 of the following symptoms: weakness, exhaustion, slowness, low physical activity, and unintentional weight loss.⁹ Utilizing a frailty index can be a useful tool in assessing a patient's preoperative risk of mortality and complications.¹⁰

While several studies in the literature have utilized a focused, modified frailty index (MFI) based on the Canadian Study of Health and Aging Frailty Index (CSHA) index to predict patient outcomes following different procedures, the effect of frailty on ACDF has not been well characterized.¹¹ The primary aim of this study is to determine the predictive value of the authors' modified MFI in rates of complications following ACDF. The secondary aim of our study is to determine the effect of frailty on rates of complications following ACDF. Our hypothesis is that our MFI will be highly predictive of postoperative complications following ACDF, and that increased frailty will directly correlate to increased rates of post-operative complications in cases of ACDF.

Methods

A retrospective analysis from 2016-2020 of the American College of Surgeons' National Surgeons Quality Improvement Program (NSQIP) database was conducted on patients undergoing ACDF. The NSQIP is a nationally recognized multi-institutional, multi-center, risk stratified database intended to measure and improve the quality of surgical care. Cases with CPT codes 22 551, 22 552, 22 554, and 63 075 were included. This project was approved of by the University of Texas Health Science Center Institutional Review Board, informed consent was not required and an IRB exception was granted.

Eight variables in the NSQIP database were used to generate a MFI. The variables included were severe obesity (BMI > 35), diagnosis of osteoporosis, non-independent functional status prior to surgery, congestive heart failure within 30 days of surgery, hypo-albuminemia (albumin < 3.5), hypertension requiring medication, history of COPD or

pneumonia, and having either type I or type II diabetes. To calculate the MFI, the presence of each variable was worth 1 point, and the total number of points for each patient was determined (range 0-8). Increased MFI score was an indication that a patient was more frail.

Patient variables collected included discharge to a non-home location, pneumonia, pulmonary embolism (PE), unplanned intubation, ventilator use for longer than 48 hours or dependency, cardiac arrest requiring cardiopulmonary resuscitation (CPR), myocardial infarction (MI), open or infected wound, dehiscence, contamination of wound, superficial or deep incisional surgical site infection, wound disruption, DVT/thrombophlebitis, bleeding transfusions, acute renal failure, progressive renal insufficiency, and 30 days mortality. Complications were sorted by severity into categories by the Clavien-Dindo scale, with Clavien-Dindo IV complications being defined as life threatening.¹² The complications graded as Clavien-Dindo IV included occurrences of cardiac arrest requiring CPR, MI, septic shock, PE, renal failure, and stroke with neurological deficit. A modified comprehensive complication index (MCCI) was created from the 11 of 20 variables from the Comprehensive Complications Index Calculator that are included in the NSQIP database, and included wound, transfusion, reoperation under general anesthesia, reoperation without general anesthesia, stroke, acute renal failure, PE, MI, cardiac arrest requiring CPR, septic shock, and death.¹³

Statistical Analysis

After proper exclusion of incomplete, and missing variables, patients were stratified into 4 groups based on their MFI score: MFI 0 (MFI score = 0), MFI 1 (MFI score = 1, 2), MFI 2 (MFI score = 3, 4), and MFI 3 (MFI score ≥ 5). Next, Statistical Package for the Social Sciences (SPSS) suite was utilized to analyze the data. G*Power Statistics tool was used to perform power analysis. Confidence intervals were set at 95% with a *P*-value of .05 being considered statistically significant.

Each group then underwent analysis to compare complication rates, and means of various variables. Multiple linear and logistic regression models were created to elucidate the connection between MFI category and various linear and categorical complications and variables. These regression models controlled for potential confounders such as age, sex, ethnicity, race, and BMI.

