Independent Predictors and Outcomes of Unanticipated Early Postoperative Tracheal Intubation after Nonemergent, Noncardiac Surgery

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ABSTRACT

Background: Although the risk of hypoxemia is greatest during the first 72 h after surgery, little is known of the incidence of respiratory failure during this period. The authors studied the incidence and predictors of unanticipated early postoperative intubation (within 3 days) and its role in mortality.

Methods: A total of 222,094 adult patients undergoing nonemergent, noncardiac surgery in the American College of Surgeons–National Surgical Quality Improvement Program database were studied to determine the incidence and independent predictors of unanticipated early postoperative intubation. A risk-class model was developed and subsequently validated in 109,636 patients.

Results: Overall, 2,828 of 5,725 (49.4%) unanticipated tracheal intubations in a period of 30 days occurred within the first 3 days after surgery. The incidence of unanticipated early postoperative intubation was 0.83–0.9% in the derivation and validation cohorts. Independent predictors of unanticipated early postoperative intubation included current ethanol use, current smoker, dyspnea, chronic obstructive pulmonary disease, diabetes mellitus needing insulin therapy, active congestive heart failure, hypertension requiring medication, abnormal liver function, cancer, prolonged hospitalization, recent weight loss, body mass index less than 18.5 or ≥40 kg/m^2, medium-risk surgery, high-risk surgery, very–high-risk surgery, and sepsis. Unanticipated early postoperative intubation was an independent predictor of 30-day mortality, with an adjusted odds ratio of 9.2. Higher risk classes were associated with increasing incidence of unanticipated early postoperative intubation and death.

Conclusions: One half of unanticipated tracheal intubations in a period of 30 days occurred within the first 3 days after nonemergent, noncardiac surgery and were independently associated with a 9-fold increase in mortality. The authors present a validated perioperative risk class index for determining risk of unanticipated early postoperative intubation.

What We Already Know about This Topic

- The first 3 days after surgery are associated with a high risk of hypoxemia, but little is known about the incidence of acute respiratory failure during this time

What This Article Tells Us That Is New

- In a review of more than 220,000 nonemergent surgeries, the incidence of unanticipated postoperative endotracheal intubation was 0.9%, with one half of these occurring in the first 3 postoperative days
- Multiple patient, surgical, and postoperative factors increase the risk of postoperative intubation

THE first 72 h after surgery is a period with direct implications for respiratory morbidity. It has been shown that respiratory failure caused by narcotic use in the postoperative period peaks during the first 24 h of surgery,[1] whereas the incidence of significant postoperative hypoxemia[2] and sleep-related breathing abnormalities continues through[3,4] and peaks[5] on the third postoperative night. Although these physiologic changes are well described for the first 3 postoperative days, we are unaware if there is a concomitant increase in the risk of unanticipated respiratory failure during this period. It is clear that postoperative respiratory failure is associated with significant morbidity, cost of care, and mortality.[6] However, previous studies on postoperative respiratory failure include mechanical ventilation longer than 48 h with or without unplanned postoperative reintubation,[6,7] limiting a better understanding of the dimensions of un-

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Received from the Department of Anesthesiology, University Hospital, Ann Arbor, Michigan. Submitted for publication December 13, 2010. Accepted for publication March 24, 2011. Support was provided solely from institutional and/or departmental sources.

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 Anesthesiology 2011; 115:44–53

anticipated postoperative intubation alone. Emergent surgery is an independent predictor of postoperative respiratory failure in successive large studies,[6,7] again limiting our understanding of the preoperative risk profile in nonemergent procedures. In addition, little is known of the interrelationship between unanticipated early postoperative intubation after nonemergent surgery and mortality. We undertook this study to describe the incidence and independent predictors of unanticipated early postoperative respiratory failure requiring tracheal intubation after nonemergent, noncardiac surgery and the impact of such intubation on postoperative mortality.

