Limited Utility in Using Frailty Scores Based on Electronic Health Record Data to Predict Acute Outcomes of Major Lung Resection

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Abstract

Background: Frailty is a risk factor for adverse outcomes after lung resection, but few centers routinely assess frailty preoperatively. We evaluated whether frailty scores can be calculated using extant electronic health record (EHR) data and whether scores are associated with acute lung resection outcomes.

Methods: A retrospective review of patients who underwent major lung resection for cancer 1995-2014 was performed to calculate four EHR-based frailty indices: modified frailty index (mFI-5), prognostic nutritional index (PNI), and two laboratory frailty indices (FI-Lab and FI-Laboratory). Scores were generated if >70% of EHR values were present for a patient within six months of surgery. The association between frailty scores and surgical complications was assessed using multivariable logistic regression.

Results: We included 496 patients (50.3% female, mean age 65.8 ± 1.0 years). The mFI-5 score could be calculated for all patients. PNI, FI-Lab and FI-Laboratory scores could be calculated for only 33.4%, 5.6% and 38.5% of patients, respectively. Adjusted odds ratios were calculated only for the mFI-5 and demonstrated that scores >1 were significantly associated with pulmonary complications ($p = 0.002$) and any complication ($p = 0.004$).

Conclusions: Among four EHR-based frailty indices evaluated, only the mFI-5 could be consistently calculated. The mFI-5 was an independent predictor of pulmonary and overall complications. Further investigation of this and other measures of frailty is necessary in order to more robustly predict surgical outcomes.

Introduction

Frailty is a growing issue worldwide and is recognized with increasing frequency among surgical and geriatric patients. It is associated with an increased risk of a variety of health problems including cardiovascular disease, hypertension, cancer, and even death. Frail adults are particularly vulnerable during and immediately following an acute health event such as surgery, which can trigger accelerated decline.[1–4] As such, extensive research has focused on identifying frailty in acute and subacute settings, mainly through the use of frailty indices, which generate a score by quantifying comorbid, functional, and symptom risk factors based on an accumulated deficits model.[5–7] The accumulated deficits model of frailty is easily adaptable to EHR data, making it appealing for acute care settings. These scoring systems are of particular interest to surgeons, as more than one third of operations in the United States are performed on individuals 65 years and older,[8] and it is well known that older adults have higher rates of complication after major elective operations than young or middle-aged adults.[9,10]

Multiple scoring systems have been developed to predict postoperative complications after surgery, many of which include specialized frailty characteristics and tests.[11–14] One particular frailty prediction system, the 5-factor modified frailty index (mFI-5), was derived from data collected for the American College of

Surgeons National Surgical Quality Improvement Program (NSQIP), and has been extensively studied in multiple populations with good results.[15–17] A number of studies have specifically considered frailty as it applies to thoracic surgery patients.[18–20] Despite this progress in developing and validating frailty risk scores, the utilization of such scores is not common due to a combination of specialized tests required to generate these scores, inability of information systems to aggregate the necessary data to generate scores at the patient's preoperative clinic visit, and the resources required to obtain frailty-related testing.[21]

The aim of the present study was to evaluate whether selected frailty scores can be calculated in surgical patients using extant data from the electronic health record (EHR). Additionally, we sought to determine whether these scores are associated with acute postoperative surgical outcomes in a population of patients undergoing lung resection.

Methods

Data collection

Institutional review board approval was obtained (IRB #15-0083-CR005; 7/12/2018) and the need for patient consent was waived. A retrospective review of patients age 18 years or older who underwent major lung resection for cancer from 1995 through 2014 was performed. Demographic, comorbidity, laboratory, and physiologic testing data were extracted from the EHR within six months of surgery. In patients with multiple values within six months, the value nearest to the date of surgery was chosen. Surgical variables, cancer stage, and information regarding surgical outcomes were abstracted from relevant records.

Data Extraction and Cleaning

We obtained data from Clinical Research Data Warehouse (CRDW) provided by the Center for Research Informatics (CRI) at the University of Chicago. This included demographics, diagnoses, and labs. We considered a total of 1107 unique diagnoses and 294,030 lab values which were filtered and extracted based on the proximity to the date of surgery. Missingness was determined for each frailty index in time periods ≤ 30 days prior to surgery and ≤ 6 months prior to surgery (Table 1).