Categorical results are reported as counts with column percentages. Continuous data are reported as means standard deviations; standard errors are given where appropriate. All data was initially analyzed to ensure a correct statistical assessment was chosen and that the variables met the requirements and assumptions for each statistical test. Comparison of normally distributed data was performed with independent sample *t* tests. For non-normally distributed data, the Wilcoxon rank-sum test was performed. Categorical variables

were assessed with Fisher's Exact Test or Chi Square with Kendall Tau. Both multiple linear and logistic regression models were analyzed to ensure all assumptions were met. Where appropriate, residuals were assessed for normal distribution and no multicollinearity was observed. All variables in the multiple linear logistic regression model were first ran separately to ensure no artifact *P*-values were present and that all effect sizes were reported honestly.

Results

A total of 17 662 patients were included in the study. The average age of patients in the sample was 55 years-old (12) and the

average MCCI was 1.27 (7.66). When considering the gender distribution of the sample, 9003 (51%) were male and 8658 (49%) were female. 8334 (47.2%) had a BMI >30, 8181 (46.3%) had hypertension, 2974 (16.8%) had diabetes mellitus, and 57 (.3%) had a history of CHF. 25 (.1%) had a diagnosis of osteoporosis and 508 (2.9%) had hypoalbuminemia. 331 (1.9%) had a reoperation, 552 (3.1%) were readmitted, 41 (.2%) died within 30 days. Further demographic information can be seen in Table 1.

When compared to the MFI 0 group, the odds of readmission were 1.73 times greater in the MFI 1 ($P < .001$), 3.19 times greater in the MFI 2 ($P < .001$), and 8.54 times greater in the MFI 3 group ($P < .001$, Figure 1, Figure 2). Odds of reoperation were 1.573, 3.29, 10.81 times greater in the MFI 1, 2, 3 groups respectively

Table 1. Population Demographics. Continuous variables are given as Means with their Standard deviations in parenthesis, categorical variables are given as numerical counts with their respective column percents.

	MFI Categories				Sig.
	0 Risk Factors	1 or 2 Risk Factors	3 or 4 Risk Factors	5 or More Risk Factors	
	Mean (SD) N (%)	Mean (SD) N (%)	Mean (SD) N (%)	Mean (SD) N (%)	
Age	51.0 (11.19)	58.0 (11.02)	60.4 (9.80)	65.9 (10.20)	0
BMI	27.3 (3.91)	31.9 (6.61)	37.8 (7.06)	35.4 (9.33)	0
Female	3593 (51.5)	4406 (47.4)	595 (48.9)	17 (51.5)	0
Black	595 (8.5)	1261 (13.6)	236 (19.4)	6 (18.2)	0
Hispanic	466 (6.7)	559 (6.0)	75 (6.2)	3 (9.1)	.13

BMI, body mass index; MFI, modified frailty index; N, numerical count; % column percent within category; sig, significance.

