The Clinical Impact of Heart Failure on the Postoperative Outcomes for Lung Cancer Patients Undergoing Lobectomy and Sublobar Resection by Video-Assisted Thoracic Surgery: A Propensity Score-Matched Analysis of 2016-2020 HCUP-NIS Data

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ABSTRACT

BACKGROUND: The clinical impact of heart failure (HF) on postoperative outcomes following video-assisted thoracic surgery (VATS) for lung cancer resection remains controversial. This study aimed to assess patient and hospital characteristics related to the type of surgery, as well as the independent impact of HF on surgical outcomes.

METHODS: We conducted a retrospective analysis using data from the National Inpatient Sample database. A total of 20 693 patients aged 18 years or older, diagnosed with lung cancer, and undergoing lobectomy or sublobar resection via VATS between 2016 and 2020 were included. Patients were stratified based on the presence of HF. The HF-present cohorts were matched to HF-absent controls using a 1:2 nearest-neighbor propensity score-matching (PSM) analysis. The matched cohorts were then compared across several endpoints, including mortality, length of stay (LOS), hospitalization costs, and postoperative complications.

RESULTS: After PSM, the study included 1781 patients who underwent lobectomy and 1157 who underwent sublobar resection, with 594 and 386 patients, respectively, having concurrent HF. In both the lobectomy and sublobar resection groups, patients with HF demonstrated significantly higher in-hospital mortality rates ($P < .001$), longer LOS ($P < .001$), increased total hospital charges ($P < .001$), and a greater risk for overall postoperative complications ($P < .001$).

CONCLUSIONS: Among patients with lung cancer undergoing VATS, the presence of HF is associated with an increased risk of postoperative complications. This finding underscores the necessity for enhanced monitoring and care for patients with HF should be treated during the postoperative recovery phase.

KEYWORDS: Heart failure, lung cancer, video-assisted thoracoscopic surgery, lobectomy, sublobar resection

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Introduction

Heart failure (HF) is a prevalent and costly medical condition that affects approximately 26 million people worldwide.[1] It is recognized as a significant risk factor for postoperative morbidity and mortality across various surgical specialties.[2] However, research examining the impact of HF on outcomes specifically in thoracic surgery remains limited. As medical care has improved, survival rates following an HF diagnosis have been substantially increased,[3] leading to a growing number of patients with HF undergoing elective thoracic procedures.[4]

Lung cancer is one of the most common malignant tumors worldwide and a leading cause of cancer-related mortality. According to 2018 data from the Global Cancer Observatory (GLOBOCAN), there were approximately 2.09 million new cases of lung cancer, which account for 11.6% of all cancer cases and 18.4% of total cancer-related deaths globally.[5,6] Heart disease and cancer share several common risk factors, including age, tobacco use, diet, and insufficient physical activity, which often leads to the 2 conditions occurring together.[7] Recent

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study has reported that HF is one of the most prevalent comorbidities of lung cancer, with an incidence rate of approximately 12.4%.[8] Surgical resection remains the primary approach for achieving curative outcomes in most early-stage lung cancer cases.[9] In addition, advancements in anesthesia and surgical techniques are expected to enable an increasing number of elderly patients with heart disease to undergo these procedures.[10]

Lung cancer resection can be performed via open surgery (such as thoracotomy) or minimally invasive techniques.[11] Video-assisted thoracic surgery (VATS) is a minimally invasive approach that uses small chest incisions.[12] Since the early 1990s, a growing body of clinical evidence has demonstrated the safety and feasibility of VATS for lung cancer resection, resulting in improved postoperative outcomes and reduced surgical trauma compared with open surgery.[13-15] In the field of lung cancer resection procedures, the cardiovascular and pulmonary benefits of lobectomy compared with pneumonectomy are well established.[16,17] However, it remains unclear whether a similar distinction exists between lobectomy and sublobar resection. Although several studies have investigated the efficacy and immediate surgical outcomes of lobectomy versus sublobar resection, the differences in mortality rates due to other causes have not yet been thoroughly examined.[18,19]

Despite the importance of understanding how HF may affect VATS outcomes, there is currently a lack of research in this area. Consequently, further investigation is warranted to fill this knowledge gap. As a result of this situation, there is a rising demand to gain a deeper insight into and accurately assess the impact of HF on postoperative risk. This understanding is crucial for optimizing clinical decision-making and enhancing preoperative counseling.

This study aimed to investigate the potential impact of HF on patients with lung cancer undergoing lobectomy and sublobar resection assisted by VATS. To achieve this, we analyzed the effects of HF on postoperative complications in a large cohort of more than 20 000 patients from a nationwide US database using a propensity score-matched cross-sectional analysis.

Methods

Data source

Patient data for this study were obtained from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample (HCUP-NIS) database. The National Inpatient Sample (NIS) is the largest publicly available all-payer inpatient care database in the United States, developed by the Agency for Healthcare Research and Quality (AHRQ). The NIS contains more than 8 million hospitalizations annually[20] and comprises a 20% stratified sample of discharges from US hospitals, providing comprehensive data elements typically included in discharge abstracts. For this study, we used data from 2016 to 2020, applying the International Classification of Diseases, Tenth Revision, Clinical Modification/Procedure Coding System (ICD-10-CM/PCS) codes.

Given that this study used a de-identified publicly available database, Institutional Review Board approval was waived.

