



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

---

# Preoperative Frailty Assessment, Operative Severity Score, and Early Postoperative Loss of Independence in Surgical Patients Age 65 Years or Older

Oluwafemi P Owodunni, MD, MPH, Joshua C Mostales, BS, Caroline Xu Qin, BS, Alodia Gabre-Kidan, MD, MPH, FACS, Thomas Magnuson, MD, FACS, Susan L Gearhart, MD, MEHP, FACS

---

- BACKGROUND:** Preoperative discussions around postoperative discharge planning have been amplified by the COVID pandemic. We wished to determine whether our preoperative frailty screen would predict postoperative loss of independence (LOI).
- STUDY DESIGN:** This single-institutional study included demographic, procedural, and outcomes data from patients 65 years or older who underwent frailty screening before a surgical procedure. Frailty was assessed using the Edmonton Frail Scale. The Operative Severity Score was used to categorize procedures. The Hierarchical Condition Category risk-adjustment score, as calculated by the Centers for Medicare and Medicaid Services, was included. LOI was defined as an increase in support outside of the home after discharge. Univariable, multivariable logistic regressions, and adjusted postestimation analyses for predictive probabilities of best fit were performed.
- RESULTS:** Five hundred and thirty-five patients met inclusion criteria and LOI was seen in 38 patients (7%). Patients with LOI were older, had a lower BMI, a higher Edmonton Frail Scale score (7 vs 3.0;  $p < 0.001$ ), and a higher Hierarchical Condition Category score than patients without LOI. Being frail and undergoing a procedure with an Operative Severity Score of 3 or higher was independently associated with an increased risk of LOI. In addition, social dependency, depression, and limited mobility were associated with an increased risk for LOI. On multivariable modeling, frailty status, undergoing an operation with an Operative Severity Score of 3 or higher, and having a Hierarchical Condition Category score  $\geq 1$  were the most predictive of LOI (odds ratio 12.72; 95% CI, 12.04 to 13.44;  $p < 0.001$ ). In addition, self-reported depression, weight loss, and limited mobility were associated with a nearly 11-fold increased risk of postoperative LOI.
- CONCLUSIONS:** This study was novel, as it identified clear, generalizable risk factors for LOI. In addition, our findings support the implementation of preoperative assessments to aid in care coordination and provide specific targets for intervention. (J Am Coll Surg 2021;232:387–395. © 2020 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)
- 

It is currently estimated that >50% of operations performed in the US are in patients older than 65 years, and the prevalence of frailty in this older patient

population ranges from 10% to 37%.<sup>1-3</sup> Frailty is an indicator of a patient's vulnerability to the physiologic stress of a surgical procedure and the potential for long-term postoperative effects.<sup>4</sup> It has become a well-established predictor of poor postoperative outcomes, including an increased risk for complication and longer length of stay, in many of the surgical subspecialties.<sup>5-7</sup> Recently, Berian and colleagues<sup>8</sup> reported that the increase in complication seen in our older patient population was significantly associated with increased rate of loss of independence (LOI) and early mortality. Frail surgical patients who experience LOI are often placed in skilled

**Disclosure Information:** Nothing to disclose.

Selected for the 2020 Southern Surgical Association Program.

Received November 29, 2020; Accepted November 30, 2020.

From the Johns Hopkins School of Medicine, Baltimore, MD (Owodunni, Qin, Gabre-Kidan, Magnuson, Gearhart) and John A Burns School of Medicine, University of Hawaii, Honolulu, HI (Mostales).

Correspondence address: Susan Gearhart, MD, MEHP, FACS, Department of Surgery, Johns Hopkins Bayview Medical Center, A Building, 4940 Eastern Ave, Baltimore, MD 21286. email: [sdemees1@jhmi.edu](mailto:sdemees1@jhmi.edu)

### Abbreviations and Acronyms

CMS	= Centers for Medicare and Medicaid Services
EFS	= Edmonton Frail Scale
EMR	= electronic medical record
HCC	= Hierarchical Condition Category
LOI	= loss of independence
OSS	= Operative Severity Score
OR	= odds ratio
PM	= predictive margin

nursing facilities on discharge from the hospital. This has been particularly challenging, given the uncertainty around severe acute respiratory syndrome coronavirus 2 infection within skilled nursing facilities. Skilled nursing facilities are particularly vulnerable to this infection and residents are at risk for severe outcomes.<sup>9</sup>

In 2013, the American College of Surgeons NSQIP, in collaboration with the American Geriatrics Society, issued best practice guidelines recommending the incorporation of frailty assessment into clinical practice to address the growing trend of a rapidly aging US population.<sup>10</sup> In a systematic review, Ko<sup>5</sup> identified 67 different frailty instruments frequently cited for their ability to identify this vulnerable population. The instrument types are categorized into 2 unique models, the Physical Frailty Phenotype, characterized by the 5 clinical features of a decline in lean body mass, grip strength, endurance, walking speed, and physical activity; and the Deficit Accumulations Model, characterized as a model of multimorbidity. Several of the instruments lack a cognitive assessment and fail to acknowledge psychosocial determinants of health. In 2018, we implemented the Edmonton Frail Scale (EFS) in our clinical setting to screen patients for the risk of frailty before a surgical intervention. This is an 11-item scale in which 9 items are self-reported. It has been reported to take, on average, 5 minutes to complete and does not require someone with geriatric expertise to administer.<sup>11,12</sup> The assessment does incorporate a cognitive screen and screens for psychosocial determinants and has been validated as a tool to evaluate frailty.<sup>11-13</sup>