Table 1
Data Available to Calculate Each Frailty Index in the Patient Cohort

Index Name	mFI-5	PNI	FI-Lab	FI-Laboratory
Total variables in index	5	2	32	27
Minimum variables required to calculate score	5	2	26	19
Patients with minimum values necessary for frailty scoring 30 days preoperatively, n (%)	496 (100)	60 (12.1)	1 (0.2)	71 (14.3)
Patients with minimum values necessary for frailty scoring 6 months preoperatively, n (%)	496 (100)	166 (33.4)	28 (5.6)	191 (38.5)
mFI-5 modified 5-factor frailty index[22]				
PNI prognostic nutritional index[35]				
FI-Lab: laboratory frailty index[24]				
FI-Laboratory: laboratory frailty index[23]				

Frailty Score Calculation and Missingness Determination

Four frailty scores were considered based on the likelihood that the information to calculate the score would be readily available in the electronic health record: the 5-factor modified frailty index (mFI-5)[22], two laboratory frailty indices (FI-Laboratory[23] and FI-Lab[24]) and the prognostic nutritional index (PNI).[25] The 5-factor mFI is composed only of comorbidities (congestive heart failure within 30 days prior to surgery, insulin-dependent or noninsulin-dependent diabetes mellitus, chronic obstructive pulmonary disease or pneumonia, partially dependent or totally dependent functional health status at time of surgery, and hypertension requiring medication), for which a patient is assigned one point each if present. Patients with scores of 1 or greater were considered frail (Supplemental Table 1). Both laboratory scores include a set of routine blood tests, which were considered normal versus abnormal based on institutional reference values (Supplemental Tables 2 and 3). Scores for each laboratory index were calculated in patients who had greater than 70% of values available, consistent with previous studies.[26] The FI-Lab includes laboratory as well as vital sign data. The PNI is calculated using serum albumin and total lymphocyte count. Detailed information on score calculation is provided in the Supplemental Methods.

For all indices, scores were calculated for values available ≤ 30 days prior to surgery and also for values available ≤ 6 months prior to surgery. For each score, missingness was determined for each study time interval based on the number of patients for whom scores could be calculated divided by the total number of patients in our cohort.

Perioperative Complications and Death

Surgical complications were classified as pulmonary (respiratory failure, pneumonia, lobar collapse requiring treatment, and prolonged air leak), cardiovascular (myocardial infarction, pulmonary embolism, arrhythmia requiring treatment, cerebrovascular accident, and transient ischemic attack) and other (recurrent nerve injury, wound infection, empyema, bronchopleural fistula, and miscellaneous). As a Commission on Cancer (CoC)-accredited cancer program, standardized data on survival were extracted by research associates by chart review, telephone or mail follow up, or through the Social Security Death Index and used to determine mortality.

Statistical Analysis

Continuous variables are displayed as mean with standard deviation and categorical variables are displayed as frequency with percentage. The association between pre-operative frailty scores and peri-operative surgical complications was evaluated using multivariable logistic regression models adjusted for age, cancer stage, performance status, comorbidities, and pulmonary function test results. The association between frailty scores and survival time postoperatively was evaluated using multivariable Cox regression analysis adjusted for age, cancer stage, performance status, comorbidities, and pulmonary function (forced expiratory volume during the first second expressed as a percent of predicted [FEV1%], diffusing capacity of the lung for carbon monoxide expressed as a percent of predicted [DLCO%]). Statistical analyses were performed using R software version 3.0.1. A $p < 0.05$ was considered statistically significant.

Results

Patient Demographics

A total of 496 patients met the inclusion criteria (Table 2). The average age in our cohort was 65.8 ± 10.4 years and 50.2% of patients were female.

