Frailty is associated with 90-day mortality in urgent thoracic surgery conditions

Jacqueline Kloos, BA,[a] Aria Bassiri, MD,[b] Vanessa P. Ho, MD, MPH, PhD,[c] Jillian Sinopoli, DO,[d] Leonidas Tapias Vargas, MD,[d] Philip A. Linden, MD,[d] and Christopher W. Towe, MD[d]

ABSTRACT

Objective: In patients undergoing elective thoracic surgery, frailty is associated with worse outcomes. However, the magnitude by which frailty influences outcomes of urgent thoracic surgery (UTS) is unknown.

Methods: We identified patients admitted with a UTS condition from January to September 2017 in the National Readmissions Database. UTS conditions were classified as esophageal perforation, hemo/pneumothorax, rib fracture, and obstructed hiatal hernia. Outcome of interest was mortality within 90 days of index admission. Frailty score was calculated using a deficit accumulation method. Cox proportional hazard modeling was used to calculate a hazard ratio for each combination of UTS disease type and frailty score, adjusted for sex, insurance payor, hospital size, and hospital and patient location, and was compared with the effect of frailty on elective lung lobectomy.

Results: We identified 107,487 patients with a UTS condition. Among UTS conditions overall, increasing frailty elements were associated with increased mortality (hazard ratio, 2270; 95% CI, 1463-3523; $P < .001$). Compared with patients without frailty undergoing elective lobectomy, increasing frailty demonstrated trending toward increased mortality in all diagnoses. The magnitude of the effect of frailty on 90-day mortality differed depending on the disease and level of frailty.

Conclusions: The effect of frailty on 90-day mortality after admission for urgent thoracic surgery conditions varies by disease type and level of frailty. Among UTS disease types, increasing frailty was associated with a higher 90-day risk of mortality. These findings suggest a valuable role for frailty evaluation in both clinical settings and administrative data for risk assessment. (JTCVS Open 2024;17:336-43)

Frailty has a valuable role in risk assessment in UTS.

CENTRAL MESSAGE

In a variety of urgent thoracic surgery disease types, increasing frailty was associated with a higher 90-day risk of mortality. These findings suggest a valuable role of frailty evaluation in risk assessment.

PERSPECTIVE

The concept of frailty has recently been expanded to surgery, where it should offer physicians a generalizable means of risk-stratifying patients. This study demonstrates the utility of frailty in urgent thoracic surgical conditions wherein frailty score is associated with higher risk for mortality.

To view the AATS Annual Meeting Webcast, see the URL next to the webcast thumbnail.

From [a]Case Western Reserve University School of Medicine, Cleveland, Ohio; [d]Division of Thoracic and Esophageal Surgery, [b]Department of Surgery, University Hospitals Cleveland Medical Center, Cleveland, Ohio; and [c]Division of Trauma, Critical Care, Burns, and Acute Care Surgery, MetroHealth Medical Center, Cleveland, Ohio.

Supported by the Clinical and Translational Science Collaborative of Cleveland (KL2TR000440 as well as KL2TR002547 to Dr Ho) from the National Center for Advancing Translational Sciences component of the National Institutes of Health and NIH Roadmap for Medical Research.

Read at the 103rd Annual Meeting of The American Association for Thoracic Surgery, Los Angeles, California, May 6-9, 2023.

Received for publication March 27, 2023; revisions received Oct 15, 2023; accepted for publication Oct 17, 2023; available ahead of print Dec 13, 2023.

Address for reprints: Christopher W. Towe, MD, Division of Thoracic and Esophageal Surgery, Department of Surgery, University Hospitals Cleveland Medical Center, 11100 Euclid Ave, Cleveland, OH 44106-5011 (E-mail: christopher.towe@uhhospitals.org).