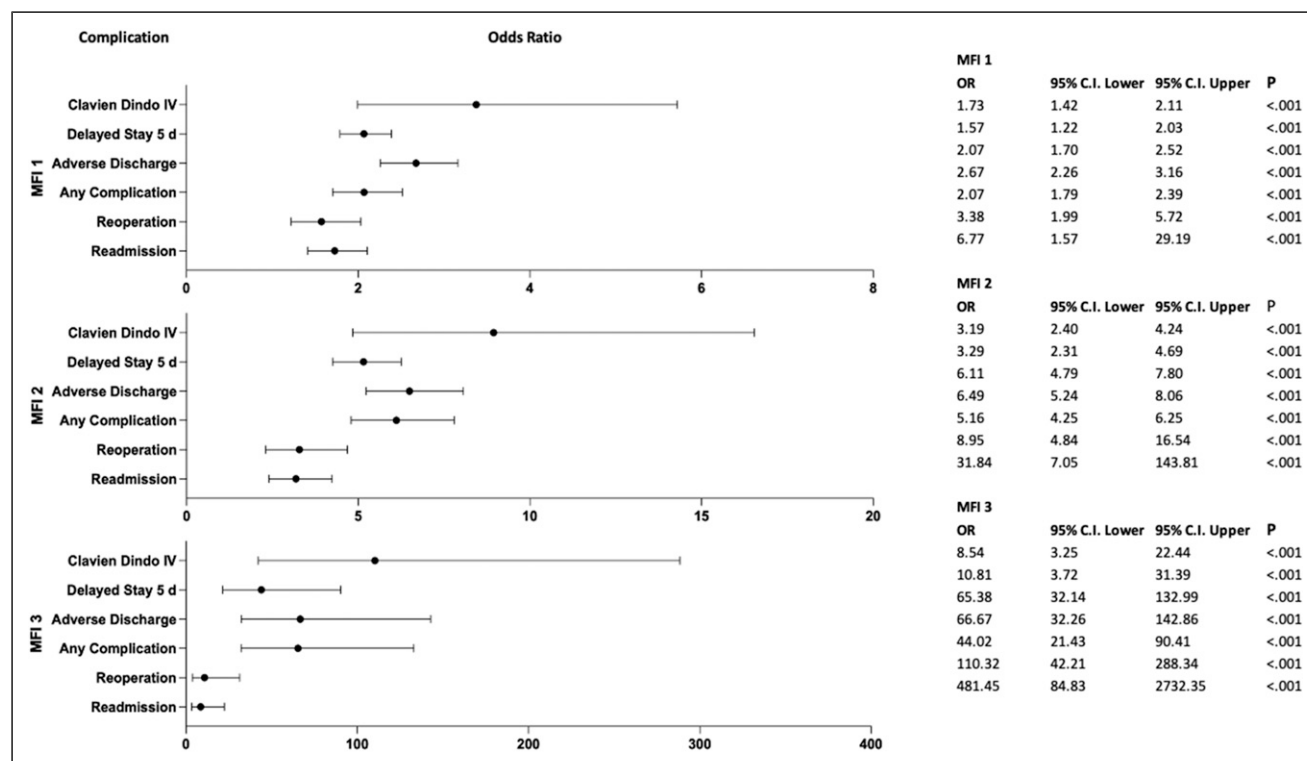


Figure 1. Odds ratios of developing each complication in each MFI group relative to MFI 0.