Understanding the interaction between frailty and surgical outcomes has been hindered by the high degree of heterogeneity of the frailty assessments. However, more important is the limitation imposed by the variability in the types of procedures performed in these patients. Most studies examining frailty have limited their patient populations to a select disease state (cancer) or procedure type, which greatly limits the generalizability of their findings. Recently, to address this issue, Shinall and colleagues<sup>4</sup> developed and validated the Operative Severity

Score (OSS), which assigns an ordinal number (1 to 5) relative to the degree of physiologic stress experienced by patients from a large variety of surgical procedures. We wished to evaluate the use of the EFS to predict postoperative outcomes in our surgical population. To aid in the generalizability of our findings, we wished to examine the use of the OSS to categorize the elective surgical interventions in our older population. In particular, we wanted to understand the effect of our frailty screen and the physiologic severity of the planned procedure on postoperative loss of independence and mortality.

## METHODS

### Patient characteristics

Between June 2019 and June 2020, patients 65 years or older who underwent frailty screening before a surgical intervention were included in this study. All patient data were abstracted from the hospital's electronic medical record (EMR). Abstracted data included patients' demographic characteristics, including age, sex, and race; and lifestyle determinants of health, including BMI, alcohol use, and smoking status. In addition, access to advanced care directives within the EMR before the planned procedure was assessed. Procedural data included CPT coding designation and procedure duration. The patient class designation of elective surgical inpatient or outpatient procedure was used.

### Risk assessment indices

#### Edmonton Frail Scale

To evaluate for the presence of frailty in patients 65 years or older, deviations from normal physiologic functions were considered across several frailty domains, including independent capacity, cognition, nutrition, disease chronicity, and the presence of geriatric syndromes. Individual scores were calculated as the proportion of deficits out of the total number of the domain-specific items included in the scale to compare frailty levels. EFS was first dichotomized, with a score of 6 or higher considered frail. To understand the impact of the individual domains of the EFS on outcomes, each domain was tallied independently using the following algorithm:

1. Cognitive impairment: complete failure of the clock-draw or partial failure and self-reporting forgetting to take medication (2 points)
2. Social dependence: self-reported failure to perform 2 or more activities of daily living, self-reported lack of any social support, or self-reported failure to perform 1 or more activities of daily living and self-reported lack of some support (2 points)

3. Depression: self-reported feeling sad (1 point)
4. Weight loss: self-reported clothes feeling loose (1 point)
5. Limited mobility: performing the Timed Get-up and Go in more than 10 seconds (1 point)

### **Operative Severity Score**

The OSS has been described previously, and the techniques for the score evaluation are reviewed.<sup>4</sup> Briefly, modified Delphi consensus methods using CPT codes were used to develop OSS. OSS is assigned using an ordinal scale of 1 to 5 relative to the degree of physiologic stress experienced by patients, with larger scores registering more physiologic stress levels. The research team assigned scores based on CPT and procedural description. Only procedures with an established OSS score were included in this study.

### **The Hierarchical Condition Category risk adjustment score**

The Centers for Medicare and Medicaid Services (CMS) use patient demographic characteristics and diagnosis-based clinical measures to generate a summary risk-adjustment scoring system.<sup>14</sup> The CMS-HCC model adjusts for patients' insurance capitation fees and predicts healthcare charges for which payment plans are subject. The CMS-HCC model is prospective, as the mean expenditures collected in 1 year provide predictive data for the following year. In addition, beneficiaries rely on several parameters for coding diagnoses and, consequently, a comprehensive clinical profile prediction is generated. Five domains of clinical and diagnostic categories are used to assign CMS-HCC and include the following sources: primary hospital inpatient diagnosis, secondary hospital inpatient diagnosis, hospital outpatient, physician visit, and clinically trained nonphysician. For the individual HCC scores, we evaluated the most updated reported predictive ratio for each patient before the surgical intervention. Ratios approaching 1 are characteristic of an accurate prediction, ratios less than 1 underpredict expenditure, and ratios greater than 1 overpredict expenditure.

### **Outcomes measure**

The main outcomes of interest evaluated included LOI and mortality. LOI was defined as discharge destination other than home. Patients discharged to skilled care facilities or other locations that differed from their point of origin were considered dependent and met the LOI definition. Mortality is defined as patients who died within a 30-day period from the primary procedure. Other outcomes of interest included length of hospital stay (days)

after the surgical procedure and readmission occurring within 30 days after discharge.

### **Statistical analysis**

Descriptive analyses were performed for the demographic and perioperative clinical variables. Reported results on variables are presented in frequencies and proportions for dichotomized and categorical variables. For continuous variables, we report the medians and interquartile range. Patient characteristics at inclusion are stratified and analyzed relative to their functional dependency status at discharge. The sample size with power set at 80% and significance at  $p \leq 0.05$  was used to compute the least number of patients required to detect a baseline change. For all other tests, 2-sided tests with statistical significance at  $p \leq 0.05$  were performed. The comparisons were performed based on the variables assessed, that is, Wilcoxon rank sum and the Kruskal-Wallis analysis for medians, chi-square, and Fisher exact tests for dichotomized or categorical variables.