Study population

We identified all patients aged 18 years and older with a primary diagnosis of lung cancer who underwent either VATS lobectomy or VATS sublobar resection between 2016 and 2020 using ICD-10-CM/PCS and codes.[21,22] Elixhauser comorbidities were generated using Elixhauser Comorbidity Software Refined for ICD-10-CM v2022.1 from AHRQ. Patient records with procedure codes for more than one type of lung resection were excluded. Patients diagnosed with metastatic cancer were excluded from the study, except for those with a diagnosis solely of secondary and unspecified malignant neoplasm of intrathoracic lymph nodes.[23] We also removed patients with missing demographic data. The final sample size for the analysis was 20 693, consisting of 13 273 patients who underwent VATS lobectomy and 7420 who underwent VATS sublobar resection. The cohorts were categorized into 2 groups (with and without comorbid HF) to compare patient and hospitalization characteristics and outcomes.[24] We defined HF using HCUP CCSR (Clinical Classifications Software Refined) codes, specifically CIR019 for HF, which includes 26 ICD-10 diagnosis codes (Supplemental Table 1). Details of ICD-10-CM/PCS codes used are listed in Supplemental Table 1.

Variables and outcome measures

Baseline characteristics of VATS lobectomy and VATS sublobar resection cohorts are listed in Tables 1 and 2. The primary outcomes of interests were the incidence of in-hospital adverse complications, including pulmonary and other complications. Secondary outcomes included overall hospitalization costs, length of stay (LOS), and incidence of in-hospital mortality. A comprehensive list of ICD-10-CM/PCS codes used to define in-hospital adverse complications is included in Supplemental Table 1.[25,26]

Statistical analyses

Descriptive statistics were summarized for the demographic, clinical, and socioeconomic characteristics of the research groups. Categorical variables were presented as counts (%), whereas continuous variables were described using median (interquartile range, IQR). The chi-square test or Fisher's exact test was conducted to evaluate categorical variables, and the Wilcoxon rank sum test was used for continuous variables that were determined to be non-normal distribution via the

Table 1. Postmatch comparison of demographics and medical covariates between propensity score-matched groups.

DEMOGRAPHICS	LOBECTOMY			SUBLOBAR RESECTION		
	HF	NON-HF	*P*	HF	NON-HF	*P*
	N=594	N=1187		N=386	N=771	
Age (median years)	72	72	.699	72	73	0.669
Sex						
Male (%)	312 (52.5)	617 (52.0)	.828	223 (57.8)	434 (56.3)	.631
Female (%)	282 (47.5)	570 (48.0)		163 (42.2)	337 (43.7)	
Race						
White (%)	472 (79.5)	951 (80.1)	.714	320 (82.9)	648 (84.0)	.764
Black (%)	79 (13.3)	147 (12.4)		40 (10.4)	80 (10.4)	
Hispanic (%)	15 (2.5)	38 (3.2)		NR (2.6)	12 (1.6)	
Asian or Pacific Islander (%)	12 (2.0)	16 (1.3)		NR (1.6)	NR (1.2)	
Native American and Others (%)	16 (2.7)	35 (2.9)		NR (2.6)	22 (2.9)	
Admission type						
Elective (%)	565 (95.1)	1128 (95.0)	.935	366 (94.8)	742 (96.2)	.258
Nonelective (%)	29 (4.9)	59 (5.0)		20 (5.2)	29 (3.8)	
Medical comorbidities						
Diabetes	215 (36.2)	415 (35.0)	.608	143 (37.0)	272 (35.3)	.554
Chronic pulmonary disease (%)	354 (59.6)	696 (58.5)	.698	255 (66.1)	489 (63.4)	.377
Hypertension (%)	527 (88.7)	1053 (88.7)	.995	349 (90.4)	708 (91.8)	.420
Obesity (%)	125 (21.0)	253 (21.3)	.895	84 (21.8)	172 (22.3)	.833
Cigarette use (%)	127 (21.4)	262 (22.1)	.709	96 (24.9)	201 (26.1)	.660
Alcohol use disorder (%)	29 (4.9)	52 (4.4)	.632	16 (4.1)	30 (3.9)	.835
Depress (%)	96 (16.2)	176 (14.8)	.460	50 (13.0)	92 (11.9)	.618

Abbreviations: NR, not reported due to cell counts ⩽10.

Kolmogorov-Smirnov test. To address baseline imbalances, we performed 1:2 nearest-neighbor propensity score matching (PSM) using the calipers of width equal to 0.2 of the standard deviation of the logit of the propensity score, creating a sample of individuals with HF that was comparable on all observed confounders to a sample of non-HF individuals. The balance in covariates after PSM was assessed using standardized mean difference (SMD). Postmatching, the HF-present study cohort and the non-HF controls were compared using the chi-square test/Fisher's exact test, Wilcoxon rank sum test, or univariate logistic regression.

The statistical software package SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA) and R software environment (version 4.2.3, R Foundation for Statistical Computing, Vienna, Austria) were used to perform statistical analyses. Propensity score-matching analysis was conducted in R using the "MatchIt" package. Standardized differences in means were computed and plotted with the "cobalt" package. Frequency tables were constructed using the "table1" package. The "car" package was used to perform Levene's test for homogeneity of variances, whereas the "stats" package was employed to conduct the Wilcoxon rank sum test. A 2-sided value of $P < .05$ was considered significant.

Results

Patient cohort overview

In this study, we analyzed a total of 20 693 patients underwent VATS for lung cancer in the prematching cohort, among which 4.7% had concomitant HF. Specifically, in the lobectomy group,

Table 2. Postmatch comparison of socioeconomic status and hospital characteristics between propensity score-matched groups.