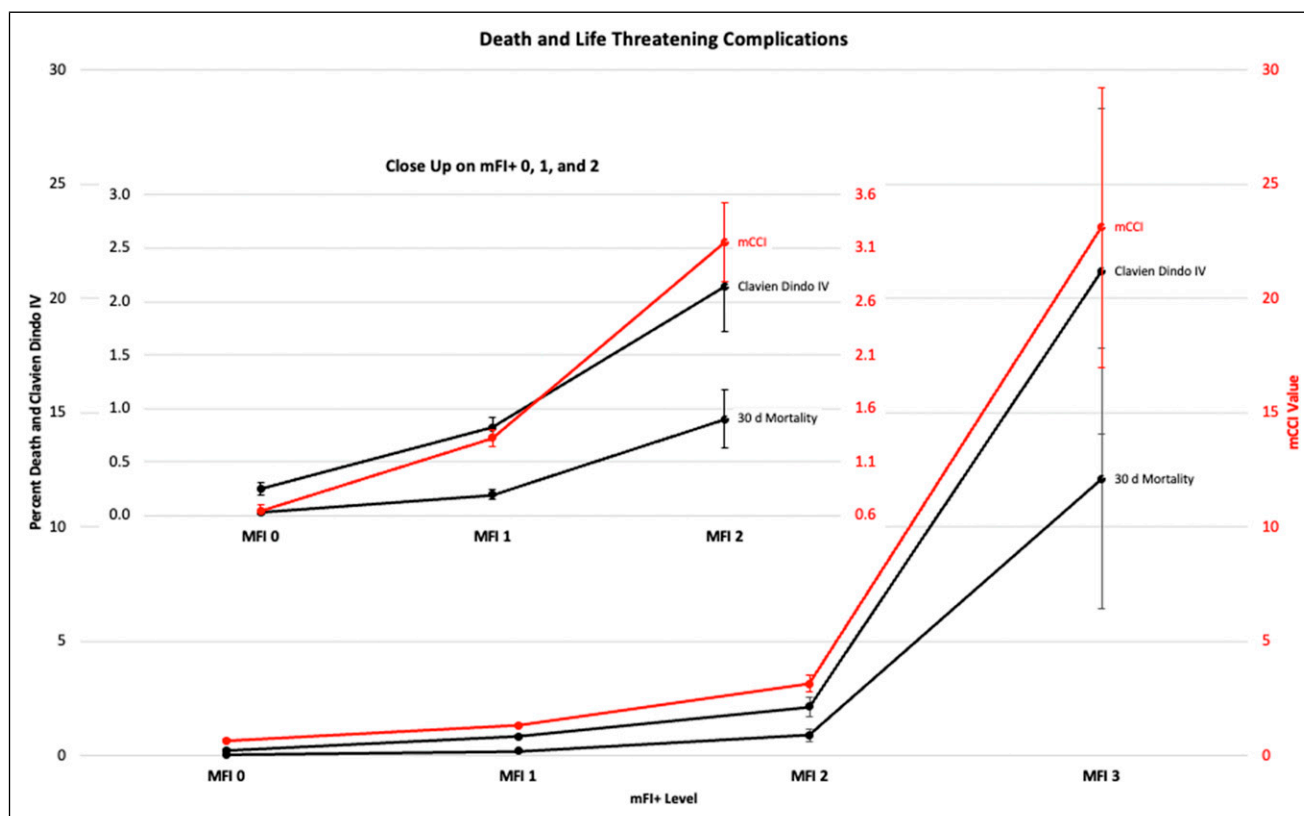


Figure 2. Rates of mortality and Clavien-Dindo IV complications by MFI category.