2666-2736

https://doi.org/10.1016/j.xjon.2023.10.037

Abbreviations and Acronyms

ICD-10 = International Classification of Diseases, 10th edition

UTS = urgent thoracic surgery

Frailty, or a lack of functional physiologic reserve, predisposes to adverse health outcomes and is an increasingly utilized metric when risk-stratifying patients.[1] When measuring the ability to withstand stressors, frailty is far more nuanced than age in its consideration of deficits or so-called health breakdowns. Although frailty is associated with age, there is no constant deficit accumulation rate, resulting in vastly different physiologic reserves among people of the same age.[2] Furthermore, frailty offers a perspective on health burden distinct from disability and comorbidity; that is, a patient may be frail in the absence of chronic disease, and disability may develop independently of frailty.[3,4] Described by Rockwood and colleagues,[2] the concept of frailty is not reliant on the details of each deficit, which would contribute great complexity and variability, but rather is built around the idea that the accumulation of deficits—the quantity—is the most significant factor in determining physiologic reserve.

Although traditionally a tool of geriatrics, the concept of frailty has more recently been expanded to surgery.[3] Risk stratification in surgery has historically been very limited, created to predict specific complications rather than general postoperative mortality, and unable to be extrapolated to other kinds of procedures or postoperative complications.[5] Hypothetically, the organized study of frailty in surgical settings should offer physicians a generalizable means of preprocedurally identifying those patients who will and will not benefit from intervention. One review of 23 surgical studies and 21 different frailty measures found that frailty was consistently associated with higher 30-day, 90-day, and 1-year mortality, as well as postoperative complications,[1] suggesting that frailty as a concept provides great benefit in risk stratification regardless of the specific deficits used in its calculation.

Emergency surgery is unique in its elevated risk of mortality and morbidity.[6] Presently, data suggest that frailty is significantly associated with poor outcomes after emergency surgery, including increased rates of hospital mortality, 90-day mortality, and hospital readmission.[6] Despite these data, a strategy to incorporate the concept into preoperative assessments to aid surgical decision making remains undefined.[6] Some evidence exists that frailty may predict postoperative outcomes in nonemergency thoracic surgery as well, although too little evidence may presently exist to make a definitive conclusion.[7] However, whereas frailty has been examined when analyzing outcomes of nonemergency thoracic surgery[7] and emergency nonthoracic surgery,[8] its utility in urgent thoracic surgery remains unstudied.

Using the National Readmissions Database, a health care database containing data from ~18 million discharges per year, we sought to determine the role of frailty in urgent thoracic surgery (UTS) conditions via its effect on 90-day mortality. We sought outcomes regardless of whether management was operative or nonoperative to aid in decision making. We hypothesized that frailty would have an overall detrimental effect on 90-day mortality, and that there would be a differing influence of frailty on mortality for different UTS conditions.

METHODS

Patient Population

We identified patients admitted with a UTS condition or for elective lobectomy between January and September 2017 via the National Readmissions Database. Given the de-identified nature of the database, institutional review board approval was not applicable. Admissions were identified via the first occurrence of the relevant International Classification of Diseases, 10th edition (ICD-10) code within a patient chart in 2017. UTS ICD-10 codes included esophageal perforation, hemo/pneumothorax, rib fracture, and obstructed hiatal hernia. These conditions were chosen from a list of conditions managed by thoracic surgeons according to definitions by the Society of Thoracic Surgeons; we then chose those diagnoses that we deemed to frequently be considered urgent as opposed to elective. We also analyzed elective lung lobectomy as a reference comparison to an elective procedure. This reference comparison serves to establish perspective between urgent and elective conditions and was included to aid in the quantification of risk of urgent procedures. Outcome of interest was mortality during index admission or readmission that occurred within 90 days of index discharge. Frailty score was determined using a deficit accumulation method, which calculates the number of deficits present among the number considered.[9] The Frailty Index utilized in this study includes 38 total deficits (Table E1) and was developed and validated using a national database.[10] Here we report frailty on scale from 0 to 5, where a score of 0 indicates that no deficits are present and a score of 5 indicates the presence of at least 5 deficits. Other patient variables of interest included demographic characteristics and Elixhauser comorbidities, which were defined using ICD-10 coding.

Statistical Analysis

The analysis included comparison of demographic characteristics between the UTS procedure (4) types. Comparison of categorical variables was performed using χ^2 tests and comparison of continuous variables was performed using the rank-sum test. We then compared demographic and clinical characteristics (including frailty) with mortality in univariate Cox proportional hazard modeling. Data are presented as a hazard ratio (HR) and 95% CI. We then used multivariable Cox proportional hazard modeling to calculate HR for each combination of UTS disease type and frailty score, using the relationship of frailty to mortality after elective lung lobectomy as a reference. Variables in the multivariable Cox analysis were chosen a priori based on clinical relevance.