We hypothesized that a significant proportion of unanticipated respiratory failure occurring in the 30 days after surgery occurs within the first 3 postoperative days. We also hypothesized that we would be able to identify clinical predictors of early postoperative respiratory failure. Finally, we hypothesized that unanticipated early postoperative respiratory failure is associated with a risk-adjusted increase in mortality.

Materials and Methods

Patients and Data Collection

This study aims to provide the stated outcomes in a large prospectively collected dataset, the American College of Surgeons–National Surgical Quality Improvement Program (ACS–NSQIP), a robust reporting system designed to provide reliable, risk-adjusted surgical outcomes from within a broad spectrum of facilities.[8–10] Institutional Review Board approval (University of Michigan Medical School, Ann Arbor, Michigan) was obtained for the data analysis of these prospectively collected data, and signed patient consent was waived because no protected health information was collected or analyzed. The following case types were excluded from the data analysis: emergent procedures, cardiac surgical procedures, patients with preoperative ventilator dependence, pediatric age group (age younger than 18 yr), and surgical procedures with less than 100 cases. Because of their low-acuity nature, outpatient procedures were excluded.

The 2005–2008 ACS-NSQIP participant use data file is a compilation of operations from more than 200 participating U.S. medical centers submitted during this period. The centers include academic medical centers and private practice centers. To maintain institutional, provider, and patient anonymity, no site- or region-specific data elements are included in the participant use data file. A full description of the ACS-NSQIP process has been published.[10] For each operation, a trained risk assessment nurse prospectively collected preoperative patient demographics, preoperative comorbidities, operative information, selected intraoperative elements, and postoperative adverse occurrences for as long as 30 days after the operation. These data were gathered through chart review, reports from morbidity and mortality conferences, and communication with each patient by letter or telephone. Surgical nurse data collectors completed standardized and detailed training regarding the definitions of study variables. Detailed, standardized definitions of ACS-NSQIP preoperative patient demographics and comorbidities of interest are described in appendix 1. Operational processes were used to ensure robustness of data, including regular conference calls, annual meetings, and site visits. Only sites with interrater reliability audit score agreement above 95% are included from the ACS-NSQIP participant use data file. Overall follow-up interrater reliability validation studies have demonstrated a 98% concordance rate.[11]

Outcomes

The ACS–NSQIP database defines *unplanned intubation* as placement of an endotracheal tube and mechanical or assisted ventilation because of the onset of respiratory or cardiac failure manifested by severe respiratory distress, hypoxia, hypercapnia, or respiratory acidosis within 30 days of the operation. In patients who were intubated for surgery, unplanned intubation occurred at any time after they had been extubated after surgery. In patients who were not intubated during surgery, intubation at any time after surgery was considered unplanned. The primary outcome measure of the study was the incidence of unanticipated early postoperative intubation (UEPI), defined as unplanned tracheal intubation occurring within 72 h of surgery (0–3 days), to account for both peak respiratory depressant periods (within 24 h)[1] to the period of most severe postoperative hypoxemia (3 days).[5,12] This time period was also considered to be sufficiently related to anesthetic management choices to provide some actionable data for clinicians. The secondary aim of the study was to examine the effect of UEPI on all-cause postoperative mortality in the first 30 days after surgery. Based on pilot estimates of event rates of unanticipated intubation (up to 2%) and inclusion of 20 independent variables into the prediction models, a minimum sample size of 15,000 was required to prevent over-fitting the model.[13]

Statistical Analysis

Statistical analysis was performed using PASW® version 18 (SPSS Inc., Chicago, IL). Patients meeting the inclusion criteria were randomly assigned to a derivation cohort (67%) and validation cohort (33%). The derivation cohort was used to develop a nonparsimonious logistic regression model and risk index classification system in predicting UEPI. The validation cohort was used to assess the validity of the risk index classification system.