Multivariable logistic regressions were performed, and odds ratios (ORs) with their corresponding 95% CIs are reported. Hosmer-Lemeshow statistics were used for model discrimination and calibration. To evaluate our hypothesis that the possible interplay of procedure complexities and the patients' clinical profile is associated with a higher likelihood of LOI and mortality, we tested interaction terms to understand the direct effect of the independent factors on LOI and mortality and the impact of other independent factors on their effect size.<sup>15</sup> In addition, we applied Stata's post-estimation predictive margins (PMs) to determine the mean predicted probability for all combinations of the different interactions (ie frailty status, OSS, and HCC). To identify specific EFS survey items that predict LOI and mortality, we calculated the mean predicted probability for all combinations of the different interactions (ie cognitive impairment, social support, depression, and weight loss). PM measures the marginal effects relative to the covariates' changes. Coefficients with their corresponding 95% CI and percent change are reported for PMs.<sup>16</sup>

Sensitivity analyses were then performed for quality assurance of our statistical model selection by matching estimators to determine the magnitude of unobserved confounding. We applied propensity score matching, a quasi-experimental method to evaluate the covariates' impact on mortality by creating matched pairs for patients who died compared with patients with similar characteristics who did not die in the postoperative period (results not reported).<sup>17</sup> Statistical analysis was performed using Stata statistical software, version 16.0 (Stata Corp).

**Table 1.** Patient Demographic and Clinical Characteristics Relative to Their Dependency Status

Characteristic	Total (n = 535)	No LOI (n = 497)	LOI (n = 38)	p Value
Age, y, median (IQR)	72.0 (68.0–77.0)	72.0 (68.0–77.0)	79.0 (73.0–82.0)	<0.001
Age, n (%)				0.007
<80 y	449 (83.9)	423 (85.1)	26 (68.4)	
≥80 y	86 (16.1)	74 (14.9)	12 (31.6)	
Sex, n (%)				0.17
Male	320 (59.8)	293 (59.0)	27 (71.1)	
Female	215 (40.2)	204 (41.0)	11 (28.9)	
Race, n (%)				0.52
White	399 (74.6)	373 (75.1)	26 (68.4)	
Black	106 (19.8)	97 (19.5)	9 (23.7)	
Other	30 (5.6)	27 (5.4)	3 (7.9)	
BMI, kg/m <sup>2</sup> , median (IQR)	27.8 (24.2–32.3)	28.1 (24.4–32.3)	24.3 (22.5–29.9)	0.02
BMI, n (%)				0.002
<25.0 kg/m <sup>2</sup>	164 (30.7)	144 (29.0)	20 (52.6)	
≥25.0 kg/m <sup>2</sup>	371 (69.3)	353 (71.0)	18 (47.4)	
Smoking history, n (%)				0.06
No	513 (95.9)	479 (96.4)	34 (89.5)	
Yes	22 (4.1)	18 (3.6)	4 (10.5)	
History of alcohol use, n (%)				1.00
No	532 (99.4)	494 (99.4)	38 (100.0)	
Yes	3 (0.6)	3 (0.6)	0 (0.0)	
EFS score, median (IQR)	3.0 (2.0–5.0)	3.0 (2.0–5.0)	7.5 (4.0–9.0)	<0.001
EFS total score <6, n (%)	406 (75.9)	392 (78.9)	14 (36.8)	<0.001
EFS total score ≥6, n (%)	129 (24.1)	105 (21.1)	24 (63.2)	
EFS domain, n (%)				
Cognitive impairment	81 (15.1)	69 (13.9)	12 (31.6)	0.003
Social dependence	44 (8.2)	34 (6.8)	10 (26.3)	<0.001
Depression	85 (15.9)	71 (14.3)	14 (36.8)	<0.001
Weight loss	109 (20.4)	98 (19.7)	11 (29.0)	0.17
Limited mobility	184 (34.4)	161 (32.4)	23 (60.5)	<0.001
HCC score, median (IQR)	0.9 (0.5–1.7)	0.8 (0.5–1.7)	1.1 (0.6–2.4)	0.04
Operative Severity Score, n (%)				0.01
1	107 (20.0)	106 (21.3)	1 (2.6)	
2	249 (46.5)	231 (46.5)	18 (47.4)	
3	154 (28.8)	137 (27.6)	17 (44.7)	
4	24 (4.5)	22 (4.4)	2 (5.3)	
5	1 (0.2)	1 (0.2)	0 (0.0)	
Procedure duration, min, median (IQR)	160.0 (105.0–230.0)	160.0 (105.0–220.0)	195.0 (115.0–270.0)	0.07
Procedure status, n (%)				<0.001
Outpatient	241 (45.0)	234 (47.1)	7 (18.4)	
Inpatient	294 (55.0)	263 (52.9)	31 (81.6)	
LOS, d, median (IQR)	1.0 (0.0–2.0)	0.0 (0.0–1.0)	4.0 (1.0–6.0)	<0.001
30-d mortality, n (%)	21 (3.9)	17 (3.4)	4 (10.5)	0.05

EFS, Edmonton Frail Scale; HCC, Hierarchical Condition Category; IQR, interquartile range; LOI, loss of independence; LOS, length of stay.