DEMOGRAPHICS	LOBECTOMY			SUBLOBAR RESECTION		
	HF	NON-HF	*P*	HF	NON-HF	*P*
	N = 594	N = 1187		N = 386	N = 771	
Income quartile by zip code						
Quartile 1 (lowest) (%)	161 (27.1)	304 (25.6)	.734	106 (27.5)	215 (27.9)	.990
Quartile 2 (%)	146 (24.6)	298 (25.1)		95 (24.6)	183 (23.7)	
Quartile 3 (%)	156 (26.3)	337 (28.4)		86 (22.3)	172 (22.3)	
Quartile 4 (highest) (%)	131 (22.1)	248 (20.9)		99 (25.6)	201 (26.1)	
Patient location						
Large central metropolitan (%)	150 (25.3)	314 (26.5)	.994	107 (27.7)	219 (28.4)	.921
Large fringe metropolitan (%)	166 (27.9)	320 (27.0)		123 (31.9)	257 (33.3)	
Medium metropolitan (%)	100 (16.8)	194 (16.3)		68 (17.6)	131 (17.0)	
Small metropolitan (%)	64 (10.8)	127 (10.7)		24 (6.2)	37 (4.8)	
Micropolitan (%)	74 (12.5)	150 (12.6)		38 (9.8)	80 (10.5)	
Noncore (%)	40 (6.7)	82 (6.9)		25 (6.7)	46 (6.0)	
Primary expected payer						
Medicare (%)	464 (78.1)	936 (78.9)	.943	313 (81.1)	625 (81.1)	.632
Medicaid (%)	22 (3.7)	36 (3.0)		17 (4.4)	29 (3.8)	
Private insurance (%)	89 (15.0)	173 (14.6)		50 (13.0)	104 (13.5)	
Self-pay (%)	NR (1.3)	17 (1.4)		NR (0.3)	NR (0)	
No charge and others (%)	11 (1.9)	25 (2.1)		NR (1.3)	13 (1.7)	
Hospital region						
Northeast (%)	128 (21.5)	266 (22.4)	.477	113 (29.3)	223 (28.9)	.537
Midwest (%)	142 (23.9)	318 (26.8)		74 (19.2)	137 (17.8)	
South (%)	244 (41.1)	452 (38.1)		137 (35.5)	304 (39.4)	
West (%)	80 (13.5)	151 (12.7)		62 (16.1)	107 (13.9)	
Hospital bed size						
Small (%)	55 (9.3)	103 (8.7)	.733	42 (10.9)	80 (10.4)	.961
Medium (%)	135 (22.7)	255 (21.5)		101 (26.2)	205 (26.6)	
Large (%)	404 (68.0)	829 (69.8)		243 (63.0)	486 (63.0)	
Hospital location/Teaching status						
Rural (%)	23 (3.9)	40 (3.4)	.862	NR (1.0)	NR (0.9)	.950
Urban nonteaching (%)	75 (12.6)	152 (12.8)		29 (7.5)	55 (7.1)	
Urban teaching (%)	496 (83.5)	995 (83.8)		353 (91.5)	709 (92.0)	

Abbreviations: NR, not reported due to cell counts ⩽10.

there were 594 patients with HF and 12 679 patients without HF. Similarly, in the sublobar resection group, there were 387 patients had HF while 7033 patients without HF (Supplemental Table 2). Overall, the presence of HF in this patient population was relatively low, but still significant, warranting further investigation into its impact on surgical outcomes.

Demographics and medical covariates postmatching

Postmatching, we evaluated patient demographics and medical covariates. As illustrated in Figure 1, the SMD for all covariates following PSM was well-balanced between the HF and non-HF groups, with all SMD values below 0.1. Table 1 details the clinicodemographic characteristics of patients with lung cancer, stratified by HF status and surgical approach. After matching, there were 1781 patients in the lobectomy cohort and 1157 in the sublobar resection cohort, with respective patients with HF being 594 and 386. Notably, no significant differences were observed in age, sex, race, or medical comorbidities between the HF and non-HF cohorts for both surgical approaches (all $P > .05$ as shown in Table 1). These findings suggest that the matched cohorts were comparable, allowing for a more reliable assessment of the impact of HF on surgical outcomes.

Socioeconomic status and hospital admission characteristics

Table 2 presents a comparison of socioeconomic status and hospital characteristics between patients with and without HF. In both the lobectomy and sublobar resection cohorts, there were no significant differences in socioeconomic status, patient location, insurance types used, hospital region, hospital bed size, as well as hospital location and teaching status. This consistency in socioeconomic status indicates that any observed differences in outcomes are likely due to clinical factors rather than disparities in access to health care.

Hospital outcomes

Table 3 outlines the hospital outcomes for patients undergoing lobectomy or sublobar resection. A key finding was that patients with HF exhibited significantly higher mortality rates (3.2% vs 0.3%, $P < .001$ for lobectomy; 3.1% vs 0.4%, $P < .001$ for sublobar resection). Furthermore, those with HF had longer hospital stays (5 days vs 4 days, $P < .001$ for lobectomy; 4 days vs 3 days, $P < .001$ for sublobar resection). The hospitalization costs were also significantly higher for patients with HF, with costs of US$103 581 versus US$84 633, ($P < .001$) for lobectomy and US$75 058 versus US$69 800 ($P = .004$) for sublobar resection. These results underscore the significant burden of HF on both mortality and resource utilization in patients undergoing lung cancer surgery.

Postoperative complications

Tables 4 and 5 demonstrate that patients with concurrent HF had significantly higher rates of postoperative complication rates compared with those without HF. Specifically, in the lobectomy cohort, the overall complication rate was 48.5% for patients with HF versus 30.5% for patients with non-HF ($P < .001$, odds ratio [OR] = 2.14). For sublobar resection, the rates were 45.9% for patients with HF versus 26.7% for patients with non-HF ($P < .001$, OR = 2.30).