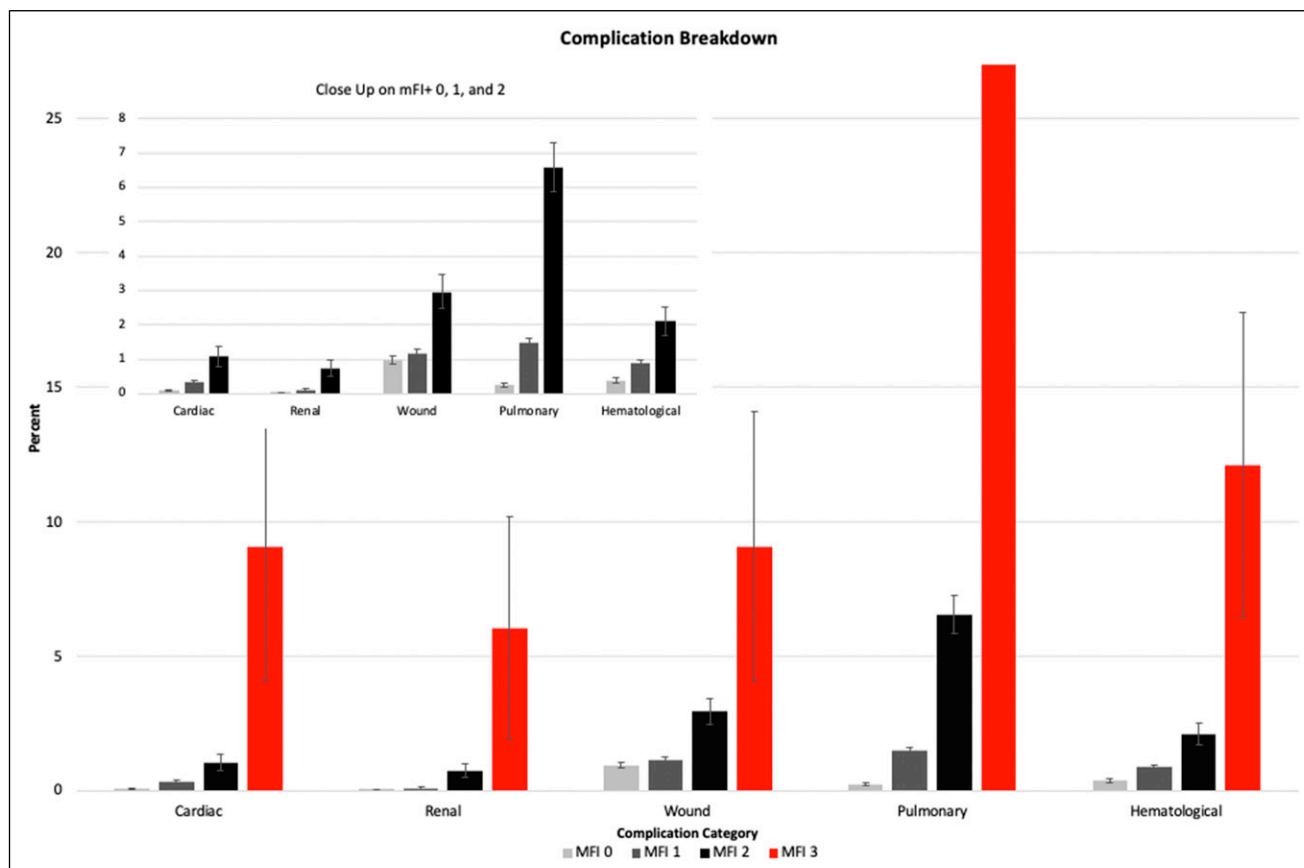


Figure 3. Rates of cardiac, renal, wound, pulmonary, and hematological complications by MFI category.

($P < .001$) when compared to the MFI 0 group (Figure 1, Figure 2). Complications were 65.38 times more likely in the MFI 3 group compared to the MFI 0 group ($P < .001$). (Figure 1, Figure 2). For all frailty groups, pulmonary, cardiac, wound, hematological, and renal complications were significantly increased when compared to MFI 0 ($P < .001$) (Figure 3).

Adverse patient discharge was 2.67 times more likely in MFI 1, 6.49 times more likely in MFI 2, and 66.67 times more likely in MFI 3 when compared to MFI 0. Average length of hospital stay significantly increased by .79 days for every increase in MFI categories ($P < .001$) (Figure 4). Additionally, prolonged stay of at least 5 days was significantly more likely in all MFI groups relative to MFI (Figure 1, Figure 4). Odds of a life threatening complication (Clavien-Dindo IV) were significantly greater in all other MFI groups compared to MFI 0 (3.38, 8.95, 110.321 times greater in MFI 1, 2, 3, respectively [$P < .001$]) (Figure 1, Figure 5). Additionally, when compared to MFI 0, the odds of 30 days mortality was increased in all MFI groups (Figure 5). Modified comprehensive complication index score was found to increase by 1.21 for every MFI category increase ($P < .001$) (Figure 5).

Discussion

The current study of 17 662 patients undergoing ACDF aimed to identify differences in post-operative complications in

normal and frail patients, and to validate the predictive value of our 8-item MFI. Our hypothesis was that patients that were more frail were more likely to experience post-operative complications, and that our MFI would be predictive of post-operative complications. We found that (1) patients with higher frailty index scores had greater odds of readmission, reoperation, rates of severe complications, and lengths of stay compared to patients who are not frail, and (2) that our 8-item MFI was highly predictive of rates of post-operative complications.