Statistical analysis was performed using STATA MP (version 17.0) (StataCorp). The study was determined to be exempt from institution review board review because all the data were de-identified.

TABLE 1. Demographic characteristics of the patients with urgent thoracic surgery conditions and elective lobectomy in the National Readmission Database, stratified by diagnosis group

	Thoracic surgery condition				
Variable	Elective lobectomy (n = 13,640)	Esophageal perf (n = 1670)	Hemo-pneumothorax (n = 3006)	Rib fracture (n = 85,810)	Obstructed hiatal hernia (n = 3361)
Age (y)	66.77 ± 10.17	58.05 ± 19.49	42.79 ± 20.64	62.73 ± 19.26	72.48 ± 14.73
% Male	6171 (45.3)	1056 (62.2)	2413 (80.3)	52,319 (61)	1187 (35.3)
Average frailty score	2.14 ± 1.49	2.22 ± 1.64	1.18 ± 1.46	2.12 ± 1.71	2.72 ± 1.61
% Death at 90 d	257 (1.9)	226 (13.5)	294 (9.8)	5255 (6.1)	238 (7.1)
Insurance type					
Medicare	8616 (63.2)	678 (46.1)	573 (19.1)	40,643 (47.5)	2515 (74.9)
Medicaid	885 (6.5)	288 (17.3)	1071 (35.8)	11,234 (13.1)	217 (6.5)
Private	3822 (28.0)	466 (28)	690 (23.1)	24,109 (28.2)	510 (15.2)
Hospital size by No. of beds					
Small	1246 (9.1)	144 (8.6)	239 (8)	9544 (11.1)	514 (15.3)
Medium	3143 (23.0)	359 (21.5)	691 (23)	21,053 (24.5)	947 (28.2)
Large	9251 (67.8)	1167 (69.9)	2076 (69.1)	55,213 (64.3)	1900 (56.5)
Hospital location					
Large metropolitan*	8595 (63.01)	1046 (62.63)	1797 (58.78)	46,923 (54.68)	1929 (57.39)
Small metropolitan†	4786 (35.09)	587 (35.15)	1124 (37.39)	34,129 (39.77)	1229 (36.57)
Micropolitan	254 (1.86)	32 (1.92)	69 (2.30)	3715 (4.33)	172 (5.12)
Nonurban residual	5 (0.04)	5 (0.30)	16 (0.53)	1043 (1.22)	31 (0.92)

Values are presented as n (%) or mean ± SD. The average frailty score is calculated by averaging the number of deficits had by each patient. *>1 million. †<1 million.

RESULTS

We identified 107,487 patients with a UTS condition or elective lobectomy. The median age at admission of our cohort was 65 years, with an interquartile range of 52 to 78 years. The demographic characteristics of the cohort for each UTS condition are shown in Table 1. Elective lobectomy had a rate of death at 90 days of 1.9%, rib fracture of 6.1%, and esophageal perforation of 13.5%. Men made up the majority of patients presenting with esophageal perforation, hemo/pneumothorax, and rib fracture. Mean patient ages among diagnoses were similar.

In univariate Cox hazard analysis, several demographic and clinical characteristics were associated with mortality (Table 2). Increasing frailty was associated with increased mortality as a linear score (HR, 2270; 95% CI, 1463-3523; $P < .001$) and as a categorical variable. Mortality was more than 5 times greater in patients with at least 5 frailty elements than none (HR, 5.28; 95% CI, 4.76-5.86; $P < .001$). Patients with Medicare had a higher death rate at 90 days compared with those with private insurance (HR, 1.73; 95% CI, 1.62-1.85; $P < .001$) and patients treated at small and medium hospitals, categorized by the number of beds, fared better than those at large hospitals (HR, 0.81; 95% CI 0.74-0.89; $P < .001$ and HR, 0.92; 95% CI, 0.87-0.98; $P = .013$, respectively).