Table 2
Patient Demographics and Clinical Data

Patients	**496**
Mean age (years), mean ± SD	65.8 ± 10.4
Male, n (%)	247 (49.8)
Coronary artery disease, n (%)	98 (19.8)
Diabetes mellitus, n (%)	87 (17.5)
COPD, n (%)	132 (27.8)
Congestive Heart Failure, n (%)	6 (1.2)
Hypertension, n (%)	278 (56.0)
Performance status, n (%)	
0	176 (35.5)
1	280 (56.5)
2	37 (7.5)
3	3 (0.6)
FEV1%, mean ± SD	85.6 ± 22.5
DLCO%, mean ± SD	81.9 ± 22.3
Clinical Cancer Stage, n (%)	
I	295 (59.6)
II	95 (19.2)
III	99 (20.0)
IV	6 (1.2)
Death during follow-up, n (%)	242 (48.8)
Data are expressed as number (%) or as mean ± standard deviation	

Calculation of Frailty Indices

The mFI-5 comorbidity and American Society of Anesthesiologists (ASA) physical status data were available for all patients at both time points; therefore, a frailty score was calculated for all patients. The FI-Laboratory, FI-Lab, and PNI scores could only be calculated for a low percentage of patients (14.3%, 0.2%, 12.1%, respectively) within 30 days of surgery. Increasing the time interval to 6 months improved the availability of data for both the FI-Laboratory (38.5%) and PNI (33.4%) substantially, but only resulted in a minimal increase in the percentage of patients for which the FI-Lab (5.6%) could be calculated. We

proceeded with determining associations with outcomes using indices that could be calculated for at least 30% of the patients.

Frailty Scores and Surgical Outcomes

In a fully adjusted logistic regression model, the mFI-5 significantly predicted both pulmonary (OR = 3.50 (95% confidence limits 1.57 to 7.46), p = 0.002) and any complications (OR = 2.47 (1.32 to 4.60), p = 0.004) but not cardiovascular (p = 0.160) or other complications (0.366). In contrast, the FI-Laboratory and PNI were not significantly predictive of any of the complication categories in our cohort (Table 3). None of the frailty indices significantly predicted survival (Table 4).

Table 3
Adjusted multivariable logistic regression analysis of frailty indices with postoperative complications

Frailty Index	Complication Type	OR (95% CI)	p-value*
mFI-5	Pulmonary	3.50 (1.57–7.46)	**0.002**
	Cardiovascular	1.74 (0.78–3.68)	0.160
	Other Complication	0.59 (0.17–1.67)	0.366
	Any Complication	2.47 (1.32–4.60)	**0.004**
PNI	Pulmonary	1.06 (0.99–1.15)	0.099
	Cardiovascular	0.95 (0.89–1.02)	0.183
	Other Complication	1.00 (0.92–1.08)	0.953
	Any Complication	1.01 (0.96–1.07)	0.634
FI-Laboratory	Pulmonary	1.20 (0.01–86.02)	0.936
	Cardiovascular	49.22 (0.94–2630.92)	0.052
	Other Complication	23.09 (0.15–3365.18)	0.214
	Any Complication	5.55 (0.22–139.39)	0.295

Frailty scores were calculated using values obtained within 6 months of surgery.

mFI-5 modified 5-factor frailty index[22]

PNI prognostic nutritional index[35]

FI-Laboratory: laboratory frailty index[23]

*p-values in **BOLD** indicate statistical significance.

Table 4
Adjusted multivariable Cox regression analysis of frailty indices with overall survival

Frailty Index	HR	95% CI	p-value
mFI-5	1.14	0.70–1.87	0.596
PNI	0.97	0.94–1.00	0.090
FI-Laboratory	5.75	0.78–42.18	0.090
Frailty scores were calculated using values obtained within 6 months of surgery.			
mFI-5 modified 5-factor frailty index[22]			
PNI prognostic nutritional index[35]			
FI-Laboratory: laboratory frailty index[23]			

Comment

The prevalence of frailty in a community-dwelling population has been estimated to be between 6.9% and 10.7% in large studies and meta-analyses, and is substantially higher in cohorts of thoracic surgical patients.[27–29] Although frailty is commonly recognized by surgeons as a risk factor for poor patient outcomes, challenges in measuring frailty in the preoperative setting remain a barrier to its use, such as the need for specialized tests and the difficulty in choosing among the many options. In many cases, surgeons continue to rely on the “eyeball test” to subjectively assess a patient’s fitness for surgery, which has been shown to be inferior to statistical risk estimates such as the VA risk estimate for cardiac surgery and the American College of Surgeons NSQIP Surgical Risk Calculator, which is widely used to estimate risk of death and complications after general surgery operations.[30]

The use of a frailty index based on a deficit accumulation assessment was advanced by Mitnitski et al. in 2001[7] and has since been adapted to both general surgical and thoracic surgery populations. Recently, there has been an interest in utilizing EHR data to develop frailty scores using routinely collected data to minimize clinician and patient burden.[31,32] However, the operationalization of a frailty index based on the EHR has gained limited traction due to the multitude of scoring systems, reliance on clinical terminology codes, and the limited availability of specialized serum biomarkers in patients undergoing operations.