In-depth examination of the lobectomy cohort revealed that patients with HF had elevated rates of specific complications, including postoperative acute respiratory insufficiency (19.0% vs 8.0%, $P < .001$, OR = 2.7), pulmonary collapse (12.6% vs 8.8%, $P = .013$, OR = 1.49), pneumonia (11.1% vs 3.5%, $P < .001$, OR = 3.41), supraventricular arrhythmia (19.5% vs 11.7%, $P < .001$, OR = 1.83), blood transfusion (4.9% vs 1.3%, $P < .001$, OR = 3.76), mechanical ventilation (8.9% vs 2.4%, $P < .001$, OR = 3.91), and noninvasive ventilation (4.0% vs 1.3%, $P < .001$, OR = 3.08). For the sublobar resection cohort, while no statistically significant difference was observed in pulmonary collapse ($P = .369$), patients with HF still exhibited significantly higher rates of postoperative acute respiratory insufficiency (18.9% vs 6.9%, $P < .001$, OR = 3.33), pneumonia (5.2% vs 2.7%, $P = .033$, OR = 1.94), supraventricular arrhythmia (21.8% vs 10.0%, $P < .001$, OR = 2.54), blood transfusion (3.6% vs 1.3%, $P = .009$, OR = 2.80), mechanical ventilation (6.2% vs 1.4%, $P < .001$, OR = 4.66), and noninvasive ventilation (4.9% vs 1.9%, $P = .005$, OR = 2.53). These findings highlight the increased risk of postoperative complications in patients with HF, emphasizing the need for careful perioperative management in this population.

Supplemental analyses

Finally, the prematch comparisons of respective primary outcomes can be found in Supplemental Tables 2 to 6, providing additional context and insights into the initial characteristics. This supplemental information complements our main findings and offers a comprehensive view of the cohort's characteristics prior to matching.

Discussions

This analysis of a large US database of hospital admissions reveals that the incidence of HF among patients with lung cancer undergoing lobectomy and sublobar resection assisted by VATS is estimated at 4.48% and 5.22%, respectively (Supplemental Table 2). HF has long been recognized as a risk factor for cardiovascular events following noncardiac surgery.[27] In the landmark 1977 publication by Goldman and colleagues, a multifactorial index of perioperative cardiac risk was introduced, which established a connection between preoperative clinical indicators of HF and severe cardiovascular complications as well as cardiac mortality.[28] The Revised Cardiac Risk Index subsequently included the presence of HF as a significant preoperative risk factor.[29] Furthermore, HF has been associated with increased perioperative morbidity and mortality across various surgical populations.[30] The prevalence of HF and lung cancer is increasing as the population ages.[31] Physicians and surgeons should be aware of the potential risks

