Original Article

A simple prediction score for postoperative mortality after decortication

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Background: Decortication of the lung, either by video-thoracoscopy or thoracotomy is potentially a morbid procedure and has significantly higher mortality compared with other major thoracic procedures. Much of this difference can be attributed to other significant comorbidities and to the non-elective nature of the surgery. Our primary goal was to recognize the preoperative unique characteristics of patients who had postoperative mortality within the first 30 days. Our secondary goal was to build a score system to calculate the odds of death after decortication.

Methods: Patients who had undergone either partial or total pulmonary decortication were retrospectively identified from the 2015–2017 databases of the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) and were employed for this analysis. Multivariable regression models were used to evaluate the possible association of multiple risk factors with postoperative death. Factors that remained significant in the multivariable regression analysis were used to develop the Decortication Prognostic Score (DPS).

Results: The final study population consisted of 2,315 patients. The overall observed mortality rate was 5.6%. The greatest independent risk factor for increased 30-day mortality in multivariable logistic regression analysis was disseminated cancer, followed by age ≥65 years, ventilator dependence, active hemodialysis, open wound or wound infection, partially or totally dependent preoperative functional status, preoperative systemic inflammatory response syndrome (SIRS), sepsis or septic shock, congestive heart failure (CHF), preoperative need for blood transfusion, dyspnea, and chronic obstructive pulmonary disease (COPD). Afterwards, we developed a prognostic score for calculating the odds of postoperative death. The total score was associated with a stepwise higher risk of postoperative death after decortication. Patients with a score of 1 had an associated mortality of 1.1% [odds ratio (OR): 2, 95% confidence interval (CI): 0.43–9.32, P=0.375], patients with scores 2–3 had an associated mortality of 6.6% (OR: 12.5, 95% CI: 3.04–51.36, P<0.001), and patients with scores ≥4 had an associated mortality of 27.1% (OR: 65.8, 95% CI: 15.86–273.2, P<0.001).

Conclusions: Preoperative factors can predict postoperative mortality after decortication. DPS may help guide surgeons with bedside decision making and heighten awareness to patients most likely to be at risk for 30-day re-intubation, failure to wean from ventilator, surgical site infections, prolong length of stay and higher mortality after decortication.

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Introduction

Decortication of the lung is a commonly performed surgical procedure and constitutes the surgical excision of abnormally thickened fibrous tissue from either parietal or visceral pleura, with final aim to facilitate the expansion of entrapped lung or evacuate complex/loculated pleural fluid collections (1). It was first described by Delorme *et al.* in 1894 (2) and can be performed either by minimal invasive approach or open approach (1,3). Lung decortication can be used in either benign complex pleural fluid collections (from either infectious or inflammatory etiology) or malignant pleural disease. Decortication of the lung, either by video-thoracoscopy or thoracotomy, is potentially a morbid procedure and postoperative mortality can approach 9% (4-7). This mortality rate is significantly higher than that of other major thoracic procedures such as anatomic lung resection. Much of this difference can be attributed to other significant preoperative comorbidities and to the non-elective nature of the surgery. In 2019, Towe and colleagues have analyzed the Society of Thoracic Surgeons' Database to describe the results of surgical decortication (excluding hemothorax and malignancy), including 30-day mortality, and found a mortality rate of 3.1% (7).

Highlight box

Key findings

- Decortication Prognostic Score (DPS) can predict morbidity and mortality after decortication.

What is known and what is new?

- It is known that individual preoperative factors can predict postoperative mortality and morbidity after decortication.
- DPS is composed of multiple preoperative risk factors and as a new prediction score can help guide surgeons with prediction of postoperative morbidity and mortality after decortication.

What is the implication, and what should change now?

- As surgeons continue to perform decortications and DPS can be used in daily clinical practice, however future studies are needed to validate it.

Much research in recent years has focused on unveiling potential comorbidities contributing to poor postoperative outcomes after decortication, but most of these studies are single institution retrospective studies with significant potential biases. There is an imperative need for a simple, objective and reliable risk assessment score that can estimate a patient's level of risk when deciding whether to proceed with this procedure. The primary aim of this study was to identify independent preoperative factors contributing to increased risk for 30-day mortality and to develop a predictive score for identifying high risk patients for postoperative mortality. We present this article in accordance with the TRIPOD reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-121/rc).