We performed a multivariable analysis to determine the independent association of frailty, demographic characteristics, and thoracic surgery condition with mortality. In that analysis (Table 3), increasing frailty was associated with increased risk of death at 90 days. Each UTS was also associated with increased risk of mortality relative to elective lobectomy. Other factors associated with mortality included large hospital size, defined as the number of beds,[11] and patient age. However, the relationship of frailty to mortality differed between UTS conditions (Figure 1), where the magnitude of the effect of frailty on mortality depended on disease and level of frailty. Using elective lobectomy with no frailty as a reference, amongst UTS conditions, esophageal perforation with 5 frailty elements had the greatest associated risk of mortality (HR, 61.98; 95% CI, 29.6-130.0; $P < .001$) (Figure 1). See Figure 2 for a graphical abstract of the study.

DISCUSSION

This study sought to determine the value of frailty assessment in UTS. This was a novel question as prior studies have focused on nonurgent thoracic surgery[7] and urgent nonthoracic surgery.[8] Furthermore, by including patients with urgent diagnoses without differentiating between management strategies, we were able to report on conditions-based rather than procedures-based outcomes related to frailty in UTS conditions to aid in presurgical evaluation. Our utilization of a national database allowed for an analysis of significant magnitude that represented a variety of health systems and patient demographic characteristics. Our analysis of 107,487 patients with a UTS condition or elective lobectomy revealed a positive association between

TABLE 2. Factors associated with overall survival among patients in the National Readmission Database using univariate Cox proportional hazard modeling

Variable	Group	Hazard ratio*	*P* value	95% CI
Age	Year	1.02	<.001	1.02-1.03
No. of frailty elements	None		Ref	
	1	2.15	<.001	1.92-2.40
	2	2.37	<.001	2.12-2.65
	3	3.22	<.001	2.89-3.60
	4	3.93	<.001	3.51-4.40
	≥ 5	5.28	<.001	4.76-5.86
Sex	Female	0.90	<.001	0.85-0.95
Condition	Elective lobectomy		Ref	
	Esophageal perf	7.05	<.001	5.87-8.46
	Hemo/pneumothorax	4.31	<.001	3.60-5.15
	Rib fracture	3.10	<.001	2.73-3.52
	Obstructed hiatal hernia	3.74	<.001	3.12-4.48
Insurance type	Private insurance		Ref	
	Medicare	1.73	<.001	1.62-1.85
	Medicaid	0.99	.90	0.90-1.10
	Self-pay	1.04	.65	0.89-1.21
	No charge	0.44	.015	0.23-0.85
	Other	1.22	.005	1.06-1.40
Hospital size by No. of beds	Large		Ref	
	Small	0.81	<.001	0.74-0.89
	Medium	0.92	.013	0.87-0.98
Hospital location	Large metropolitan†		Ref	
	Small metropolitan‡	1.06	.031	1.00-1.12
	Micropolitan	0.92	.24	0.80-1.06
	Nonurban residual	0.71	.028	0.52-0.96

CI, 95% Confidence interval; *Ref*, reference category. *Hazard ratio is for overall survival. †>1 million. ‡<1 million.

frailty and mortality across all diagnoses. Notably, the influence of frailty on 90-day mortality varied between conditions and depended on the level of frailty, although even 1 element of frailty increased mortality risk overall. Mortality rate also varied with hospital size and insurance payor, where outcomes were better in small and medium hospitals and among patients with private insurance. These factors, particularly insurance data, may reflect age and socioeconomic status of the patients, both of which tend to be associated with a greater number of comorbidities and chronic diseases.[12]

Frailty has been previously used to facilitate risk modeling in patients receiving elective surgery, which notably showed that frailty scoring identified patients at higher risk for morbidity and mortality postoperatively.[13] Ours is the first study to shows this effect in UTS conditions. We report that patients with urgent conditions experienced higher mortality risk than their elective lobectomy counterparts. However, there are a number of factors that complicate risk modeling in urgent conditions, including patient selection, time constraints, and preexisting physiologic derangement. Patients with UTS conditions may have a higher baseline risk, predisposing them to emergency situations; for example, proneness to a fall that causes a rib fracture or hemo/pneumothorax. Conversely, elective procedures are likely offered to patients who are less vulnerable and more likely to benefit and recover well from surgical intervention. Urgent situations also may not allow for medical optimization of patients before surgery, increasing the likelihood of postoperative complications and mortality. These factors all complicate risk modeling and may contribute to our different findings between elective and urgent outcomes. A similar study in abdominal surgery demonstrated that urgent colectomy carries a greater mortality risk than elective, believed to be influenced by the older age of the urgent group and its overall higher burden of comorbid disease.[14] Another theorized that a delay in urgent treatment due to preoperative medical optimization may have contributed to poorer outcomes because mortality rates between the groups differed even when preoperative comorbidities were controlled for in a multivariate analysis.[15]