The results of our study demonstrate that patients with increased frailty were more likely to experience post-operative complications when undergoing ACDF. Yagi et al echo similar findings reporting that frailty prior to corrective surgery for adult spinal deformity (ASD) was associated with a doubled rate of complications when compared to non-frail patients ($P < .01$).¹⁴ Additionally, Miller et al also found that as patients became more frail they had longer hospital stays ($P < .001$), a higher risk of intra-operative or post-operative complications, higher rates of wound dehiscence ($P < .05$), and a 2.1 times higher chance of reoperation ($P < .05$) when undergoing corrective surgery for ASD.¹⁵ There is contention as to what factors should be included in the MFI. Ali et al conducted a retrospective study that created a 16-item MFI to predict 30 day morbidity and mortality in 18 294 patients from the

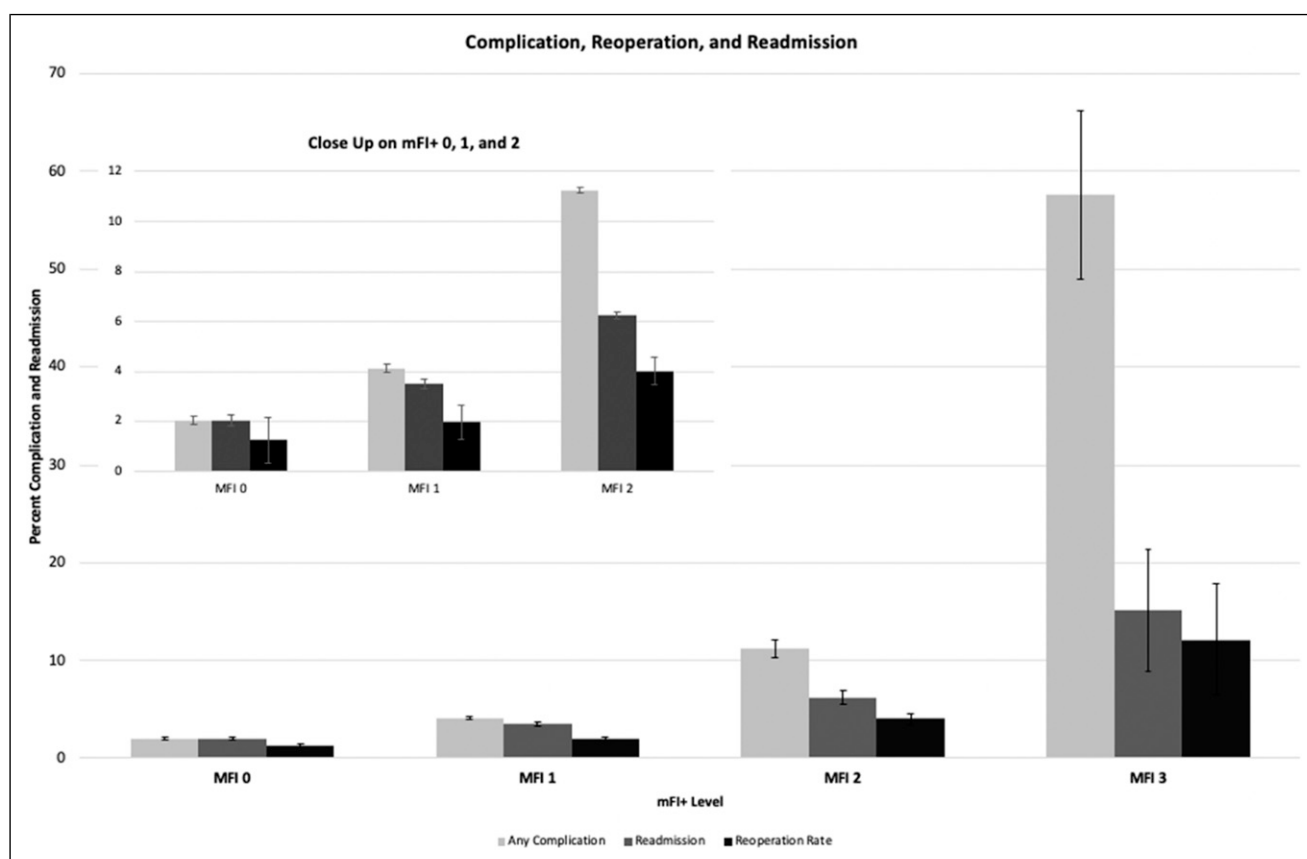


Figure 4. Rates of any complication, readmission, and reoperation rate by MFI category.