Methods

Study population

Patients undergoing either partial or total pulmonary decortication were identified in the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database from 2015 to 2017. The ACS-NSQIP program is a nationally validated, risk-adjusted, outcomes-based program to measure and improve the quality of surgical care, with the participation of more than 700 hospitals in the USA and other countries (8). The ACS-NSQIP provides patient data on demographics, preoperative comorbidities, laboratory values, intraoperative variables and postoperative outcomes for the first 30-day period. A trained and certified nurse from each participating hospital imports the data, which is audited by ACS on a regular basis to ensure its integrity. More details of the NSQIP database are available on its official website (8). Our primary goal was to recognize the preoperative unique characteristics of patients who had post-operative death in the first 30 days after decortication. Our secondary goal was to build a score system to calculate the odds of postoperative death after decortication. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Table 1 Number of patients among the CPT codes groups

CPT code	Procedure	N (%)
32651	Thoracoscopy, surgical; with partial pulmonary decortication	770 (33.3)
32652	Thoracoscopy, surgical; with total pulmonary decortication, including intrapleural pneumonolysis	702 (30.3)
32320	Decortication and parietal pleurectomy	195 (8.4)
32220	Decortication, pulmonary (separate procedure); total	454 (19.6)
32225	Decortication, pulmonary (separate procedure); partial	194 (8.4)

CPT, Current Procedural Terminology.

Patients who underwent pulmonary decortication were identified based on primary Current Procedural Terminology (CPT) codes: 32651 (thoracoscopy, surgical; with partial pulmonary decortication), 32652 (thoracoscopy, surgical; with total pulmonary decortication, including intrapleural pneumonolysis), 32320 (decortication and parietal pleurectomy), 32220 [decortication, pulmonary (separate procedure); total] and 32225 [decortication, pulmonary (separate procedure); partial] (*Table 1*). Inclusion criteria were age ≥18 years and available data on the type of decortication procedure and postoperative outcomes. Patients undergoing other related morbid thoracic procedures, were excluded in order to avoid any potential confounding factors that could affect the final outcomes, such as a concurrent diagnosis of mesothelioma.

The cohort was divided into two groups consisting of patients with 30-day postoperative mortality and those surviving the initial 30 days. Demographic, preoperative clinical and laboratory characteristics, and intraoperative variables were analyzed to identify unique features of patients who had mortality in the first 30 days. The analyzed preoperative variables were age, body mass index (BMI), gender, race, American Society of Anaesthesiologists (ASA) score, diabetes mellitus, functional status, smoking, dyspnea, ventilator dependence, history of chronic obstructive pulmonary disease (COPD), ascites, congestive heart failure (CHF), hypertension (HTN), need for chronic hemodialysis, disseminated cancer, existing preoperative wound infection, chronic steroid use, weight loss >10%, blood transfusion, and existing systemic inflammatory response syndrome (SIRS) or sepsis or septic shock. Intraoperative variables were the total operative time and the operative approach. The analyzed preoperative laboratories were serum sodium (*Table 2*). The primary study endpoint was to determine whether the group of patients with postoperative death had any unique characteristics that could contribute to the prediction of postoperative mortality. Secondary study end points included the length of postoperative hospital stay, incidence of unplanned intubation, failure to wean from ventilator and surgical site infections. Patients with missing data in primary outcomes were excluded from analysis.

Statistical analysis

Statistical analysis was performed using the program IBM SPSS Statistics 25.0. Data on categorical variables were expressed as frequencies and proportions (%) and were compared between groups using the Chi-Square test. Data on continuous variables were summarized with descriptive statistics such as means, and standard deviations (SDs) and group comparisons of these variables were performed using the *t*-test or non-parametric test based on the data distribution. Initial data analysis was carried out with the aim to unveil presumptive differences in the rate of postoperative mortality between the study groups. Consequently, univariable logistic regression analysis was carried out to examine the associations of preoperative/intraoperative factors with mortality in first postoperative 30 days, one at a time. Next, multivariable logistic regression was performed to evaluate the possible association of multiple variables with postoperative mortality after decortication. Wald tests were used to assess the significant contribution of each predictor variable, and unadjusted raw or adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) were reported as appropriate for postoperative mortality. Two-tailed P values of less than 0.05 were deemed statistically significant. Finally, the factors that remained significant in the multivariable regression analysis were used to develop the Decortication Prognostic Score (DPS). Every patient was allotted one point for each of the preoperative/intraoperative factors that remained significant