## RESULTS

Overall, 535 surgical patients 65 years or older with a pre-operative EFS score participated in this study. Median age was 72 years (interquartile range 68 to 77 years); 59.8%

were male and 74.6% were White (Table 1). Median EFS score for the study population was 3.0 (interquartile range 2.0 to 5.0). Within the domains of the EFS assessment there was a 15.1% rate of cognitive impairment, an

8.2% rate of social dependence, and a 16.0% rate of depression; 20.4% of patients experienced weight loss and 34.4% of patients had limited mobility. Most procedures were classified as inpatient (55.0%) and median procedure duration was 160 minutes (105 to 230 minutes). Using the OSS to define the case type, the majority of procedures performed were an OSS of 2 with 33.5% of the total population having a procedure with an OSS of 3 or higher performed.

Comparisons between patients with LOI and those without LOI showed that patients with LOI were older (79 vs 72 years;  $p < 0.001$ ), had a lower BMI (24.3 vs 28.1 kg/m<sup>2</sup>;  $p = 0.02$ ), and a higher total EFS score (7.5 vs 3.0;  $p < 0.001$ ). Inpatient procedures resulted in more LOI than outpatient procedures; however, it was noted that 7 patients (18.4%) who had LOI had a designated outpatient procedure. Procedures performed in patients with LOI had a significantly higher OSS score. Patients with LOI had an increased length of hospital stay compared with patients without LOI (4 vs 0 days;  $p < 0.001$ ). The 30-day mortality rate among patients with LOI was higher than patients without LOI (10.5% vs 3.4%;  $p = 0.05$ ) (Table 1).

When evaluating risk associated with LOI using EFS as an indicator of frail or not frail, several factors were identified (Table 2). There was a significant risk of LOI for patients 80 years or older (OR 1.69; 95% CI, 1.62 to 1.77;  $p < 0.001$ ) and a decreased risk for LOI in patients with a BMI  $\geq 25$  kg/m<sup>2</sup> (OR 0.41; 95% CI, 0.38 to 0.43;  $p < 0.001$ ). Being frail (EFS score  $\geq 6$ ; OR 6.98; 95% CI, 6.90 to 7.06;  $p < 0.001$ ) and undergoing a procedure with an OSS  $\geq 3$  (OR 1.19; 95% CI, 1.12 to 1.25;  $p < 0.001$ ) was associated with an increased risk of LOI. In addition, analyzing domains of the EFS assessment showed that reporting social dependency, presence of depression, and limited mobility were associated with an increased risk for LOI. Analyzing interactions between independent variables to develop a predictive model for LOI demonstrated that frailty status, undergoing an operation with an OSS  $\geq 3$ , and having an HCC score  $\geq 1$  were the most predictive of LOI (OR 12.72; 95% CI, 12.04 to 13.44;  $p < 0.001$ ) (Table 3). Postestimation PMs of these variables suggested that age 80 years or older along with frailty status and undergoing an operation with an OSS  $\geq 3$  conferred a nearly 40% risk for postoperative LOI (PM 0.39; 95% CI, 0.13 to 0.66;  $p = 0.004$ ).

**Table 2.** Multivariable Analysis of Postoperative Loss of Independence and Mortality, Including the Overall Edmonton Frail Scale Score and the Domains Within the Edmonton Frail Scale

Variable	LOI		30-d mortality	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Age				
65–79 y	Ref	—	Ref	—
$\geq 80$ y	1.69 (1.62–1.77)	$<0.001$	0.96 (0.83–1.11)	0.594
BMI				
$<25$ kg/m <sup>2</sup>	Ref	—	Ref	—
$\geq 25$ kg/m <sup>2</sup>	0.41 (0.38–0.43)	$<0.001$	1.01 (0.92–1.12)	0.77
Outpatient				
Ref	Ref	—	Ref	—
Inpatient	4.58 (4.06–5.15)	$<0.001$	1.60 (1.58–1.62)	$<0.001$
EFS score				
$<6$	Ref	—	Ref	—
$\geq 6$	6.98 (6.90–7.06)	$<0.001$	3.36 (3.09–3.65)	$<0.001$
OSS				
$<3$	Ref	—	Ref	—
$\geq 3$	1.19 (1.12–1.25)	$<0.001$	0.80 (0.78–0.82)	$<0.001$
HCC score	1.02 (0.96–1.08)	0.564	21.83 (21.51–22.14)	$<0.001$
EFS domain*				
Cognitive impairment	1.31 (0.98–1.76)	0.07	1.21 (0.92–1.60)	0.18
Social support	2.02 (2.01–2.04)	$<0.001$	0.19 (0.17–0.21)	$<0.001$
Depression	2.42 (2.38–2.46)	$<0.001$	1.74 (1.55–1.94)	$<0.001$
Weight loss	0.90 (0.54–1.52)	0.70	1.60 (1.50–1.69)	$<0.001$
Mobility	2.31 (1.86–2.87)	$<0.001$	3.04 (2.75–3.36)	$<0.001$

\*Adjusted for age, BMI, inpatient disposition, and HCC.