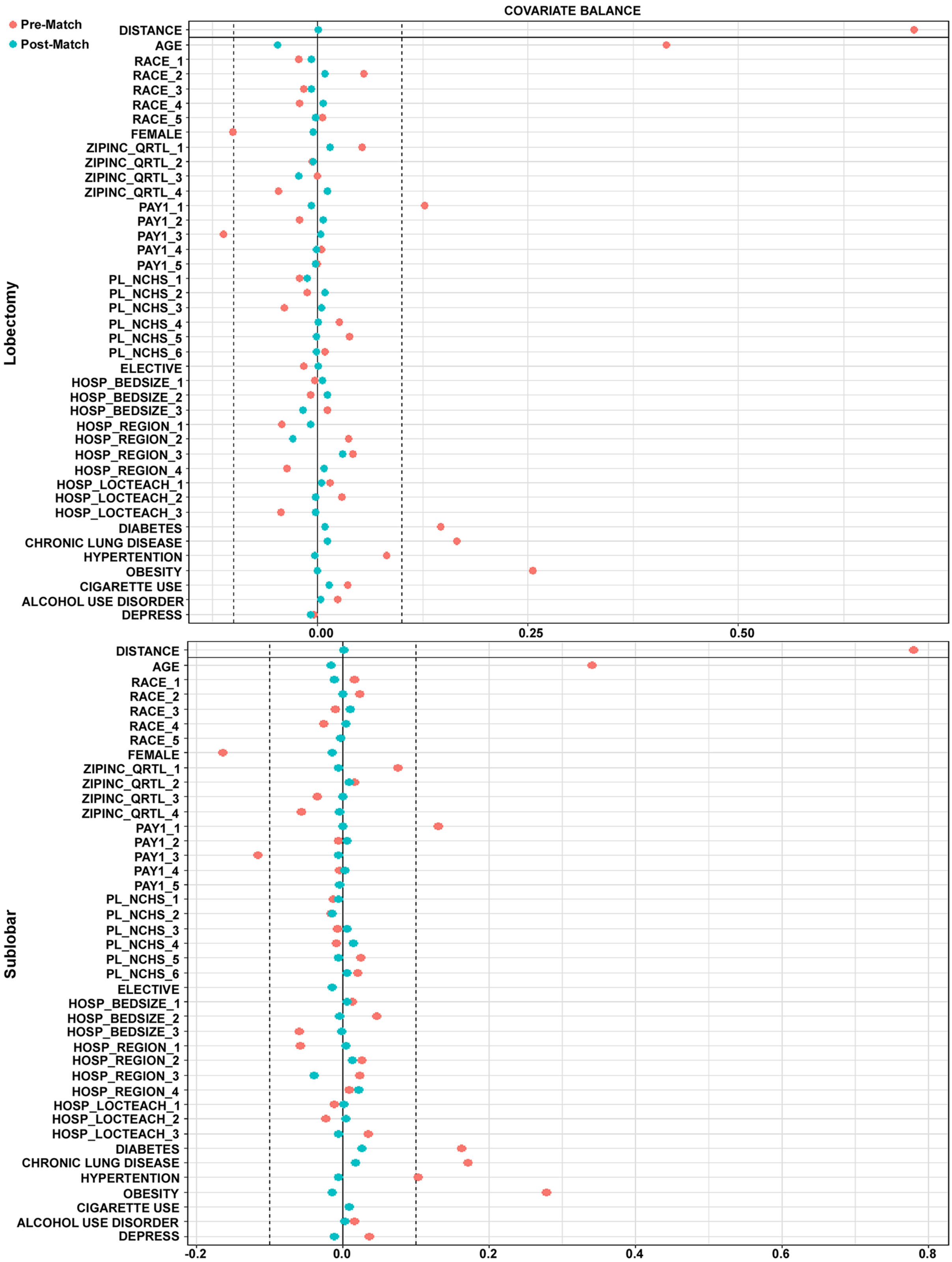

Figure 1. Balance of covariates in the PSM analysis.

involved as more patients with HF choose to undergo VATS. It is crucial for surgeons to recognize the impact of HF on surgical outcomes, underscoring the significance of providing optimal perioperative care, particularly in fluid management, for this at-risk population. However, to date, there have been no research evaluating the impact of perioperative HF on the morbidity and mortality in patients with lung cancer undergoing VATS.

Table 3. Postmatch comparison of hospital outcomes in HF and non-HF patients who underwent lobectomy or sublobar resection.

HOSPITAL OUTCOMES	LOBECTOMY			SUBLOBAR RESECTION		
	HF	NON-HF	*P*	HF	NON-HF	*P*
	N = 594	N = 1187		N = 386	N = 771	
In-hospital mortality (%)	3.2	0.3	<.001	3.1	0.4	<.001
Length of stay (days)						
Median	5	4	<.001	4	3	<.001
First quartile	3	3		2	2	
Third quartile	8	6		6	5	
Hospitalization costs ($)						
Median	103 581	84 633	<.001	75 058	69 800	.004
First quartile	70 151	61 713		50 849	47 837	
Third quartile	169 956	127 017		129 622	104 442	

In our propensity score analysis, we compared short-term postoperative outcomes between patients with HF and non-HF who underwent VATS for lung cancer in a cohort of more than 20 000 patients. Our findings demonstrate that the patients with HF in both the lobectomy and sublobar resection groups experienced increased in-hospital mortality, prolonged hospital stays, significantly higher total hospital charges, and a greater susceptibility to various postoperative complications.

Heart failure is a well-established risk factor for poor prognosis following surgery across multiple medical specialties. A study conducted in Sweden found that patients with HF had higher crude and adjusted hazard ratios (HRs) for 30-day mortality after elective surgery, with values of 5.36 and 1.79, respectively.[32] Another analysis of a large data set comprising more than 21 million surgical hospitalizations revealed that patients with HF had a 2.15 times higher adjusted OR for in-hospital perioperative mortality compared with those without HF.[2] Likewise, in a study involving hospitalized patients with preexisting cancer, the presence of HF was significantly associated with a 41% increased risk of in-hospital mortality in patients aged 65 years or older, even after controlling for covariates.[24] These findings highlight the importance of considering HF as a significant factor influencing surgical outcomes. Our study complements the existing literature, providing initial evidence that the presence of HF amplifies the risk of in-hospital mortality following VATS in patients with lung cancer. Specifically, our findings revealed that patients with lung cancer with HF have a 10-fold increased risk of mortality after undergoing VATS lobectomy and a 7.75-fold increased risk after VATS sublobar resection. These results underscore the importance of considering HF as a crucial factor in assessing surgical outcomes for patients with lung cancer undergoing VATS procedures. The exact reasons behind the increased perioperative mortality in patients with lung cancer with HF undergoing VATS remain unclear. However, a higher incidence of certain perioperative complications may partially explain this phenomenon.

In our study, the overall incidence of complications in the lung lobectomy group and lung sublobar resection group among patients with HF was 2.16 times and 2.32 times higher, respectively, compared with patients with non-HF. Our study findings align with prior research on patients undergoing non-cardiac surgery,[4,33] indicating that HF substantially raises the risks of postoperative supraventricular arrhythmia, acute respiratory insufficiency, pulmonary, pneumonia, need for mechanical/noninvasive ventilation, and blood transfusion among individuals undergoing VATS. The increased occurrence of these complications in patients with HF can be attributed to several factors. For instance, clinicians may opt to prolong mechanical ventilation in patients with HF compared with those without HF,[34] as this may potentially benefit cardiac loading conditions and reduce oxygen consumption. However, this approach may inadvertently lead to a higher incidence of ventilator-associated pneumonia, necessitating tracheal reintubation and prolonged mechanical ventilation. In addition, health care providers may extend the placement of central venous catheters or urinary catheters to maintain hemodynamic stability and accurately assess fluid balance, which paradoxically increases the risk of infections.

Our study demonstrated that patients with HF who underwent VATS for lung cancer face an increased risk of adverse inpatient outcomes. This finding serves as a reminder for surgeons to pay closer attention to high-risk patients. To enhance the prognosis for those undergoing surgery, it may be essential for surgeons to implement more refined preoperative risk stratification to identify high-risk individuals for careful

Table 4. Incidence of postoperative complications of HF versus non-HF lung cancer patients who underwent lobectomy after propensity score matching.