Table 2 Baseline characteristics of patients

Preoperative clinical and laboratory patient characteristics	Total	Death	No death	P value
Population	2,315	129 (5.6)	2,186 (94.4)	
Age (years)				
Mean (SD)	57.6 (16.1)	68.2 (14.2)	57 (16.0)	0.007
Median [IQR]	59 [47–70]	71 [61–78]	59 [47–69]	<0.001†
Age ≥65, n (%)	847 (36.6)	89 (69.0)	758 (34.7)	<0.001
BMI, kg/m^2				
Mean (SD)	28.2 (7.1)	26.7 (6.7)	28.2 (7.1)	0.619
Median [IQR]	27.1 [23–32]	25.5 [22–30]	27.3 [23–32]	0.007†
Gender female, n (%)	757 (32.7)	39 (30.2)	718 (32.8)	0.539
Race, n (%)				
Caucasian	1,775 (84.4)	97 (75.2)	1,678 (76.8)	0.691
African American	237 (11.3)	14 (10.9)	223 (10.2)	
Asia	63 (3.0)	4 (3.1)	59 (2.7)	
Other (American Indian or Alaska Native or Native Hawaiian or Pacific Islander)	28 (1.3)	0	28 (1.3)	
ASA score ≥3, n (%)	2,011 (86.9)	127 (98.4)	1,884 (86.2)	<0.001
Diabetes mellitus, n (%)	473 (20.4)	30 (23.3)	443 (20.3)	0.413
Total operative time (minutes)				
Mean (SD)	106.8 (63.5)	105.4 (60.5)	106.9 (63.7)	0.586
Median [IQR]	93 [65–132]	84 [63–137]	94 [65–132]	0.601†
Functional status, n (%)				
Independent	2,126 (92.3)	97 (75.8)	2,029 (93.3)	<0.001
Partially or totally depended	177 (7.7)	31 (24.2)	146 (6.7)	
Smoking, n (%)	740 (32.0)	28 (21.7)	712 (32.6)	0.01
Dyspnea, n (%)	692 (29.9)	68 (52.7)	624 (28.5)	<0.001
Ventilator dependent, n (%)	121 (5.2)	22 (17.1)	99 (4.5)	<0.001
History of COPD, n (%)	346 (14.9)	38 (29.5)	308 (14.1)	<0.001
Preoperative ascites, n (%)	20 (0.9)	1 (0.8)	19 (0.9)	0.9; 0.693‡
Preoperative CHF, n (%)	118 (5.1)	20 (15.5)	98 (4.5)	<0.001
Preoperative hypertension under treatment, n (%)	1,137 (49.1)	83 (64.3)	1,054 (48.2)	<0.001
Currently on dialysis, n (%)	109 (4.7)	22 (17.1)	87 (4.0)	<0.001
Preoperative disseminated cancer, n (%)	159 (6.9)	32 (24.8)	127 (5.8)	<0.001
Open wound/wound infection, n (%)	140 (6.0)	21 (16.3)	119 (5.4)	<0.001
Preoperative steroid use, n (%)	163 (7.0)	15 (11.6)	148 (6.8)	0.036; 0.034‡
Preoperative weight loss >10%, n (%)	137 (5.9)	14 (10.9)	123 (5.6)	0.015; 0.018‡