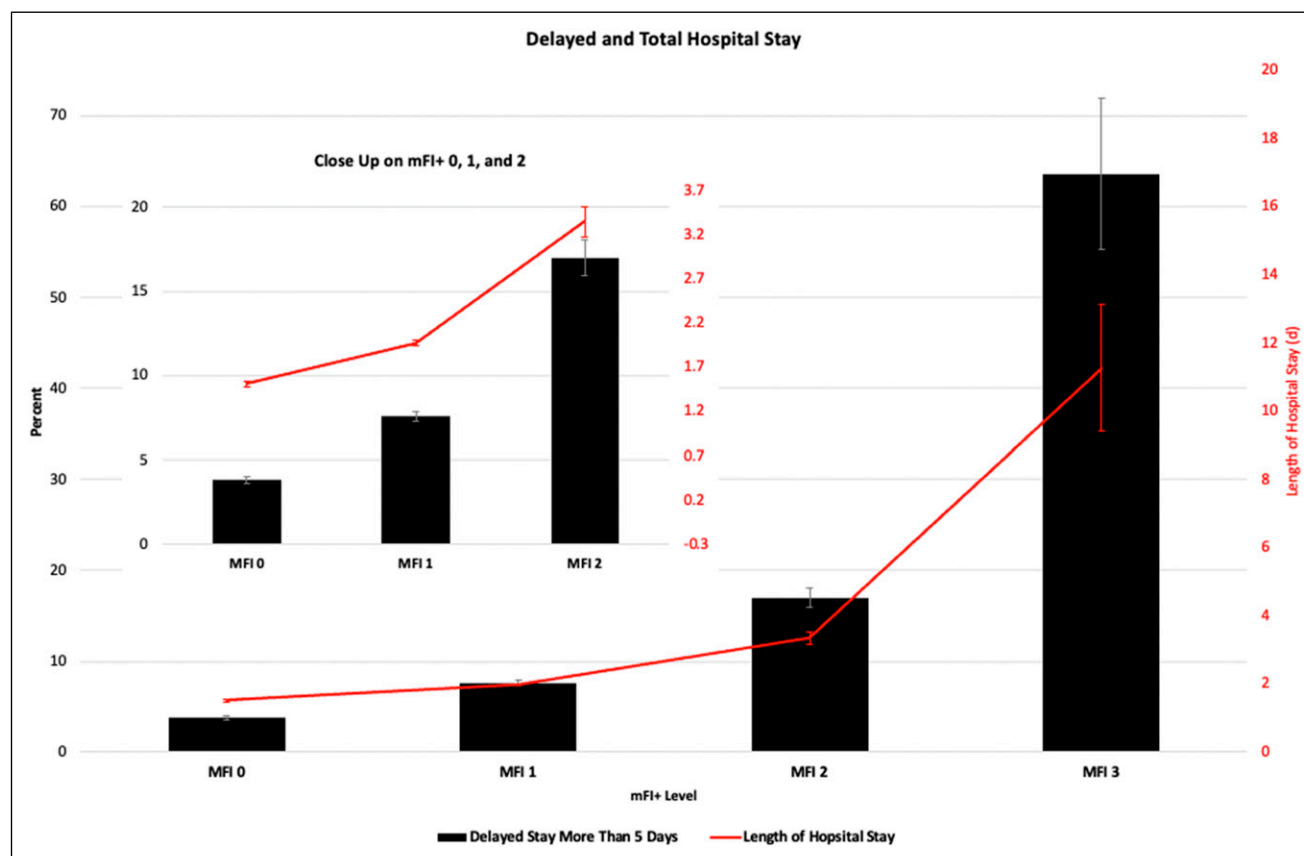


Figure 5. Rates of delayed stay longer than 5 days and average length of stay by MFI category.