First, univariate descriptive statistics were individually performed on preoperative comorbidities of interest to determine associations with UEPI. Candidate variables included male sex, white race, alcohol use, current smoker, dyspnea, chronic obstructive pulmonary disease, pneumonia, diabetes (oral and insulin therapy), history of

coronary artery disease, concurrent coronary artery disease event, congestive heart failure, hypertension requiring medication, liver function abnormality, renal failure, altered sensorium or coma, preexisting neurologic condition, disseminated cancer, previous hospitalization, steroid use, recent weight loss, transfusion, sepsis, type of surgical procedure, body mass index class, and age (see appendix 1 for definitions). All patient and operative characteristics were compared using the Student *t* test or Mann–Whitney U test for continuous variables and the Pearson chi-square test for categorical variables.

To determine independent predictors of UEPI in the derivation cohort, a nonparsimonious logistic regression model was developed using variables deemed to be clinically relevant by three of the investigators (S.K.R., A.S., and S.K.). To improve clinical usability, body mass index was classified using the World Health Organization groups: underweight (less than 18.50 kg/m^2), normal weight (18.50–24.99 kg/m^2), overweight (25.00–29.99 kg/m^2), obese class I (30.00–34.99 kg/m^2), obese class II (35.00–39.99 kg/m^2), and obese class III (≥40.00 kg/m^2). For purposes of the logistic regression model, normal weight body mass index was considered the reference group. Age was included as a continuous variable. Based on the mean frequency of UEPI (0.83–1%), surgical procedures[14] were risk-stratified into quartiles of increasing incidence of UEPI as low (0–0.5%), medium (0.6–1.0%), high (1.0–1.5%), and very high (≥1.6%). These surgical procedure risk classes are described in appendix 2. In terms of surgical procedure risk, the low-risk group was considered the reference group. White race was compared against Hispanic, black, American Indian or Alaska Native, and Pacific Islander. Diabetes groups, requiring oral therapy and insulin therapy, were compared against the reference group of no diabetes. Collinearity diagnostics and bivariate correlation matrix were evaluated for all preoperative variables in the derivation cohort. Any variable with $P < 0.05$ and an adjusted odds ratio less than 0.8 or more than 1.2 was established as an independent predictor of UEPI. The derivation model's predictive value was evaluated using the area under receiver operating characteristics curve. We evaluated the model using the bootstrap method (R statistical package 2.12; The Comprehensive R Archive Network, Palo Alto, CA), which estimates a correction for over-fitting in the model to determine predictive accuracy if applied to a comparable patient population.[13] Somers' Dxy rank correlation estimates the difference in the probability of concordance and discordance between predicted and observed outcomes for all possible pairs of patients.[13,15] One hundred random samples with replacement were used and tested against the original sample.

The independent predictors were used to develop unweighted and weighted risk scores in the derivation cohort. The weighted risk score was developed based on the β coefficient in the nonparsimonious logistic regression model. To calculate the weighted score for each independent predictor, the β coefficient was multiplied by a factor of 1 if the patient had the dichotomous independent predictor, or 0 if the patient did not have the dichotomous independent predictor, and then all the independent variables were summed to get a weighted score. Unweighted risk scores were calculated by assigning 1 point per independent predictor. Weighted and unweighted UEPI risk scores were evaluated using area under the receiver operating characteristics curve, to quantify the loss of accuracy in prediction with use of unweighted risk classes. Using the unweighted risk score, a risk index classification system was arbitrarily developed based on doubling of incidence of UEPI between risk index classes. The UEPI risk classes were validated by comparing the incidence of UEPI in patients with similar preoperative risk scores between the derivation and validation cohorts.