Table 2 *(continued)*

Table 2 *(continued)*

Preoperative clinical and laboratory patient characteristics	Total	Death	No death	P value
Transfusion of PRBC, n (%)	140 (6.0)	21 (16.3)	119 (5.4)	<0.001
Preoperative SIRS or sepsis or septic shock, n (%)	1,072 (46.3)	75 (58.1)	997 (45.6)	0.006; 0.004‡
Preoperative bleeding disorders, n (%)	185 (8.0)	17 (13.2)	168 (7.7)	0.025; 0.025‡
Thoracoscopic *vs.* open thoracotomy, n (%)	1,472 (63.6)	77 (59.7)	1,395 (63.8)	0.344
	843 (36.4)	52 (40.3)	791 (36.2)	
Preop serum sodium (mmol/L)				
Mean (SD)	137 (3.9)	138 (4.5)	137 (3.9)	0.253
Median [IQR]	137 [135–140]	138 [135–140]	137 [135–140]	0.007†
Sodium <135 or >145 mmol/L, n (%)	568 (24.5)	26 (20.2)	542 (24.8)	0.201
(%) Preop serum albumin (g/dL)				
Mean (SD)	2.8 (0.8)	2.55 (0.7)	2.82 (0.8)	0.236
Median [IQR]	2.7 [2.2–3.3]	2.6 [2–3]	2.8 [2.2–3.3]	0.001

†, non-parametric comparison; ‡, Fisher exact test. ASA, American Society of Anaesthesiologists; SD, standard deviation; IQR, interquartile range; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CHF, congestive heart failure; PRBC, packed red blood cell; SIRS, systemic inflammatory response syndrome.

in multivariable regression analysis.

Results

A total of 2,315 patients underwent decortication from January 1, 2015 through December 31, 2017, after implementing the inclusion and exclusion criteria. There were 2,186 (94.4%) patients without postoperative mortality and 129 (5.6%) who expired in the first postoperative 30 days (*Table 2*). Out of these 2,315 patients, 770 (33.3%) patients underwent thoracoscopic partial decortication, 702 (30.3%) patients underwent thoracoscopic total pulmonary decortication, 454 (19.6%) patients underwent open total decortication, 195 (8.4%) underwent open decortication and parietal pleurectomy and 194 (8.4%) underwent open partial decortication. The mean age of the population was 57.6 (SD ±16.1) years and patients with postoperative mortality had a higher mean age compared to those without postoperative mortality. The overall mean BMI was 28.2 (SD ±7.1) kg/m^2 and the median was 27.1 (IQR 23–32) kg/m^2. Of the total population, 757 (32.7%) patients were female and 1,775 (84.4%) patients were of the Caucasian race. The group of patients with postoperative mortality had increased rates of age ≥65 years (69% *vs.* 34.7%, P<0.001), ASA scores ≥3 (98.4% *vs.* 86.2%, P<0.001), partially or totally dependent functional status (24.2% *vs.* 6.7%, P<0.001) and non-smokers (78.3% *vs.* 67.4%, P=0.01). Moreover, the cohort with postoperative death had higher rates of preoperative dyspnea (52.7% *vs.* 28.5%, P<0.001), ventilator depended (17.1% *vs.* 4.5%, P<0.001), history of COPD (29.5% *vs.* 14.1%, P<0.001), CHF (15.5% *vs.* 4.5%, P<0.001), HTN (64.3% *vs.* 48.2%, P<0.001), hemodialysis depended (17.1% *vs.* 4%, P<0.001) and disseminated cancer (24.8% *vs.* 5.8%, P<0.001). Finally, patients with postoperative mortality had statistically significant higher rates of preoperative open wound or wound infection (16.3% *vs.* 5.4%, P<0.001), preoperative chronic steroid use (11.6% *vs.* 6.8%, P=0.036), weight loss >10% (10.9% *vs.* 5.6%, P=0.015), preoperative need for blood transfusion (16.3% *vs.* 5.4%, P<0.001), preoperative SIRS or sepsis or septic shock (58.1% *vs.* 45.6%, P=0.006) and preoperative bleeding disorder (13.2% *vs.* 7.7%, P=0.025). Further demographic and preoperative information are summarized in *Table 2*.