NSQIP database undergoing spine surgery, and determined that their MFI was a powerful predictive tool for morbidity and mortality ($P < .001$).¹⁶ Meanwhile, Shin et al used a 15 factor MFI to predict complications following ACDF in 6148 patients from the NSQIP database and found that the rate of Clavien-Dindo grade IV complications was predicted by frailty score ($P < .001$).¹⁷ These results are supported by the findings in our study, however we assessed a larger sample and found that our MFI is predictive of a number of variables including readmission, reoperation, pulmonary complications, cardiac complications, wound complications, hematological complications, renal complications, adverse discharge, delayed hospital stay longer than 5 days, Clavien-Dindo IV complications, and 30 days mortality. Zreik et al's 2020 study predicted the rate of complications following ACDF with a 5 factor MFI in 23 754 patients from the NSQIP database, and found that MFI of 1 was associated with increased rates of unplanned readmission, extended LOS, and non-home discharge ($P = .003$, $P < .001$, $P = .023$ respectively).³ However, they determined that their MFI had similar or less predictive value than other predictive tools such as American Society of Anesthesiologists (ASA) score or age.³

Frailty indices have also been used to predict complication rates throughout the orthopaedic literature. Wilson et al created a 5-item MFI that successfully stratified complication risk

in 6494 patients undergoing distal radius fractures that included rates of Clavien-Dindo IV, cardiac, renal, and wound complications.¹⁸ Evans et al used a different 5-item MFI that included new diagnosis of diabetes mellitus, CHF, hypertension requiring medication, COPD or pneumonia, and non-independent functional status to stratify risk in 2004 patients with proximal humerus fractures.¹⁹ Neither of these indices included the same number of variables as our index, and may have improved predictive value by including some variables included in the current MFI. While these indices were not compared to scales commonly used to stratify patient complication risk, such as ASA score, Bellamy et al created an 11-item MFI including history of diabetes mellitus, CHF, HTN requiring medication, MI, cardiac problems, cerebrovascular problems, delirium, COPD, pneumonia, decreased peripheral pulses, and independent functional status that successfully stratified complication risk in 51 582 patients undergoing primary total hip arthroplasty more effectively than ASA score.²⁰

Our MFI is unique because it also includes osteoporosis and malnutrition as predictive factors for post-operative complications. Patients with osteoporosis undergoing spine surgery are more likely to have nonunion, proximal junctional failure or fractures, and increased rates of revision surgery.^{21,22} Malnutrition is also known to result in

significantly increased medical complications and 1-year mortality rates following spinal fusion.²³ While it is debated on what measures should be included in a frailty index, the authors' believe the inclusion of osteoporosis and hypoalbuminemia adds merit to the current index, allowing for better prediction of surgical outcomes. The current study adds to a growing body of literature that indicates that frailty is an effective pre-operative tool to predict patient risk for post-operative complications. It is imperative that at-risk patients with high frailty scores be identified and treated in the preoperative period so that postoperative outcomes can be optimized.²⁴

Limitations

This study is retrospective in nature, predisposing the findings to bias. Although the large size of the ACS NSQIP database is a strength of the project, the database does not contain some information that limits the findings of this study. Some of the factors included in 11-point MFIs used in other studies were not available in this database. Furthermore, details about the surgical approach, treatment, rehabilitation protocol, length of follow-up, and patient reported outcomes were not reported. The lack of these factors makes it difficult to assess the severity of the patient's condition prior to treatment. Furthermore, the database does not include information about the indication for ACDF, which can affect the frequency and severity of complications. Lastly, though all efforts were taken to ensure accuracy, as an inherent nature of large-scale data bases, the quality of each individual data point cannot be guaranteed.

Conclusions

Anterior cervical discectomy and fusion is a surgery that can dramatically ease a patient's pain and neurological symptoms, while also carrying a high rate of complications. Tools that are more effective for predicting the probability of complications following this procedure can ease clinical decision making and reduce the rate of complications by selecting patients that are at low risk to have complications. Our study found that our 8 item MFI was highly predictive of complication rates following ACDF. Further research should be conducted to determine the relative predictive value of this frailty index relative to other predictive tools.

Declaration of Conflicting Interests

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