EFS, Edmonton Frail Scale (frail = EFS score  $\geq 6$ ); OSS, Operative Severity Score; HCC, Hierarchical Condition Category; LOI, loss of independence; Ref, reference.

**Table 3.** Multivariable Analysis Examining for an Interaction Between Age, Edmonton Frail Scale Score, Operative Severity Score, and Hierarchical Condition Category and the Outcomes of Loss of Independence and Mortality

EFS score* (total)	LOI		30-d mortality	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Age < 80 y, nonfrail, OSS <3 <sup>†</sup>	Ref	—	Ref	—
Age ≥ 80 y, frail, OSS <3	4.59 (3.77–5.59)	<0.001	4.41 (4.22–4.61)	<0.001
Age ≥ 80 y, frail, OSS ≥3	9.92 (5.78–17.02)	<0.001	3.26 (1.74–6.12)	<0.001
Nonfrail, OSS <3, HCC <1 <sup>‡</sup>	Ref	—	Ref	—
Nonfrail, OSS ≥3, HCC ≥1	1.91 (1.89–1.92)	<0.001	NII	—
Frail, OSS <3, HCC ≥1	7.49 (5.67–9.89)	<0.001	NII	—
Frail, OSS ≥3, HCC <1	19.76 (10.98–35.57)	<0.001	NII	—
Frail, OSS ≥3, HCC ≥1	12.72 (12.04–13.44)	<0.001	NII	—
EFS domain <sup>§,  </sup>				
Depression–, weight loss–, mobility–	Ref	—	Ref	—
Depression+, weight loss–, mobility+	5.52 (4.02–7.57)	<0.001	NII	—
Depression+, weight loss+, mobility–	5.86 (5.38–6.37)	<0.001	NII	—
Depression+, weight loss+, mobility+	NII	<0.001	NII	—
Cognitive impairment–, weight loss–, mobility–	Ref	—	Ref	—
Cognitive impairment–, weight loss+, mobility+	NII	—	8.78 (7.82–9.87)	<0.001
Cognitive impairment+, weight loss–, mobility+	NII	—	1.54 (1.41–1.68)	<0.001
Cognitive impairment+, weight loss+, mobility+	NII	—	2.73 (2.70–2.76)	<0.001

\*EFS score ≥6 indicates frail.

<sup>†</sup>Adjusted for BMI, inpatient disposition, and HCC.

<sup>‡</sup>Adjusted for age, BMI, and inpatient disposition.

<sup>§</sup>–, not present; +, present.

<sup>||</sup>Adjusted for age, BMI, inpatient disposition, and HCC.

EFS, Edmonton Frail Scale; HCC, Hierarchical Condition Category; LOI, loss of independence; NII, no interaction indicated; OR, odds ratio; OSS, Operative Severity Score; Ref, reference.

(Table 4). Finally, combining the domains of the EFS showed that self-reported depression and weight loss and measured limited mobility were associated with a

nearly 11-fold increased risk in postoperative LOI (OR 10.88; 95% CI, 8.41 to 14.08;  $p < 0.001$ ) (Table 3). These findings were mirrored in our analysis of PMs,

**Table 4.** Multivariable Post-Estimation Predictive Margins for Postoperative Loss of Independence and Mortality

EFS score* (total)	LOI		30-d mortality	
	PM (95% CI)	p Value	PM (95% CI)	p Value
Age < 80 y, nonfrail, OSS <3 <sup>†</sup>	Ref	—	Ref	—
Age ≥ 80 y, frail, OSS <3	0.17 (0.02–0.32)	0.02	0.14 (0.0–0.28)	0.07
Age ≥ 80 y, nonfrail, OSS ≥3	NII	—	NII	—
Age ≥ 80 y, frail, OSS ≥3	0.39 (0.13–0.66)	0.004	0.07 (0.0–0.22)	0.3
Nonfrail, OSS <3, HCC <1 <sup>‡</sup>	Ref	—	Ref	—
Nonfrail, OSS ≥3, HCC ≥1	NII	—	0.07 (0.003–0.13)	0.04
Frail, OSS <3, HCC ≥1	0.13 (0.04–0.21)	0.01	0.17 (0.06–0.27)	0.001
Frail, OSS <3, HCC ≥1	0.25 (0.04–0.47)	0.02	NII	—
Frail, OSS ≥3, HCC ≥1	0.19 (0.06–0.31)	0.004	NII	—
EFS domains <sup>§,  </sup>				
Depression–, weight loss–, mobility–	Ref	—	Ref	—
Depression+, weight loss–, mobility+	0.15 (0.001–0.29)	0.05	NII	—
Depression+, weight loss+, mobility+	0.24 (0.09–0.39)	0.002	NII	—
Cognitive impairment–, weight loss+, mobility+	NII	—	0.12 (0.04–0.21)	0.004

\*EFS score ≥6 indicates frail.

<sup>†</sup>Adjusted for BMI, inpatient disposition, and HCC.

<sup>‡</sup>Adjusted for age, BMI, and inpatient disposition.

<sup>§</sup>–, not present; +, present.

<sup>||</sup>Adjusted for age, BMI, inpatient disposition, and HCC.