In multivariable logistic regression analysis, the variables that continued to be significant were age ≥65 years [adjusted odds ratio (aOR): 4.18, 95% CI: 2.63–6.65, P<0.001], dyspnea (aOR: 1.83, 95% CI: 1.21–2.77, P=0.004), ventilator dependence (aOR: 3.71, 95% CI: 1.99–6.91, P<0.001), COPD (aOR: 1.69, 95% CI: 1.05–2.73,

P=0.031), CHF (aOR: 1.93, 95% CI: 1.02–3.64, P=0.042), currently on hemodialysis (aOR: 3.37, 1.79–6.36, P<0.001), disseminated cancer (aOR: 6.60, 95% CI: 3.94–11.03, P<0.001), open wound or wound infection (aOR: 2.58, 95% CI: 1.40–4.74, P=0.002), preoperative need for blood transfusion (aOR: 1.94, 95% CI: 1.05–3.61, P=0.036, preoperative SIRS or sepsis or septic shock (aOR: 2.01, 95% CI: 1.31–3.07, P=0.001) and partially or totally dependent preoperative functional status (aOR: 2.51, 95% CI: 1.51–4.17, P<0.001). Univariable and multivariable regression analysis for postoperative SSI are shown in *Table 3*. Afterward, we created a prognostic score incorporating clinical and intraoperative data to predict postoperative mortality. One point was allotted for each of the aforementioned factors and the theoretical possible values ranged from 0 to 11, but the actual final score was ranged between 0 and 8. Our score was associated with a stepwise higher risk of postoperative mortality after decortication (*Table 4*). We did not use the ASA score in the multivariable logistic regression analysis since multiple comorbidities that constitute the ASA score were already included.

The final population was grouped into four categories for easier clinical use of the prognostic score: patients with zero score, patients with score 1, patients with score 2–3 and patients with score ≥4. The total score was associated with a stepwise higher risk of postoperative death after decortication. Patients with a score of 1 had an associated mortality of 1.1% (OR: 2, 95% CI: 0.43–9.32, P=0.375), patients with scores 2–3 had an associated mortality of 6.6% (OR: 12.5, 95% CI: 3.04–51.36, P<0.001), and patients with scores ≥4 had an associated mortality of 27.1% (OR: 65.8, 95% CI: 15.86–273.2, P<0.001). Patients with higher scores were also associated with higher risk of unplanned re-intubation (score ≥4 OR 7.1, 95% CI: 3.18–15.87, P<0.001), failure to wean from ventilator (>48 hours) (score ≥4 OR 21.7, 95% CI: 9.15–51.44, P<0.001), postoperative surgical site infection (score ≥4 OR 2.03, 95% CI: 1.01–4.07, P=0.046) and prolonged length of stay (*Table 4*). Interestingly, we found that the score has lower predictive power in subgroup analysis of male population (score ≥4 OR 49.6, 95% CI: 11.8–208.6, P<0.001).

Discussion

Despite significant recent improvements in both preoperative medical optimization and intraoperative surgical techniques, decortication remains one of the most morbid procedures in thoracic surgery with disproportionally high postoperative mortality rates (5). However, significant variability persists regarding the postoperative mortality between several studies depends on the type of the study (single institutional *vs.* multi-institutional) and the primary disease for the operation. On the other hand, there should be obviously significant variability regarding the postoperative mortality between the patients of the same study cohort based on preoperative characteristic like patient's age, comorbidities or frailty status (4,5,7). On account of this, we examined the role of multiple independent preoperative risk factors and their

Table 3 Univariate and multivariate regression analysis of risk factors for postoperative 30 days mortality

Risk factors	Univariate analysis			Multivariate analysis		
	uOR	95% CI	P value	aOR	95% CI	P value
Age ≥65 years	4.24	2.88–6.24	<0.001	4.18	2.63–6.65	<0.001
Dyspnea	2.79	1.95–3.99	<0.001	1.83	1.21–2.77	0.004
Ventilator dependent	4.33	2.63–7.15	<0.001	3.71	1.99–6.91	<0.001
History of COPD	2.55	1.71–3.79	<0.001	1.69	1.05–2.73	0.031
CHF	3.91	2.33–6.56	<0.001	1.93	1.02–3.64	0.042
HTN under treatment	1.94	1.34–2.81	<0.001	0.99	0.64–1.55	0.979
Currently on dialysis	4.96	2.99–8.23	<0.001	3.37	1.79–6.36	<0.001
Disseminated cancer	5.35	3.45–8.28	<0.001	6.60	3.94–11.03	<0.001
Open wound/wound infection	3.38	2.04–5.58	<0.001	2.58	1.40–4.74	0.002