TABLE 3. Analysis of factors associated with overall survival using multivariable Cox hazard analysis. Variables included in analysis include sex, insurance payor, hospital size, and hospital and patient location (not shown)

Group	Hazard ratio*	*P* value	95% CI
Age			
Year	1.01	<.001	1.01-1.02
Frailty elements			
None		Ref	
1	2.24	<.001	2.00-2.51
2	2.50	<.001	2.22-2.80
3	3.36	<.001	2.99-3.77
4	3.98	<.001	3.53-4.49
5	5.12	<.001	4.57-5.74
Condition			
Elective lobectomy		Ref	
Esophageal perf	6.94	<.001	5.78-8.34
Hemo/pneumothorax	6.14	<.001	5.11-7.37
Rib fracture	3.21	<.001	2.83-3.65
Obstructed hiatal hernia	3.37	<.001	2.81-4.03
Insurance type			
Private insurance		Ref	
Medicare	1.24	<.001	1.15-1.33
Medicaid	0.95	.30	0.85-1.05
Self-pay	1.04	.63	0.89-1.21
No charge	0.41	.011	0.20-0.82
Other	1.11	.12	0.97-1.28
Hospital size by No. of beds			
Large		Ref	
Small	0.72	<.001	0.65-0.79
Medium	0.86	<.001	0.80-0.91
Hospital location			
Large metropolitan†		Ref	
Small metropolitan‡	1.04	.38	0.95-1.15
Micropolitan	0.65	<.001	0.55-0.77
Nonurban residual	0.59	.002	0.42-0.82

Ref, Reference category. *Hazard ratio is for overall survival. †>1 million. ‡<1 million.

As the role of frailty in surgical risk stratification continues to be defined, our findings demonstrate the utility of frailty in urgent thoracic conditions as a factor in risk assessment in both clinical and administrative settings. The deficit accumulation method of determining frailty offers a simple, practical measure of quantifying health vulnerability. As an extension of its use in patient prognostication, frailty may find a purpose in offering an evidence-based guide to preoperative counseling and shared decision making with patients and families. Furthermore, unsatisfactory risk assessments may unjustly result in negative performance evaluations for physicians and inaccurate comparisons of surgical quality. One study that compared urgent and general surgical outcomes theorized that acute care and emergency surgeons are at risk for inferior reimbursement and receiving poor performer labels due to current outcomes reporting guidelines.[15] An accurate and widely established risk stratification tool for urgent procedures could mitigate interinstitutional quality gaps and improve outcomes reporting. Frailty assessments may also find utility in preventive care because there is emerging evidence that frailty may be modifiable, with targeted interventions found to reduce frailty score.[16,17] This evidence may inform the preoperative care of frail individuals planning to undergo elective procedures. Of course, urgent conditions do not provide the same opportunity for preoperative frailty optimization as do elective procedures. However, 1 review found that “exercise programs that optimize the health of frail older adults seem to be different from those recommended for healthy older adults,”[16] suggesting a possible role for general preventative measures.