POSTOPERATIVE COMPLICATIONS	HF	NON-HF	*P*	UNIVARIATE ANALYSIS		*P*
	N=594	N=1187		OR	95% CI	
Pulmonary						
Postoperative acute respiratory insufficiency (%)	113 (19.0)	95 (8.0)	<.001	2.70	2.01-3.62	<.001
Postoperative acute pneumothorax (%)	50 (8.4)	77 (6.5)	.136	1.32	0.91-1.92	.172
Pulmonary collapse (%)	75 (12.6)	105 (8.8)	.013	1.49	1.09-2.04	.008
Empyema with and without fistula (%)	NR (0.7)	NR (0.6)	.832	1.14	0.33-3.92	.832
Pneumonia (%)	66 (11.1)	42 (3.5)	<.001	3.41	2.28-5.09	<0.001
Others						
Supraventricular arrhythmia (%)	116 (19.5)	139 (11.7)	<.001	1.83	1.4-2.39	<.001
DVT/PE (%)	NR (1.3%)	NR (0.6%)	.099	2.30	0.83-6.38	.109
Gastrointestinal (%)	14 (2.4%)	17 (1.4%)	.159	1.66	0.81-3.39	.164
Blood transfusion (%)	29 (4.9%)	16 (1.3%)	<.001	3.76	2.02-6.97	<.001
Mechanical ventilation (%)	53 (8.9)	29 (2.4)	<.001	3.91	2.46-6.22	<.001
Noninvasive ventilation (%)	24 (4.0%)	16 (1.3%)	<.001	3.08	1.62-5.85	.001
Any complication (%)	288 (48.5)	362 (30.5)	<.001	2.14	1.75-2.63	<.001

Abbreviations: NR, not reported due to cell counts ⩽10.

Table 5. Incidence of postoperative complications of HF versus non-HF lung cancer patients who underwent sublobar resection after propensity score matching.

POSTOPERATIVE COMPLICATIONS	HF	NON-HF	*P*	UNIVARIATE ANALYSIS		*P*
	N=385	N=764		OR	95% CI	
Pulmonary						
Postoperative acute respiratory insufficiency (%)	73 (18.9)	53 (6.9)	<.001	3.33	2.23-4.96	<.001
Postoperative acute pneumothorax (%)	22 (5.7)	41 (5.3)	.787	1.08	0.64-1.82	.786
Pulmonary collapse (%)	36 (9.3)	60 (7.8)	.369	1.22	0.79-1.87	.369
Empyema with and without fistula (%)	NR (1.6)	NR (0.4)	.033	4.00	1-15.99	.050
Pneumonia (%)	20 (5.2)	21 (2.7)	.033	1.94	1.04-3.62	.037
Others						
Supraventricular arrhythmia (%)	84 (21.8)	77 (10.0)	<.001	2.54	1.80-3.59	<.001
DVT/PE (%)	NR (0.8)	NR (0.3)	.206	3.00	0.5-17.95	.229
Gastrointestinal (%)	NR (1.6)	NR (1.3)	.724	1.20	0.44-3.3	0.724
Blood transfusion (%)	14 (3.6)	NR (1.3)	.009	2.80	1.24-6.30	.013
Mechanical ventilation (%)	24 (6.2)	11 (1.4)	<.001	4.66	2.23-9.77	<.001
Noninvasive ventilation (%)	19 (4.9)	15 (1.9)	.005	2.53	1.29-4.99	.007
Any complication (%)	177 (45.9)	205 (26.7)	<.001	2.30	1.77-2.97	<.001

Abbreviations: NR, not reported due to cell counts ⩽10.

surgical management. In addition, multidisciplinary consultations for patient management and the optimization of HF medications, such as beta-blockers, ACE (Angiotensin-Converting Enzyme) inhibitors, and diuretics, can improve cardiac function and enhance surgical outcomes. Furthermore, future research should focus on strategies to mitigate perioperative cardiac complications in patients with HF.

The NIS is the largest all-payer inpatient care database in the United States.[15] To our knowledge, no previous analysis has examined patients with HF undergoing VATS for lung cancer using data from the NIS. With a sample size exceeding 20 000, our study enhances statistical power and minimizes the likelihood of sampling error. The NIS database includes data from a broad range of hospitals and patient demographics, ensuring national representativeness and following the generalization of our findings to a broader inpatient population.

This study has several limitations. First, although PSM was employed in a large patient cohort, this analysis cannot replace a randomized trial, and the conclusions await further confirmation from prospective clinical studies. Second, an important limitation is the unavailability of data on cardiac ejection fraction (EF) from the NIS database, despite the recognized significance of low EF as a risk factor in patients undergoing surgery.[24,35] Similarly, the database did not provide information on tumor stage or perioperative variables (eg, laboratory results, preoperative lung function, and anesthetic duration), which may also impact postoperative complications. Third, the cross-sectional nature of NIS data and the lack of longitudinal data prior to hospitalization hinder the ability to gather information on the underlying causes of HF in these patients. Fourth, the identification of comorbidities relied on ICD-10 codes, and there may be missing registrations or discrepancies in actual complications. Fifthly, the calculation of hospital LOS may not precisely reflect postoperative outcomes, as elective surgery can be delayed for reasons unrelated to patients' health status. In addition, HF-related codes might be missed in the patient's medical records, as HF is often not the primary diagnosis or reason for admission, potentially underestimating the HF population. Finally, our study focused solely on postoperative complications occurring during the hospital stay and could not assess comorbidities that may have arisen after discharge due to the lack of available data sources. Therefore, this study primarily addresses postoperative outcomes occurring during hospitalization, while adverse outcomes emerging after discharge and readmission rates remain unassessed.