Table 3 *(continued)*

Table 3 *(continued)*

Risk factors	Univariate analysis			Multivariate analysis		
	uOR	95% CI	P value	aOR	95% CI	P value
Steroid use	1.81	1.03–3.18	0.039	1.53	0.82–2.85	0.182
Preoperative weight loss >10%	2.04	1.14–3.66	0.017	1.32	0.66–2.62	0.430
Transfusion of PRBC	3.38	2.04–5.58	<0.001	1.94	1.05–3.61	0.036
Sepsis within 48 hours prior to surgery	1.66	1.16–2.37	0.006	2.01	1.31–3.07	0.001
Bleeding disorders	1.82	1.07–3.11	0.027	0.98	0.53–1.81	0.950
Depended functional status	4.44	2.87–6.88	<0.001	2.51	1.51–4.17	<0.001
Current smoker	0.57	0.37–0.88	0.011	0.91	0.549–1.51	0.713

Dyspnea may be symptomatic of numerous disorders that interfere with adequate ventilation or perfusion of the blood with oxygen and is defined as difficult, painful or labored breathing (dyspnea upon moderate exertion or Dyspnea at rest). Ventilator dependent: the patient requires ventilator-assisted respiration. COPD: medical record must document that there is a historical or current diagnosis of COPD and at least one of the following, within the 30 days prior to the principal operative procedure or at the time the patient is being considered as a candidate for surgery: functional disability from COPD or requires chronic bronchodilator therapy with oral or inhaled agents or other medication specifically targeted to this disease or hospitalization at any time in the past (can be outside of the 30 day preop timeframe) for treatment of COPD or an FEV_1 of <75% of predicted on a prior (can be outside of the 30 day preop timeframe) PFT. CHF: newly diagnosed CHF or a diagnosis of chronic and active CHF with current signs or symptoms, in the 30 days prior to the principal operative procedure or at the time the patient is being considered as a candidate for surgery. HTN: the diagnosis of HTN must be documented in the patient's medical record and the condition is severe enough that it requires antihypertensive medication, within 30 days prior to the principal operative procedure or at the time the patient is being considered as a candidate for surgery. The patient must have been receiving or required long-term treatment of their chronic HTN for >2 weeks. Dialysis: acute or chronic renal failure requiring treatment with peritoneal dialysis, hemodialysis, hemofiltration, hemodiafiltration, or ultrafiltration, within two weeks prior to the principal operative procedure. The medical record must document that such a treatment was indicated. Disseminated cancer: the patient has a primary cancer that has metastasized or disseminated to a major organ AND the patient also meets AT LEAST ONE of the following criteria: The patient has received active treatment for the cancer within one year of their ACS-NSQIP assessed procedure surgery date. If the ACS-NSQIP assessed surgical procedure is the treatment for the metastatic cancer, assign disseminated cancer to the case or the extent of disease is first appreciated at the time of the surgical procedure in question or the patient has elected not to receive treatment for the metastatic disease, but such treatment was indicated or the patient's metastatic cancer has been deemed untreatable or information is obtained within 30 days following the principal operative procedure indicating disseminated cancer was present at the time of the principal operative procedure. Open wound: preoperative evidence of a documented open wound at the time of the principal operative procedure. Examples: (I) open drains currently in place and placed during a previous procedure should be considered an open wound [e.g., Penrose drains]. (II) Open wounds currently undergoing dressing changes or with negative pressure wound devices (e.g., wound vacs). (III) Any abnormal passageway leading from an internal organ (e.g., intestinal tract) to the surface of the body/skin (e.g., ECF). An ostomy scabbed over wound with or without drainage, minor wound small enough to be covered by a Band-Aid and tracheostomy would not be considered an open wound. Steroid use: patient has required the regular administration of oral or parenteral corticosteroid medications or immunosuppressant medications, for a chronic medical condition, within the 30 days prior to the principal operative procedure. A one-time pulse, limited short course, or a taper of less than 10 days duration would not qualify. Long-interval injections of long-acting agents (e.g., monthly) that are part of an ongoing regimen would qualify. Weight loss: a greater than 10% decrease in body weight in the six-month interval immediately preceding the principal operative procedure. Transfusion of PRBC: preoperative loss of blood or anemia necessitating any transfusion (minimum of 1 unit) of whole blood/PRBCs initiated during the 72 hours prior to the principal operative procedure surgery start time, including any blood transfused in the emergency room. Sepsis within 48 hours prior to surgery: preoperative SIRS or sepsis or septic shock, criteria must be noted within 48 hours prior to the principal operative procedure. Bleeding disorders: any chronic/persistent/active condition that places the patient at risk for excessive bleeding (e.g., vitamin K deficiency, hemophilia, thrombocytopenia, chronic anticoagulation therapy that has not been discontinued prior to surgery). Depended functional status: partially dependent: The patient requires some assistance from another person for ADL. This includes a person who utilizes prosthetics, equipment, or devices but still requires some assistance from another person for ADLs, or totally dependent: The patient requires total assistance for all ADL. Smoking: a current smoker has smoked cigarettes at any point within the 12 months prior to admission for surgery. This does not include the use of cigars, pipes, chewing tobacco, or marijuana. uOR, unadjusted odds ratios; aOR, adjusted odds ratios; CI, confidence interval; COPD, chronic obstructive pulmonary disease; PRBC, packed red blood cell; FEV1, forced expiratory volume in the first second; PFT, pulmonary function test; CHF, congestive heart failure; HTN, hypertension; ECF, enterocutaneous fistula; SIRS, systemic inflammatory response syndrome; ADL, activities of daily living.