Limitations of this study include our selection of urgent thoracic surgical conditions, which was based on both Society of Thoracic Surgeons definitions as well as author expertise and therefore may present a bias. Our use of an administrative database with limited availability on context of illness; that is, each of our diagnoses still exists on a more nuanced spectrum of severity and acuity not reflected in its ICD-10 code. Furthermore because the database is de-identified, we cannot confirm any missing or inaccurate data. We defined a patient’s initial presentation as the first occurrence of the relevant ICD-10 code within their chart during the year 2017; however, it is possible that the diagnosis could have been carried over from the previous calendar year and represent a past or subacute issue. It is impossible to state whether the appearance of the ICD-10 code in the patient chart is the actual date of occurrence of the event. As a result of this limitation, we cannot claim causality between the diagnosis and mortality, but rather report an association. We have also not corrected for how patients were treated for their conditions. This may have an influence on the outcome of interest because frail patients may not have been offered heroic lifesaving procedures that could be construed as futile. However, by focusing on diagnosis rather than treatment we provide pertinent, undifferentiated data for surgeons determining the best approach for patient care, whether operative or not. Another limitation is inherent to the deficit accumulation method, which weights each deficit equally despite the reality that the various conditions do not pose the same level of disability. This method of calculating frailty may influence the findings of the study and limit the generalizability. The Frailty Index utilized in this study does not include age as a deficit; however, because age is often associated with increasing comorbidities, it may be difficult to fully differentiate the independent influence of frailty versus age. In addition, there may exist several factors associated with postoperative mortal-

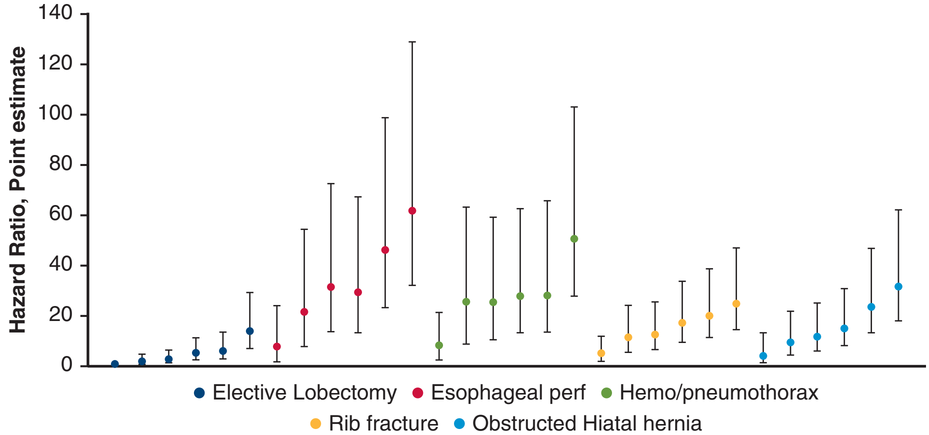

FIGURE 1. Relationship of 90-day survival to frailty and surgical condition in a multivariable Cox hazard analysis. Within each diagnosis, *each data point* represents the number of frailty deficits present, from 0 to ≥5. Variables included in analysis but not shown include sex, insurance payor, hospital setting (urban/rural), hospital county characteristics, and hospital teaching status.

ity not controlled for in this study, including time to and duration of surgery. Concurrent, nonthoracic diagnoses may present a bias between our reported exposure and mortality and were not accounted for in this study. Despite these limitations, we believe our study was able to capture the positive association between frailty and mortality in patients with UTS conditions.

Overall, our findings support the use of frailty as a measure in UTS, which, in combination with existing evidence of its utility in other settings, bolsters its potential as a