To compare all-cause, 30-day mortality in patients with UEPI, patients from the derivation cohort were risk matched based on the propensity score of the nonparsimonious logistic regression model, as described previously.[16] Matching was performed on a one-to-one basis for the outcome variable UEPI, and all univariates were reassessed after matching to determine sufficient matching. Once the data were matched and no significant differences existed between the outcome groups for each of the preoperative comorbidities, the overall 30-day, all-cause mortality was assessed using a Pearson chi-square test, for which a *P* value <0.05 was considered statistically

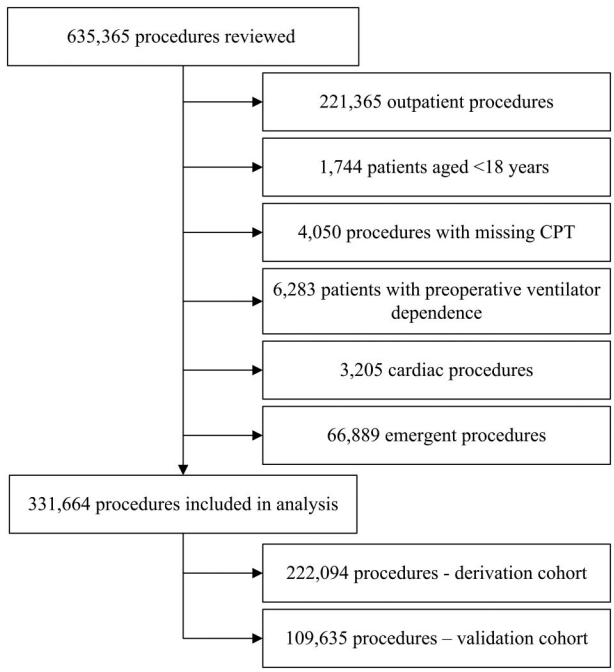

Fig. 1. Patient inclusions and exclusions. The number of patients excluded because of each exclusion criterion is demonstrated. CPT = current procedural terminology.

significant. Effect size was reported as odds ratio with 95% CI. To determine whether UEPI was an independent predictor of mortality, a semiparsimonious logistic regression model was developed in the matched cohort. Any preoperative variable from the matched cohort with a $P < 0.5$ was entered into the semiparsimonious logistic regression model. A P value <0.05 was considered statistically significant. Effect size was assessed using adjusted odds ratio and 95% CI. The mortality model's predictive value was evaluated using area under the receiver operating characteristics curve. Finally, the incremental effect of UEPI risk class on mortality was compared by analyzing death rates between patients with and without UEPI within each risk class for the entire derivation cohort.

Results

A total of 331,664 adult patients underwent nonemergent, noncardiac surgery and were included for analysis. Figure 1 describes the inclusion process for the study. Patients were randomly allocated to a derivation cohort of 222,094 patients and a validation cohort of 109,635 patients. Of the derivation cohort, 1,853 (0.83%) had UEPI. Table 1 demonstrates demographics and univariate associations with UEPI in the derivation cohort. The incidence of UEPI in the validation cohort was 0.9%. Within the whole data set, 2,828 of 5,725 (49.4%) unanticipated postoperative tracheal intubations in the 30 days after surgery occurred within 3 days.

Collinearity diagnostics did not demonstrate a condition index above 30, so no bivariate correlation matrix was needed. No correlation issues were identified, and no variables were removed. All variables listed in table 1 were entered into the nonparsimonious logistic regression model, with UEPI as the dependent dichotomous variable. A total of 200,831 (90.4%) patients of the derivation cohort had complete data, and the data were used to derive the independent predictors. Current ethanol use, current smoker, dyspnea, chronic obstructive pulmonary disease,

Table 1. Univariate Analysis for Derivation Cohort (N = 222,094)