The frailty indices that we selected to investigate have been previously validated in large patient cohorts, though the patient population in each study was somewhat different. The mFI-5 used data from the NSQIP 2015 database in patients undergoing surgery[22], while the FI-Laboratory[23] was validated in hospitalized medical patients alone, and the FI-Lab[26] and PNI[33] were validated in hospitalized and community-dwelling patients. Increases in each of the four indices were associated with increased mortality in each study. The variable nature of patient settings in these studies was likely the driving

factor behind the availability of data for the present study. The mFI-5 was able to be calculated in all patients in our study because comorbidities and ASA class are frequently collected for surgical patients. On the other hand, a minority of patients had sufficient data for the FI-Lab, likely stemming from the fact that a majority of patients in that index study were community-dwelling and were participants in a cohort study in which a specific set of labs were prospectively determined and collected.

Frailty is a risk factor for increased hospital length of stay, hospital complications, readmission, and death.[34,35] Thus, we attempted to use comorbidity, vital signs, and lab data routinely collected preoperatively to test the applicability of existing frailty scores in a cohort of thoracic surgery patients. We found that only the mFI-5 could be calculated within 30-days of surgery, and that the FI-Laboratory, PNI and FI-Lab could be calculated in only a minority of patients within six months of surgery using routinely available EHR data. Although these scoring systems were previously validated in a non-lung resection patient population, we found that most had limited utility in predicting postoperative complications and death in a cohort of thoracic surgery patients undergoing lung resection at a single, urban academic medical center.

The mFI-5 was the most robust index in the present study, both in terms of the ability to calculate scores for patients and its utility in predicting complications, specifically pulmonary and overall complications. The further benefit of the mFI-5 is its ease of use, especially in a surgical population in which comorbidities are elicited and ASA class is assigned preoperatively. As such, the mFI-5 could be considered in the preoperative evaluation of patients undergoing major thoracic or abdominal surgery, although further investigation is necessary into whether EHR-based mFI-5 scores can be generalized to surgical populations as a whole.

Our study has a number of potential limitations, including its retrospective nature, relatively small sample size, and the long time frame over which patients were included. We analyzed preoperative and perioperative complication data for patients as early as 1995, and changes in surgical technique and postoperative care over that time period may have led to changes in the frequency and type of complications, limiting significant findings.

In conclusion, the availability of extant data in the EHR does not permit calculation of many frailty scores possibly related to surgical risk. A possible exception is the mFI-5 score, which we found to be predictive of some outcomes after major lung resection in our population. Further evaluation of mFI-5 in larger retrospective sample or prospective cohorts may be useful. Identifying a reliable EHR-based frailty assessment tool could be helpful determining which patients are a higher preoperative risk for adverse events. Using this data, surgeons may be able to preemptively mitigate a patient's surgical risk with appropriate perioperative resources, referrals, and prehabilitation.

Abbreviations

EHR

electronic health record
mFI-5
5-factor modified frailty index
PNI
prognostic nutritional index
FEV1
forced expiratory volume
DLCO
diffusing capacity for carbon monoxide
NSQIP
National Surgical Quality Improvement Program
FI-Lab
lab frailty index
FI-Laboratory
laboratory frailty index

Declarations

Ethics approval and consent to participate: University of Chicago Institutional Review Board (IRB) Approval: IRB#15-0082, approved on 7/12/2018. The need for patient consent was waived. No additional administrative permissions aside from IRB approval, which was obtained and supplied prior to any medical records were accessed, were required to access and use the medical records.

Consent for publication: For the following instruments, no license/copyright was required for their use in the present study: the 5-factor modified frailty index (mFI-5), the two laboratory frailty indices (FI-Laboratory23 and FI-Lab24), the prognostic nutritional index (PNI)

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests

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Authors' contributions: MA performed the acquisition and interpretation of the data and analysis and was a major contributor in writing the manuscript. AL assisted in the acquisition and interpretation of the data. SML performed the statistical analysis of the data. MHS analyzed the interpreted the patient data and was a contributor in writing the manuscript. MK analyzed and interpreted the data and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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