EFS, Edmonton Frail Scale; LOI, loss of independence; OSS, Operative Severity Score; HCC, Hierarchical Condition Category; NII, no interaction indicated; PM, predictive margin.

where the combination of these same domains is associated with a 24% increased risk for postoperative LOI (PM 0.24; 95% CI, 0.09 to 0.39;  $p = 0.002$ ) (Table 4).

In this data set, the risk factors for 30-day mortality included frailty (EFS score  $\geq 6$ ; OR 3.36; 95% CI, 3.09 to 3.65;  $p < 0.001$ ) and, more significantly, a higher HCC score (OR 21.83; 95% CI, 21.51 to 22.14;  $p < 0.001$ ) (Table 2). A higher OSS score was associated with a decreased risk of 30-day mortality (OR 0.80; 95% CI, 0.78 to 0.82;  $p < 0.001$ ). As for the domains of the EFS, all domains except cognitive impairment were associated with a significant increased risk of mortality, with limited mobility being the highest risk (OR 3.04; 95% CI, 2.75 to 3.36;  $p < 0.001$ ) (Table 2). Multivariable analysis of variable interactions demonstrated age 80 years or older and frailty were associated with a 4.4-fold increase in mortality (OR 4.41; 95% CI, 4.22 to 4.61;  $p < 0.001$ ) (Table 3). For the domains of the EFS score, having self-reported weight loss and measured poor mobility was associated with an 8.7-fold increase in mortality (OR 8.78; 95% CI, 7.82 to 9.87;  $p < 0.001$ ). This finding was confirmed with postestimation PMs that demonstrated a 12% increased risk for mortality in patients with self-reported weight loss and measured limited mobility (PM 0.12; 95% CI, 0.04 to 0.21;  $p = 0.004$ ) (Table 4).

## DISCUSSION

LOI is part of the conceptual pathway known as “the disablement process” that elderly people often experience. Verbrugge and Jette<sup>18</sup> define the disablement process as a description of how chronic and acute conditions affect functioning in specific body systems and how personal and environmental factors speed up or slow down the disablement process. One of the environmental factors that has been shown to facilitate the disablement process is subjecting an elderly person to the physiologic stress of an operation and the complications often associated with an operative intervention. It therefore is not surprising that LOI occurs in elderly patients after many surgical interventions for vascular disease, colorectal cancer, and general abdominal emergencies.<sup>6,8,19,20</sup> Frailty is an established risk factor for poor postoperative outcomes, including an increased risk of discharge to a skilled nursing facility. In addition, LOI identified on postoperative discharge has been shown to be predictive of long-term LOI. In patients 80 years or older undergoing operation for colorectal cancer, nearly one-half of patients with LOI at discharge continued to have LOI at 30 days.<sup>19</sup> Similarly, De Roo and associates<sup>21</sup> demonstrated that 33% of older adults undergoing major colorectal

operation experienced a functional decline, as measured by the activities of daily living scale at 1 year. We therefore wanted to determine the ability of our frailty assessment tool, the EFS, to predict postoperative LOI at our institution.

We implemented the EFS into our multispecialty surgical clinic workflow through integration with our EMR. An EFS score of 6 or higher is an indicator of vulnerability and this score has been used to trigger intervention, including a referral to geriatric medicine for a comprehensive geriatric assessment. As our surgical population is heterogeneous, each surgical procedure was assigned an OSS. Our results demonstrated that frailty status (EFS score  $\geq 6$ ) was significantly associated with LOI in both the inpatient and outpatient surgical populations. This finding validates the independent use of this screening system to predict this end point and supports the use of existing resources and workflow to complete the screening assessment and the incorporation of the screening results into shared decision-making with the patient during the clinic visit. In addition, this finding supports the allocation of appropriate resources needed for coordination of perioperative care. In a similar study, Donald and colleagues<sup>20</sup> used the validated Clinical Frailty Score in the preoperative setting to successfully predict LOI in patients undergoing major vascular operation only. Our findings are more generalizable, as they apply to a variety of surgical procedures. In this data set, the CMS-HCC score was not associated with a risk for LOI, however, was significantly associated with the risk of 30-day mortality. Our findings are corroborated by Kumar and colleagues,<sup>22</sup> who recently reported that current risk adjustment and comorbidity index, including the CMS-HCC, were poor at predicting post-acute care skilled nursing facility use and readmission in patients undergoing joint replacement. This suggests that automated scoring systems that rely heavily on coding data and multimorbidity might not provide the granularity necessary to evaluate some of our important surgical outcomes.

In this study, we chose to examine all variables for an interaction to develop the best predictive model for LOI. After examining all potential variables for possible interactions, we did note that using all 3 scoring systems—frailty (EFS score  $\geq 6$ ), OSS  $\geq 3$ , and HCC score  $\geq 1$ —was associated with a 13-fold increase risk for LOI. As predictive models vary in outcomes, we also chose to examine our findings using postestimation PMs. Using this modeling, we determined that frail (EFS score  $\geq 6$ ), older (80 years or older) patients undergoing a more physiologically stressful procedure (OSS  $\geq 3$ ) were at a nearly 40% risk of postoperative LOI. Our combined results suggest that knowledge of the



preoperative frailty status and application of validated global score of operative stress provides the surgeon with valuable information to incorporate into the process of shared decision-making with the patient and should assist in the allocation of appropriate resources to coordinate perioperative care.