—	No UEPI (N = 220,241)	UEPI (N = 1,853)	*P* Value	Odds Ratio (95% CI)
Male sex	92,226 (42%)	954 (52%)	<0.001	1.5 (1.3–1.6)
White race	162,405 (80%)	1,430 (82%)	0.04	1.1 (1.0–1.3)
Alcohol use	5,940 (2.7%)	92 (5.0%)	<0.001	1.9 (1.5–2.3)
Current smoker	46,684 (21%)	561 (30%)	<0.001	1.6 (1.5–1.8)
Dyspnea	30,813 (14%)	540 (29%)	<0.001	2.5 (2.3–2.8)
COPD	12,527 (5.7%)	340 (18%)	<0.001	3.7 (3.3–4.2)
Pneumonia	822 (0.4%)	33 (1.8%)	<0.001	4.8 (3.4–6.9)
Diabetes, no	180,403 (82%)	1,371 (74%)		Reference
Diabetes, orally treated	23,595 (11%)	254 (14%)	<0.001	1.4 (1.2–1.6)
Diabetes, insulin treated	16,243 (7%)	228 (12%)	<0.001	1.8 (1.6–2.1)
History of CAD	27,793 (13%)	439 (24%)	<0.001	2.2 (1.9–2.4)
Recent CAD event	3,299 (1.5%)	59 (3.2%)	<0.001	2.2 (1.7–2.8)
Congestive heart failure	2,183 (1.0%)	83 (4.5%)	<0.001	4.7 (3.7–5.9)
Hypertension requiring medication	115,646 (53%)	1,341 (72%)	<0.001	2.4 (2.1–2.6)
Liver function	8,074 (3.7%)	132 (7.1%)	<0.001	2.0 (1.7–2.4)
Renal failure	6,360 (2.9%)	105 (5.7%)	<0.001	2.0 (1.7–2.5)
Sensorium or coma	1,201 (0.5%)	39 (2.1%)	<0.001	3.9 (2.8–5.4)
Prior neurologic condition	20,624 (9.4%)	292 (16%)	<0.001	1.8 (1.6–2.1)
Cancer	10,300 (4.7%)	149 (8.0%)	<0.001	1.8 (1.5–2.1)
Prior hospitalization	52,415 (24%)	773 (42%)	<0.001	2.3 (2.1–2.5)
Steroid use	8,429 (3.8%)	104 (5.6%)	<0.001	1.5 (1.2–1.8)
Weight loss	7,819 (3.6%)	161 (8.7%)	<0.001	2.6 (2.2–3.0)
Transfusion	385 (0.2%)	3 (0.2%)	1.000	0.9 (0.3–2.9)
Sepsis	13,499 (6.1%)	259 (14%)	<0.001	2.5 (2.2–2.8)
Prior operation within 30 days	5,789 (3.0%)	70 (4.4%)	0.001	1.5 (1.2–1.9)
Very–low-risk surgical procedures	75,835 (35%)	210 (11%)		Reference
Low-risk surgical procedures	102,460 (47%)	900 (49%)	<0.001	3.2 (2.7–3.7)
Medium-risk surgical procedures	25,011 (11%)	303 (16%)	<0.001	4.4 (3.7–5.2)
High-risk surgical procedures	16,404 (7.5%)	438 (24%)	<0.001	9.6 (8.2–11.4)
BMI (kg/m^2)	30.5 ± 9.0	28.8 ± 8.6	<0.001	—
Age	57.9 ± 16.5	66.9 ± 13.7	<0.001	—

Detailed definitions of all American College of Surgeons–National Surgical Quality Improvement Program data elements are available in appendix 1. All patient and operative characteristics were compared using Mann–Whitney U test for continuous variables and chi-square for categorical variables.

BMI = body mass index; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; UEPI = unanticipated early postoperative intubation.

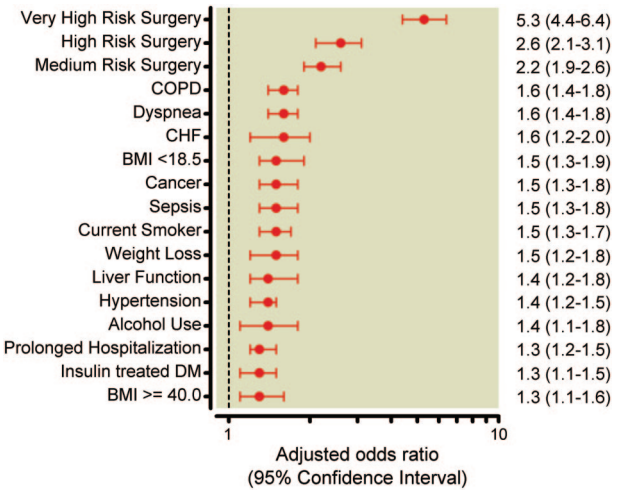

Fig. 2. General surgery UEPI independent predictor adjusted odds ratios. The figure is based on the adjusted odds ratios and 95% CIs identified in the logistic regression model. Refer to appendices 1 and 2 for definitions of the independent predictors and description of surgical risk classes. BMI = body mass index; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; DM = diabetes mellitus; UEPI = unanticipated early postoperative intubation.