Despite these limitations, this is the first study to evaluate the impact of HF on perioperative outcomes in patients with lung cancer undergoing VATS using a nationwide database. This study offers a national perspective that can serve as a foundation for future research in this area.

Conclusions

This study confirmed that in patients undergoing VATS for lung cancer, the presence of HF is associated with elevated risks of adverse inpatient outcomes, including increased in-hospital mortality, prolonged hospital stays, higher total hospital charges, and a greater incidence of general surgical complications. These findings emphasize the importance of exercising caution when considering surgery for patients with HF and the necessity for close monitoring during postoperative recovery. Furthermore, proactive preventive measures, such as adjusting medication regimens and managing fluid and electrolyte balance, should be implemented to mitigate surgical risks in patients with HF. Overall, this study serves as a valuable reference for clinical practice, aiding surgeons and patients in developing more effective personalized treatment plans.

Author Contributions

XH and WW: Formal analysis, Methodology, Writing. YW: Investigation, Methodology. JX: Methodology, Writing review and editing. JF: Formal analysis, Writing review and editing. HH: Investigation, Methodology. YC: Investigation, Validation. RH: Validation, Writing review and editing. HG and HL: Conceptualization, Project administration, Writing.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

The database used in this study is a de-identified publicly available database; the study was exempt from Institutional Review Board (IRB) approval and informed consent.

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Supplemental Material

Supplemental material for this article is available online.

REFERENCES

1. Savarese G, Becher PM, Lund LH, Seferovic P, Rosano GMC, Coats AJS. Global burden of heart failure: a comprehensive and updated review of epidemiology. *Cardiovasc Res*. 2023;118:3272-3287. doi:10.1093/cvr/cvac013.
2. Smilowitz NR, Banco D, Katz SD, Beckman JA, Berger JS. Association between HF and perioperative outcomes in patients undergoing non-cardiac surgery. *Eur Heart J Qual Care Clin Outcomes*. 2021;7:68-75. doi:10.1093/ehjqcco/qcz066
3. Vigen R, Maddox TM, Allen LA. Aging of the United States population: impact on HF. *Curr Heart Fail Rep*. 2012;9:369-374. doi:10.1007/s11897-012-0114-8
4. Lerman BJ, Popat RA, Assimes TL, Heidenreich PA, Wren SM. Association between heart failure and postoperative mortality among patients undergoing ambulatory noncardiac surgery. *JAMA Surg*. 2019;154:907-914. doi:10.1001/jamasurg.2019.2110
5. World HealthOrganization. Cancer fact sheets, lung cancer, 2018. Accessed February 4, 2025. http://gco.iarc.fr/today/fact-sheets-cancers
6. Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin*. 2018;68:394-424. doi:10.3322/caac.21492
7. Tuzovic M, Yang EH, Sevag Packard RR, Ganz PA, Fonarow GC, Ziaeian B. National outcomes in hospitalized patients with cancer and comorbid heart failure. *J Card Fail*. 2019;25:516-521. doi:10.1016/j.cardfail.2019.02.007