When examining the domains of the EFS to determine for possible areas of intervention, we noted that self-reported depression and weight loss and limited mobility were associated with LOI using both predictive modeling methods. This finding is similar to a recent study from Pederson and colleagues,<sup>23</sup> which demonstrated that a delay in mobilization, defined as out of bed 36 hours or more after operation, was independently associated with a 2-fold higher risk of 30-day readmission or mortality. In their study, 24% of patients undergoing emergent abdominal operation (the most common procedure was cholecystectomy) had delayed mobilization. In addition, Hirvensalo and colleagues<sup>24</sup> demonstrated similar findings in community-dwelling older adults. In their study, mobility impairments independently predicted a 5-fold increase in LOI among older men and a 3-fold increase among older women. It is also important to note that LaCroix and colleagues,<sup>25</sup> in a similar study, found that a higher level of physical activity was associated with better functioning in those with chronic disease. In addition, those patients with chronic disease who had a higher level of physical functioning were less likely to lose their mobility than those individuals with chronic disease who were sedentary. In aggregate, this work supports the implementation of a multimodal prehabilitation protocol, such as the Michigan Surgical Home and Optimization Program,<sup>26</sup> to optimize preoperative mobility and nutrition in a targeted population of frail patients undergoing a higher physiologically stressful procedure.

It is interesting to note that our data did not show that cognitive impairment assessed with the clock-draw was independently associated with LOI or mortality. Previous work using NSQIP data has shown cognitive impairment as well as postoperative delirium to be predictors of early postoperative LOI.<sup>19</sup> As we have recently implemented our delirium screening tool at our institution, we currently lack the ability to identify the rate of postoperative delirium, which is more likely to occur in patients with underlying cognitive impairment and is a known risk factor for poor surgical outcomes.<sup>27</sup> It is also plausible that early identification of these at-risk individuals with cognitive impairment in our patient population has prevented LOI, and additional work to examine the effect of cognitive impairment is necessary.

This study has several limitations. First, we used the EMR to obtain our data and, therefore, our data are

dependent on correct documentation in the appropriate location within the EMR. Our EFS data might not have reflected the absolute condition of the patient at the time of operation, as we have allowed for a 6-month gap in performance of the assessment. In addition, we internally validated administration of the EFS by our medical assistants, and there is always change in staffing, which could allow for some newer medical assistants to be less familiar with EFS scoring. We did develop an EFS learning tool and have performed several re-education sessions, however, we currently do not have a method of assessing the performance of the medical assistants before they administer the EFS assessment. Second, although we were able to assess a variety of elective surgical procedures, some procedures might have been more urgent than others, given our current operating room release policy and the ability of some procedures in inpatients to be posted to the next day's schedule as an elective case. In addition, nearly one-half of our cases were outpatient procedures. As we noted that nearly 20% of our patients with LOI were scheduled for outpatient procedures, we thought it was important to include these cases in our study, as unplanned admissions can use a large amount of hospital resources. Finally, we were concerned about our low number of patients with LOI, which is most likely a result of including outpatient procedures. Low numbers might have made predictive models less accurate; however, we used 2 separate models to investigate our population.

## CONCLUSIONS

Additional work in this area is necessary to better define measures to identify vulnerable individuals and implement strategies to prevent poor outcomes in this patient population.

## Author Contributions

Study conception and design: Owodunni, Gearhart

Acquisition of data: Owodunni, Mostales, Qui

Analysis and interpretation of data: Owodunni, Mostales, Qui, Gearhart

Drafting of manuscript: Owodunni, Gearhart

Critical revision: Gabre-Kidan, Magnuson

## REFERENCES

1. US Census Bureau. National Population Projections Report. Washington, DC: US Census Bureau; 2017.
2. Etzioni DA, Liu JH, O'Connell JB. Elderly patients in surgical workloads: a population based analysis. *Am Surg* 2004;691–695.
3. Dall RM, Gallo PD, Chakradarti R. An aging population and growing disease burden will require a large and specialized health care workforce by 2025. *Health Aff (Millwood)* 2013; 32:2013–2020.