diabetes mellitus needing insulin therapy, congestive heart failure, hypertension requiring medication, abnormal liver function, disseminated cancer, previous hospitalization, recent weight loss, body mass index less than 18.5 or ≥40 kg/m^2, medium-risk surgery, high-risk surgery, very–high-risk surgery, and sepsis were independent predictors of UEPI (fig. 2). The definitions of each of the independent predictors are described in appendix 1. The omnibus tests of model coefficients showed a chi-square of 1,688.243 with 32 degrees of freedom and $P < 0.001$. The area under the receiver operating characteristics curve of the logistic regression model was 0.77 ± 0.01. Somers' Dxy in the original sample was 0.54. The bootstrap adjusted Dxy for training sample was 0.55 and test sample was 0.54, indicating very good agreement. Risk classes were generated based on the doubling of incidence of UEPI between classes in the derivation cohort (table 2). The area under the receiver operating characteristics curve decreased marginally from 0.75 ± 0.01 in the weighted model to 0.72 ± 0.01 in the unweighted model. To improve clinical usability, the simpler unweighted risk classification was used. Risk class I (0–1 risk factors) had UEPI incidence of 0.2%; class II (2 risk factors), 0.5%; class III (3 risk factors), 1.0%; class IV (4–5 risk factors), 1.9%; and class V (≥6 risk factors), 3.7%. The incidence of UEPI within risk classes demonstrated consistency across the derivation and validation cohort (table 2).

Risk-matched groups from the derivation cohort were developed using a preoperative UEPI propensity score (table 3). A one-to-one, five-digit match was achieved for 979 patients (table 4). In the matched cohort, all-cause 30-day unadjusted mortality for the patients who had UEPI was 15.2%

Table 2. Independent Risk Factors for Unanticipated Early Postoperative Intubation—Derivation Cohort

Risk Factor	*P* Value	Adjusted Odds Ratio (95% CI)
BMI <18.5 kg/m^2	<0.001	1.5 (1.3–1.9)
BMI ≥40.0 kg/m^2	0.011	1.3 (1.1–1.6)
Alcohol use	0.004	1.4 (1.1–1.8)
Current smoker	<0.001	1.5 (1.3–1.7)
Dyspnea	<0.001	1.6 (1.4–1.8)
Chronic obstructive pulmonary disease	<0.001	1.6 (1.4–1.8)
Diabetes, insulin treated	0.003	1.3 (1.1–1.5)
Congestive heart failure	0.001	1.6 (1.2–2.0)
Hypertension	<0.001	1.4 (1.2–1.5)
Liver function	<0.001	1.4 (1.2–1.8)
Cancer	<0.001	1.5 (1.3–1.8)
Prolonged hospitalization	<0.001	1.3 (1.2–1.5)
Weight loss	<0.001	1.5 (1.2–1.8)
Sepsis	<0.001	1.5 (1.3–1.8)
Medium-risk surgery	<0.001	2.2 (1.9–2.6)
High-risk surgery	<0.001	2.6 (2.1–3.1)
Very–high-risk surgery	<0.001	5.3 (4.4–6.4)

Detailed definitions of all American College of Surgeons–National Surgical Quality Improvement Program data elements are available in appendix 1. Any variable with a $P < 0.05$ and an adjusted odds ratio <0.8 or >1.2 was established as an independent predictor of unanticipated early postoperative intubation.
BMI = body mass index.

versus 1.9% in those who did not have UEPI (unadjusted odds ratio of 9.1; 95% CI, 5.6–14.8). UEPI was an independent predictor of all-cause 30-day mortality ($P < 0.001$; adjusted odds ratio, 9.2; 95% CI, 5.6–15.0). The area under the receiver operating characteristics curve for the mortality model was 0.74 ± 0.02.