Table 4 Odds of postoperative mortality and morbidity after decortication

Score	uOR	95% CI	P value	Total number of each group/number of patients with postoperative mortality (%)
Odds of having postoperative mortality after decortication in total study population				
Score 0	Reference			357/2 (0.6)
Score 1	2.00	0.43–9.32	0.375	806/9 (1.1)
Score 2–3	12.5	3.04–51.36	<0.001	913/60 (6.6)
Score ≥4	65.8	15.86–273.2	<0.001	207/56 (27.1)
Odds of having postoperative mortality after decortication in male subgroup				
Score 0	Reference			273/2 (0.7)
Score 1	1.83	0.39–8.70	0.445	599/8 (1.3)
Score 2–3	8.79	2.12–36.53	0.003	722/44 (6.1)
Score ≥4	49.6	11.8–208.6	<0.001	153/41 (26.8)
Odds of having postoperative unplanned re-intubation[#] after decortication				
Score 0	Reference			357/8 (2.2)
Score 1	1.34	0.60–3.01	0.480	806/24 (3.0)
Score 2–3	3.51	1.67–7.38	<0.001	913/68 (7.4)
Score ≥4	7.1	3.18–15.87	<0.001	207/29 (14.0)
Odds of failure to wean from ventilator* after decortication				
Score 0	Reference			357/6 (1.7)
Score 1	2.11	0.86–5.13	0.101	806/28 (3.5)
Score 2–3	7.28	3.16–16.74	<0.001	913/101 (11.1)
Score ≥4	21.7	9.15–51.44	<0.001	207/56 (27.1)
Odds of having postoperative surgical site infections** after decortication				
Score 0	Reference			357/16 (4.5)
Score 1	1.26	0.7–2.26	0.438	806/45 (5.6)
Score 2–3	1.16	0.65–2.07	0.623	913/47 (5.1)
Score ≥4	2.03	1.01–4.07	0.046	207/18 (8.7)

Score factors: age ≥65 years =1, preoperative dyspnea =1, ventilator dependent =1, history of COPD =1, congestive heart failure =1, currently on dialysis =1, disseminated cancer =1, open wound/wound infection =1, transfusion of PRBC =1, sepsis within 48 hours prior to surgery =1, depended functional status =1, missing: 32. [#], on ventilator greater than 48 hours. *, patient required placement of an endotracheal tube or other similar breathing tube and ventilator support within 30 days following surgery which was not intended or planned. **, superficial incisional SSI or deep incision SSI or organ/space SSI. uOR, unadjusted odds ratio; CI, confidence interval for odds ratio; COPD, chronic obstructive pulmonary disease; PRBC, packed red blood cell; SSI, surgical site infection.

cumulative effect for postoperative mortality in patients undergoing decortication for either malignant or benign disease. Moreover, we developed a predictive score for postoperative mortality which can help thoracic surgeons with preoperative patient evaluation and most importantly offering an additional risk estimation tool to all patients for making the final decision on proceeding with decortication. To our knowledge, this study constitutes the first decortication-specific prediction score for postoperative mortality, developed using a multi-institutional database.