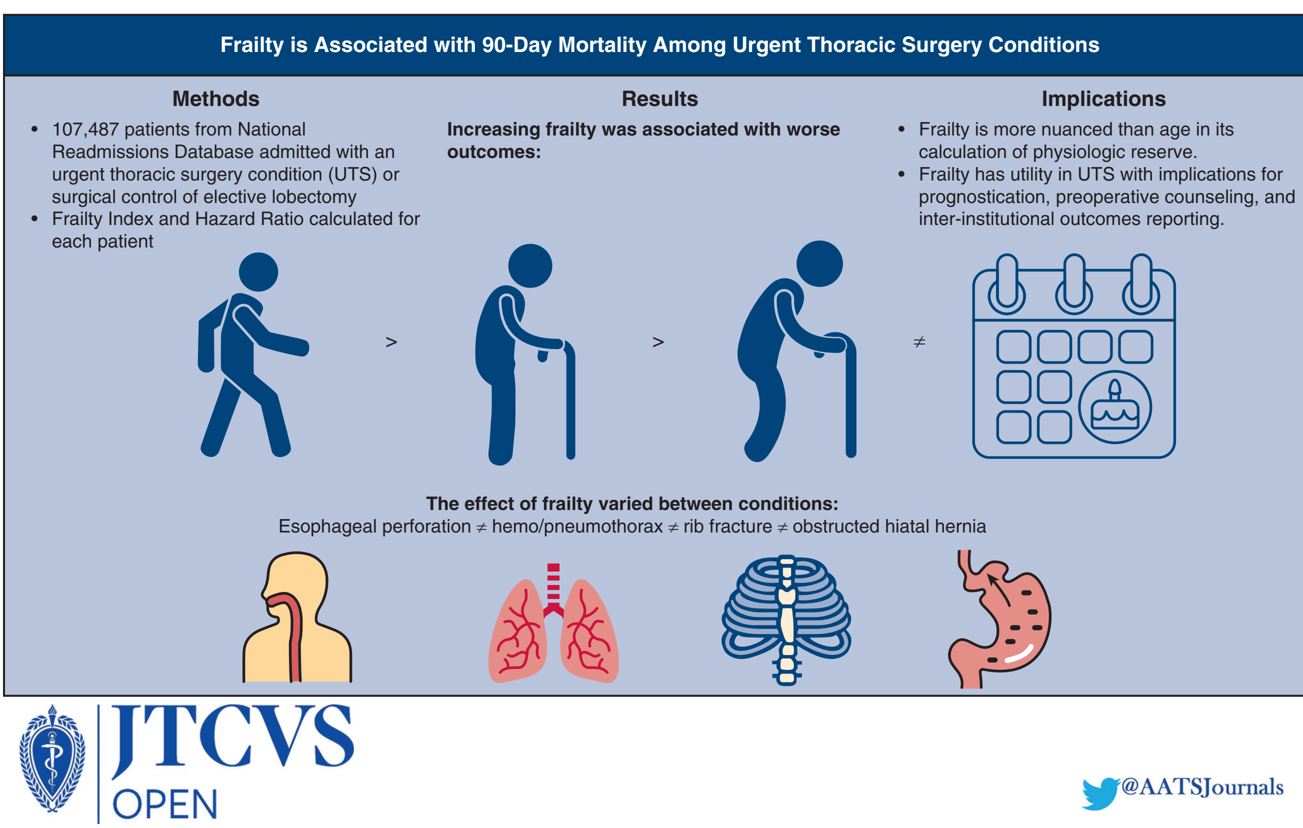

FIGURE 2. A graphical abstract depicting our research showing that, among urgent thoracic surgery (UTS) disease types, increasing frailty was associated with a higher 90-day risk of mortality. These findings suggest a valuable role of frailty evaluation in risk assessment.

powerful risk stratification tool across medical fields. However, it is not presently known which frailty assessment tool offers the most accurate prediction. Furthermore, although a single metric is ideal for the purpose of ease of adoption, it is possible that 1 tool may not be practical for both urgent and nonurgent situations. Future research is needed to determine which instrument holds the most validity and feasibility in acute settings, and if this differs from elective operations. Next, to promote ease and validity of implementation, guidelines may need to be established to aid management decisions by surgeons. With a growing body of literature demonstrating promise, additional studies should seek to optimize frailty's ability to forecast adverse consequences and improve surgical decision making, reduce variation in care, and promote better outcomes.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://www.aats.org/resources/effect-of-frailty-level-on-90-day-survival-in-urgent-thoracic-surgery.