Finally, comparison of all-cause mortality between subjects with and without UEPI in each risk class of the derivation cohort demonstrated a significant increase in death rates with UEPI across increasing risk classes (fig. 3). Low-risk (class I risk) subjects with UEPI had 9.7% mortality compared with 0.2% in similar risk subjects without UEPI. Class V subjects with and without UEPI had 30.6% *versus* 9.5% mortality, respectively.

Discussion

We report a 0.83–0.9% incidence of UEPI after nonemergent, noncardiac surgery using a large prospectively collected national clinical research data set. We demonstrated that one half of all unanticipated tracheal intubations done within 30 days after surgery are done within the first 3 days. Unanticipated early postoperative tracheal intubation was independently associated with an adjusted 9-fold increase in all-cause 30-day mortality. In addition, we validated a linear UEPI risk classification system, which demonstrates increasing mortality with higher risk class.

The first 72 h after surgery are a high-risk period for postoperative hypoxemia related to surgical procedure[17]

Table 3. Unanticipated Early Postoperative Intubation Risk Class Index

	Derivation (N = 222,094)			Validation (N = 109,636)		
	n	UEPI n (%)	Odds Ratio (95% CI)	n	UEPI n (%)	Odds Ratio (95% CI)
Class I (0 or 1 risk factors)	70,166	144 (0.2)	Reference	34,799	82 (0.2)	Reference
Class II (2 risk factors)	64,120	349 (0.5)	2.7 (2.2–3.2)	31,751	173 (0.5)	2.3 (1.8–3.0)
Class III (3 risk factors)	46,282	466 (1.0)	4.9 (4.1–6.0)	22,667	262 (1.2)	5.0 (3.9–6.3)
Class IV (4 or 5 risk factors)	35,619	675 (1.9)	9.4 (7.8–11.3)	17,495	333 (1.9)	8.2 (6.4–10.5)
Class V (6+ risk factors)	5,907	219 (3.7)	18.7 (15.1–23.1)	2,924	125 (4.3)	18.9 (14.3–25.0)

Patients are assigned to a risk class based on the number of preoperative risk factors they possess: very–high-risk surgery, high-risk surgery, medium-risk surgery, chronic obstructive pulmonary disease, dyspnea, congestive heart failure, body mass index <18.5 or >40.0 kt/m^2, cancer, sepsis, current smoker, weight loss, abnormal liver function, hypertension, alcohol use, previous hospitalization, and insulin-treated diabetes mellitus. Detailed definitions of all American College of Surgeons–National Surgical Quality Improvement Program data elements are available in appendix 1.

UEPI = unanticipated early postoperative intubation.

and analgesic therapy.[1] Although these findings have been replicated in several studies, there are limited data on the incidence and impact of respiratory failure in this specific postoperative period. None of these mechanisms were specifically studied in the current study, but our study shows that approximately one half of unanticipated postoperative respiratory failure occurs during this period, highlighting the importance of this period for both anes-

Table 4. Univariate Analysis for Matched Cohort (N = 1,958)