8. Islam KM, Jiang X, Anggondowati T, Lin G, Ganti AK. Comorbidity and survival in lung cancer patients. *Cancer Epidemiol Biomarkers Prev*. 2015;24:1079-1085. doi:10.1158/1055-9965.EPI-15-0036
9. National Comprehensive Cancer Network. National comprehensive cancer network (NCCN) clinical practice guidelines in oncology. Non-Small Cell Lung Cancer Version 2, 2018. Accessed 23 February 2019. https://www.nccn.org/professionals/physician_gls/pdf/nscl.pdf
10. Yang R, Wolfson M, Lewis MC. Unique aspects of the elderly surgical population: an anesthesiologist's perspective. *Geriatr Orthop Surg Rehabil*. 2011;2:56-64. doi:10.1177/2151458510394606
11. Bhagat R, Bronsert MR, Henderson WG, et al. Analysis of discharge destination after open versus minimally invasive surgery for lung cancer. *Ann Thorac Surg*. 2020;109:375-382. doi:10.1016/j.athoracsur.2019.08.059
12. Cheng X, Onaitis MW, D'amico TA, Chen H. Minimally invasive thoracic surgery 3.0: lessons learned from the history of lung cancer surgery. *Ann Surg*. 2018;267:37-38. doi:10.1097/SLA.0000000000002405
13. Whitson BA, Groth SS, Duval SJ, Swanson SJ, Maddaus MA. Surgery for early-stage non-small cell lung cancer: a systematic review of the video-assisted thoracoscopic surgery versus thoracotomy approaches to lobectomy. *Ann Thorac Surg*. 2008;86:2008-2016; discussion 2016-2018. doi:10.1016/j.athoracsur.2008.07.009
14. Stephens N, Rice D, Correa A, et al. Thoracoscopic lobectomy is associated with improved short-term and equivalent oncological outcomes compared with open lobectomy for clinical Stage I non-small-cell lung cancer: a propensity-matched analysis of 963 cases. *Eur J Cardiothorac Surg*. 2014;46:607-613. doi:10.1093/ejcts/ezu036
15. Napolitano MA, Sparks AD, Werba G, Rosenfeld ES, Antevil JL, Trachiotis GD. Video-assisted thoracoscopic surgery lung resection in united states veterans: trends and outcomes versus thoracotomy. *Thorac Cardiovasc Surg*. 2022;70:346-354. doi:10.1055/s-0041-1728707
16. Brunswicker A, Taylor M, Grant SW, et al. Pneumonectomy for primary lung cancer: contemporary outcomes, risk factors and model validation. *Interact Cardiovasc Thorac Surg*. 2022;34:1054-1061. doi:10.1093/icvts/ivab340
17. Yun J, Choi YS, Hong TH, et al. Nononcologic mortality after pneumonectomy compared to lobectomy. *Semin Thorac Cardiovasc Surg*. 2022;34:1122-1131. doi:10.1053/j.semtcvs.2021.07.014
18. Koike T, Yamato Y, Yoshiya K, Shimoyama T, Suzuki R. Intentional limited pulmonary resection for peripheral T1 N0 M0 small-sized lung cancer. *J Thorac Cardiovasc Surg*. 2003;125:924-928. doi:10.1067/mtc.2003.156
19. Nakao M, Suzuki A, Ichinose J, Matsuura Y, Okumura S, Mun M. Risk of death from other diseases in lung cancer patients after sublobar resection versus lobectomy [published online ahead of print October 2, 2024]. *J Surg Oncol*. 2024. doi:10.1002/jso.27927.
20. Healthcare Cost and Utilization Project (HCUP). 2017 Introduction to the HCUP National Inpatient Sample (NIS). Rockville, MD: U.S. Agency for Healthcare Research and Quality; 2019. Accessed September 20, 2020. https://www.hcup-us.ahrq.gov/db/nation/nis/NISIntroduction2017.pdf
21. Kirkland RS, Kole AJ, Batra H, et al. Predictors of in-hospital death in patients with lung cancer admitted for acute radiation pneumonitis: a Healthcare Cost and Utilization Project (HCUP) analysis. *Clin Lung Cancer*. 2021;22:e716-e722. doi:10.1016/j.cllc.2021.01.016
22. Clark JM, Utter GH, Nuño M, Romano PS, Brown LM, Cooke DT. ICD-10-CM/PCS: potential methodologic strengths and challenges for thoracic surgery researchers and reviewers. *J Thorac Dis*. 2019;11:S585-S595. doi:10.21037/jtd.2019.01.86
23. Jawitz OK, Wang Z, Boffa DJ, Detterbeck FC, Blasberg JD, Kim AW. The differential impact of preoperative comorbidity on perioperative outcomes following thoracoscopic and open lobectomies. *Eur J Cardiothorac Surg*. 2017;51:169-174. doi:10.1093/ejcts/ezw239
24. Yu A, Thaliffdeen R, Park SK, Park C. Hospital outcomes and costs for prostate cancer patients with comorbid heart failure by age group: an analysis of the US Nationwide Inpatient Sample. *J Eval Clin Pract*. 2023;29:1016-1024. doi:10.1111/jep.13869
25. Peck NM, Bania TC, Chu J. Low rates of thiamine prescribing in adult patients with alcohol-related diagnoses in the emergency department. *Am J Drug Alcohol Abuse*. 2021;47:704-710. doi:10.1080/00952990.2021.1889575
26. Ogeil RP, Gao CX, Rehm J, Gmel G, Lloyd B. Temporal changes in alcohol-related mortality and morbidity in Australia. *Addiction*. 2016;111:626-634. doi:10.1111/add.13213
27. Turrentine FE, Sohn MW, Jones RS. Congestive heart failure and noncardiac operations: risk of serious morbidity, readmission, reoperation, and mortality. *J Am Coll Surg*. 2016;222:1220-1229. doi:10.1016/j.jamcollsurg
28. Goldman L, Caldera DL, Nussbaum SR, et al. Multifactorial index of cardiac risk in noncardiac surgical procedures. *N Engl J Med*. 1977;297:845-850. doi:10.1056/NEJM197710202971601
29. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation*. 1999;100:1043-1049. doi:10.1161/01.cir.100.10.1043
30. van Diepen S, Bakal JA, McAlister FA, Ezekowitz JA. Mortality and readmission of patients with heart failure, atrial fibrillation, or coronary artery disease undergoing noncardiac surgery: an analysis of 38 047 patients. *Circulation*. 2011;124:289-296. doi:10.1161/CIRCULATIONAHA.110.011130
31. Kratzer TB, Jemal A, Miller KD, et al. Cancer statistics for American Indian and Alaska native individuals, 2022: including increasing disparities in early onset colorectal cancer. *CA Cancer J Clin*. 2023;73:120-146. doi:10.3322/caac.21757
32. Faxén UL, Hallqvist L, Benson L, Schrage B, Lund LH, Bell M. Heart failure in patients undergoing elective and emergency noncardiac surgery: still a poorly addressed risk factor. *J Card Fail*. 2020;26:1034-1042. doi:10.1016/j.cardfail.2020.06.015
33. Maile MD, Engoren MC, Tremper KK, Jewell E, Kheterpal S. Worsening preoperative HF is associated with mortality and noncardiac complications, but not myocardial infarction after noncardiac surgery: a retrospective cohort study. *Anesth Analg*. 2014;119:522-532. doi:10.1213/ANE.0000000000000116
34. Thille AW, Boissier F, Ben Ghezala H, Razazi K, Mekontso-Dessap A, Brun-Buisson C. Risk factors for and prediction by caregivers of extubation failure in ICU patients: a prospective study. *Crit Care Med*. 2015;43:613-620. doi:10.1097/CCM.0000000000000748
35. Kristensen SD, Knuuti J, Saraste A, et al. 2014 ESC/ESA Guidelines on non-cardiac surgery: cardiovascular assessment and management: the Joint Task Force on non-cardiac surgery: cardiovascular assessment and management of the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA). *Eur Heart J*. 2014;35:2383-2431. doi:10.1093/eurheartj/ehu282