Conflict of Interest Statement

Dr Towe is a consultant for Atricure and Zimmer Biomet. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Lin HS, Watts JN, Peel NM, Hubbard RE. Frailty and post-operative outcomes in older surgical patients: a systematic review. *BMC Geriatr*. 2016;16:157.
2. Rockwood K, Mitnitski A. Frailty defined by deficit accumulation and geriatric medicine defined by frailty. *Clin Geriatr Med*. 2011;27:17-26.
3. Koh LY, Hwang NC. Frailty in cardiac surgery. *J Cardiothorac Vasc Anesth*. 2019;33:521-31.
4. Fried LP, Ferrucci L, Darer J, Williamson JD, Anderson G. Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care. *J Gerontol A Biol Sci Med Sci*. 2004;59:255-63.
5. Sankar A, Beattie WS, Wijeysundera DN. How can we identify the high-risk patient? *Curr Opin Crit Care*. 2015;21:328-35.
6. Leiner T, Nemeth D, Hegyi P, Ocskay K, Virag M, Kiss S, et al. Frailty and emergency surgery: results of a systematic review and meta-analysis. *Front Med (Lausanne)*. 2022;9:811524.
7. Dunne MJ, Abah U, Scarci M. Frailty assessment in thoracic surgery. *Interact Cardiovasc Thorac Surg*. 2014;18:667-70.
8. Kennedy CA, Shipway D, Barry K. Frailty and emergency abdominal surgery: a systematic review and meta-analysis. *Surgeon*. 2022;20:e307-14.
9. Kojima G, Liljas AEM, Iliffe S. Frailty syndrome: implications and challenges for health care policy. *Risk Manag Healthc Policy*. 2019;12:23-30.
10. Lai HY, Huang ST, Chen LK, Hsiao FY. Development of frailty index using ICD-10 codes to predict mortality and rehospitalization of older adults: an update of the multimorbidity frailty index. *Arch Gerontol Geriatr*. 2022;100:104646.
11. Agency for Healthcare Research and Quality. NRD description of data elements. 2022. Accessed November 28, 2023. https://hcup-us.ahrq.gov/db/nation/nrd/nrdde.jsp
12. Akinyemiju T, Jha M, Moore JX, Pisu M. Disparities in the prevalence of comorbidities among US adults by state Medicaid expansion status. *Prev Med*. 2016;88:196-202.
13. Tsiouris A, Hammoud ZT, Velanovich V, Hodari A, Borgi J, Rubinfeld I. A modified frailty index to assess morbidity and mortality after lobectomy. *J Surg Res*. 2013;183:40-6.
14. Hajirawala L, Leonardi C, Orangio G, Davis K, Barton J. Urgent inpatient colectomy carries a higher morbidity and mortality than elective surgery. *J Surg Res*. 2021;268:394-404.
15. Mullen MG, Michaels AD, Mehaffey JH, Guidry CA, Turrntine FE, Hedrick TL, et al. Risk associated with complications and mortality after urgent surgery vs elective and emergency surgery: implications for defining "quality" and reporting outcomes for urgent surgery. *JAMA Surg*. 2017;152:768-74.
16. Theou O, Stathokostas L, Roland KP, Jakobi JM, Patterson C, Vandervoort AA, et al. The effectiveness of exercise interventions for the management of frailty: a systematic review. *J Aging Res*. 2011;2011:569194.
17. Ng TP, Feng L, Nyunt MS, Feng L, Niti M, Tan BY, et al. Nutritional, physical, cognitive, and combination interventions and frailty reversal among older adults: a randomized controlled trial. *Am J Med*. 2015;128:1225-36.e1221.

Key Words: thoracic surgery, frailty, risk stratification

TABLE E1. A list of International Classification of Diseases, 10th edition Clinical Modification (ICD-10) codes considered in the Frailty Index utilized by this study[10]

ICD-10-CM code	Deficit
E87	Disorders of electrolyte and fluid balance
F03	Dementia
G47	Sleep disorders and apnea
H02	Disorders of eyelids
H35	Retinopathy and other eye disorders
H40	Glaucoma and ocular hypertension
H81	Vertigo or other disorder of vestibular function
I10	Hypertension
I11	Hypertensive heart disease with/without heart failure
I20	Angina
I25	Atherosclerotic heart disease and chronic ischemic heart disease
I48	Atrial fibrillation and atrial flutter
I49	Cardiac arrhythmia
I50	Heart failure
I63	Cerebral infarction
I67	Cerebral vascular disease
I69	Late effect of cerebrovascular diseases
J18	Pneumonia
J44	Chronic obstructive pulmonary disease
J45	Asthma
K25	Gastric ulcer
K27	Peptic ulcer
K30	Functional dyspepsia
K59	Constipation
L03	Cellulitis
L30	Dermatitis
M10	Gout
M15	Polyosteoarthritis
M19	Osteoarthritis
M48	Spinal stenosis and spondylopathy
M81	Osteoporosis
N18	Chronic kidney disease
N39	Urinary tract infection
N40	Enlarged and nodular prostate
R05	Cough
R10	Abdominal pain
R42	Dizziness and giddiness
Z96	Presence of functional implant