Prior studies have examined potential preoperative risk factors for postoperative morbidity after decortication,

but most are single institution retrospective studies with inconsistent results. Mikkola *et al.* studied 143 consecutive patients who underwent decortication for parapneumonic pleural empyema in the Oulu University Hospital in Finland and found that preoperative serum albumin, cerebrovascular disease, pulmonary embolism and Thoracoscore were independent predictors for postoperative mortality (4). Schweigert *et al.* performed a retrospective analysis of 335 patients who underwent surgery for parapneumonic pleural empyema and found that pulmonary sepsis, respiratory failure, acute renal failure and Charlson score ≥3 were associated with higher mortality (5). An important finding was that patients ≥80 years old showed no higher odds for postoperative mortality. Recently, Towe *et al.* studied 7,316 patients from the Society of Thoracic Surgeons' Database who underwent decortication and found that age, estimated glomerular filtration rate less than 60, COPD, BMI, ASA score, Zubrod score, and thoracotomy were associated with increased postoperative mortality (7). In 2007, Falcoz and colleagues developed a risk model for in-hospital death (the Thoracoscore) in 15,183 patients requiring thoracic surgery and found that age, sex, dyspnea score, ASA score, performance status, priority of surgery, diagnosis group, procedure class, and comorbid disease were significantly associated with postoperative mortality (9). However, the development of this score was based on major procedures like mediastinoscopy or other mediastinal surgery, wedge resection, lobectomy or bi-lobectomy and pneumonectomy; decortication procedures were not included. Moreover, subsequent studies of "Thoracoscore" fails to predict mortality in Indian population or United Kingdom population (10,11).

Our results provide compelling evidence that our scoring system is a beneficial predictor of unplanned re-intubation, failure to wean from ventilator, surgical site infections, extended length of stay and 30-day mortality for postoperative patients who have undergone decortication. Compared to the aforementioned studies, our study, though also retrospective, aims to create a scoring process to predict preoperative risk. Of the possible predicting factors, we denoted that the following with the most statistically significant: age ≥65 years, preoperative dyspnea, ventilator dependence, history of COPD, CHF, preoperative need for chronic hemodialysis, disseminated cancer, existing preoperative open wound (with or without infection), preoperative blood transfusion, existing SIRS or sepsis or septic shock within 48 hours before index operation and partially or totally dependent preoperative functional status. Although a number of our parameters mirrored those of previous studies, the advent of our scoring system provides a promising tool for predicting possible post-operative complications. Patients with DPS 2–3 have eleven times higher odds for postoperative mortality and 2.5 times higher odd for postoperative unplanned re-intubation. Patients with DPS ≥4 have more than 64 times higher odds for postoperative mortality and more than 6 times higher odd for postoperative unplanned re-intubation. Moreover, higher DPS is associated with prolonged length of hospital stay.

Undoubtedly, our study may have multiple limitations. The first potential limitation is the retrospective nature of the ACS-NSQIP database and as a consequence the preoperative variables are predefined and potential other risk factors are lacking. For example, information regarding preoperative treatment is not available. A third potential limitation is that hospitals participating in the ACS-NSQIP database do so voluntarily, which can increase selection bias because these centers have higher referrals and there are higher chances of treating more sick patients (12,13). Another significant limitation is the fact that we do not have available data for the extent of lung decortication.

Conclusions

Preoperative factors can predict postoperative mortality and morbidity after decortication. Patients with DPS 2 or higher have statistically significant higher chances of postoperative mortality, failure to wean from ventilator and re-intubation. Our Prognostic Score may help guide surgeons with bedside decision making and heighten awareness to patients most likely to be at risk for 30-day re-intubation, failure to wean from ventilator, surgical site infections, prolonged length of stay and mortality. Individualized assessment of patients by DPS components may assist in the decision to pursue surgical decortication or an alternative treatment option. Moreover, patients with high DPS (especially those with score ≥4) should be informed about the higher risk of postoperative morbidity and mortality after decortication.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

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