4. Shinall M, Arya S, Youk A. Association of preoperative patient frailty and operative stress with postoperative mortality. *JAMA Surg* 2020;155[1]:e194620.
5. Ko F. Preoperative frailty evaluation: a promising risk stratification tool in older adults undergoing general surgery. *Clin Ther* 2019;41:387–399.
6. Engelhardt K, Reuter Q, Liu J. Frailty screening and a frailty pathway decrease length of stay, loss of independence, and 30-day readmission rates in frail geriatric trauma and emergency general surgery patients. *J Trauma Acute Care Surg* 2018;85:167–173.
7. Rothenberg K, Stern J, George E. Association of frailty and postoperative complications with unplanned readmissions after elective outpatient surgery. *JAMA Netw Open* 2019;2[5]:1–13.
8. Berian J, Mhanty S, Ko C. Association of loss of independence with readmission and death after discharge in older patients after surgical procedures. *JAMA Surg* 2016;151:1–7.
9. Patel M, Chaisson L, Borgetti S. Asymptomatic SARS-CoV-2 infection and COVID-19 mortality during an outbreak investigation in a skilled nursing facility. *Clin Infect Dis* 2020;71:2920–2926.
10. Mahanty S, Rosenthal R, Russel M. Optimal perioperative management of the geriatric patient: a best practices guideline from the American College of Surgeons NSQIP and the American Geriatrics Society. *J Am Coll Surg* 2016;22:930–942.
11. Bissot M, Henin PY, Aunac S, et al. Preoperative frailty assessment: a review. *Acta Anestheiol Belg* 2016;67:157–173.
12. Stoicea N, Baddigam R, Wajahn J. The gap between clinical research and standard of care: a review of frailty assessment scales in perioperative surgical settings. *Front Public Health* 2016;4:150.
13. Partridge J, Dhesi J, Cross J, et al. The prevalence and impact of undiagnosed cognitive impairment in older vascular surgical patients. *J Vasc Surg* 2014;60:1002–1011.
14. Pope GC, Kautter J, Ellis RP, et al. Risk adjustment of Medicare capitation payments using the CMS-HCC model. *Health Care Financ Rev* 2004;25:119–141.
15. Norton EC, Wang H, Ai C. Computing interaction effects and standard errors in logit and probit models. *Stata J* 2004;4:154–167.
16. Williams R. Using the Margins command to estimate and interpret adjusted predictions and marginal effects. *Stata J* 2012;12:308–331.
17. Nannicini T. Simulation-based sensitivity analysis for matching estimators. *Stata J* 2007;7:334–350.
18. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med* 1994;38:1–14.
19. Gearhart SL, Do EM, Owodunni O, et al. Loss of independence in older patients after operation for colorectal cancer. *J Am Coll Surg* 2020;230:573–582.
20. Donald G, Chaffarian A, Isaac F. Preoperative frailty assessment predicts loss of independence after vascular surgery. *J Vasc Surg* 2018;68:1382–1389.
21. De Roo A, Li Y, Abrahamse P, et al. Long-term functional decline after high-risk elective colorectal surgery in older adults. *Dis Colon Rectum* 2020;63:75–83.
22. Kumar A, Karmarkar A, Downer B, et al. Current risk adjustment and comorbidity index underperforms in predicting post-acute utilization and hospital readmissions after joint replacement: implications for comprehensive care for joint replacement model. *Arthritis Care Res (Hoboken)* 2017;69:1668–1675.
23. Pederson J, Padwal R, Warkentin L, et al. The impact of delayed mobilization on post-discharge outcomes after

emergency surgery: a prospective cohort study in older patients. *PLoS One* 2020;15[11]:e0241554.

24. Hirvensalo M, Rantanene T, Hekkinen E. Mobility difficulties and physical activity as predictors of mortality and loss of independence in the community-living older population. *J Am Geriatr Soc* 2000;48:493–498.
25. LaCroix AZ, Guralnik JM, Berkman LF, et al. Maintaining mobility in late life II. Smoking, alcohol consumption, physical activity and body mass index. *Am J Epidemiol* 1993;137:858–869.
26. Englesbe JH, Grenda DR, Sullivan JA, et al. The Michigan Surgical Home and Optimization Program is a scalable model to improve care and reduce costs. *Surgery* 2017;161:1659–1666.
27. Berian J, Zhou L, Russell M, et al. Postoperative delirium as a target for surgical quality improvement. *Ann Surg* 2018;268:93–99.

## Invited Commentary



Susan Galandiuk, MD, FACS  
Louisville, KY

Dr Owodunni and colleagues present a study<sup>1</sup> evaluating 535 patients older than 65 years who were assessed using an Edmonton Frail Scale score. The authors wished to determine whether this score could help predict postoperative loss of independence, defined as an “increase in the in support outside of the home after discharge.” Roughly 84% of patients were older than 80 years. Fifty-five percent of patients underwent inpatient procedures; but the median length of stay was 1 day. More than 65% of patients underwent very-low-stress or low-stress procedures according to the scoring system that was used.

This topic is extremely important, as we face operating on an increasingly aging population. In their article, the authors cite the dilemma of discharge disposition in the COVID-19 era. Hopefully this concern will soon be irrelevant! As the authors cite, there have been numerous frailty assessment instruments and, for the busy surgeon who might not have the luxury of working with an established geriatric service, there have been many efforts, such as those by the American Society of Colon and Rectal surgeons, to educate their membership on simple methods of assessing frailty and potential morbidity in the elderly population.<sup>2</sup> Obviously all risks are not equal. It has been recognized that all risk level procedures can be associated with mortality that increases with increasing frailty. Although the authors demonstrate that there was some loss of independence associated with outpatient procedures, I believe that our main focus for improvement should lie with inpatient procedures. The authors did not provide supplemental data defining the operative procedures performed. With a median stay of 1 day, and an interquartile range of 0 to 2 days, one questions the type of procedures that might have been performed and how relevant these data are to the typical surgeon. Although the numbers would be smaller, inpatient and outpatient procedures should be examined separately, or if they are examined together, the list of procedures must be provided, and endoscopic and ophthalmologic procedures explicitly excluded.