	No UEPI (N = 979)	UEPI (N = 979)	*P* Value
Male sex	462 (47%)	474 (48%)	0.587
White race	757 (83%)	752 (82%)	0.609
Alcohol use	17 (1.7%)	17 (1.7%)	1.000
Current smoker	252 (26%)	252 (26%)	1.000
Dyspnea	181 (19%)	181 (19%)	1.000
COPD	97 (9.9%)	97 (9.9%)	1.000
Pneumonia	2 (0.2%)	5 (0.5%)	0.288
Diabetes, no	786 (80%)	786 (80%)	Reference
Diabetes, orally treated	128 (13%)	128 (13%)	1.000
Diabetes, insulin treated	65 (6.6%)	65 (6.6%)	1.000
History of CAD	175 (18%)	175 (18%)	1.000
Concurrent CAD event	21 (2.1%)	15 (1.5%)	0.313
Congestive heart failure	3 (0.3%)	3 (0.3%)	1.000
Hypertension	703 (72%)	703 (72%)	1.000
Liver function	14 (1.4%)	14 (1.4%)	1.000
Renal failure	14 (1.4%)	14 (1.4%)	1.000
Altered sensorium or coma	7 (0.7%)	10 (1.0%)	0.465
Prior neurological condition	128 (13%)	153 (16%)	0.107
Cancer	34 (3.5%)	34 (3.5%)	1.000
Prolonged hospitalization	271 (28%)	271 (28%)	1.000
Steroid use	45 (4.6%)	49 (5.0%)	0.672
Weight loss	24 (2.5%)	24 (2.5%)	1.000
Transfusion	0 (0.0%)	0 (0.0%)	1.000
Sepsis	44 (4.5%)	44 (4.5%)	1.000
Prior operation <30 days	16 (1.8%)	18 (2.1%)	0.668
Very–low-risk procedures	149 (15%)	149 (15%)	Reference
Low-risk procedures	520 (53%)	520 (53%)	1.000
Medium-risk procedures	119 (12%)	119 (12%)	1.000
High-risk procedures	191 (20%)	191 (20%)	1.000
BMI (kg/m^2)	29.3 ± 8.2	29.3 ± 8.7	0.848
Age	66.7 ± 13.9	66.7 ± 13.9	1.000
Mortality, 30-day all-cause	19 (1.9%)	149 (15%)	<0.001
			9.1 (5.6–14.8)*

Detailed definitions of all American College of Surgeons–National Surgical Quality Improvement Program data elements are available in appendix 1. All patient and operative characteristics were compared using Mann–Whitney U test for continuous variables and chi-square for categorical variables.

* Odds ratio with 95% confidence interval.

BMI = body mass index; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; UEPI = unanticipated early postoperative intubation.

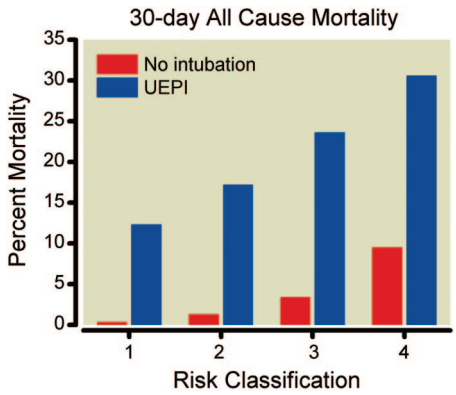

Fig. 3. The 30-day all-cause mortality. Comparison of all-cause mortality between patients with and without UEPI in the derivation cohort demonstrates significant increases in death rate in patients with UEPI across increasing risk classes. UEPI = unanticipated early postoperative intubation.

thesiologists and surgeons. The current study differs from previous studies on postoperative respiratory failure from the ACS-NSQIP data set in several ways: first, unlike previous studies, we were interested in analyzing only subjects undergoing nonemergent, noncardiac surgery without previous ventilatory requirements because this population has not been studied previously. Both Arozullah[7] and Johnson[6] included emergency surgery in their studies. Second, previous outcome measures of 30-day postoperative respiratory failure were defined as mechanical ventilation longer than 48 h after surgery or unanticipated postoperative reintubation, or both. In contrast, our primary outcome measure of interest was purely unanticipated postoperative intubation, to limit the confounding influence of planned postoperative ventilation. Finally, the impact of increasing UEPI risk classes on mortality rates was not explored previously.

In common with previous literature, we identified chronic obstructive pulmonary disease[6,7] as a significant independent predictor of UEPI. We also demonstrated current smoking or ethanol use as significant predictors of UEPI. This finding underlines the importance of evaluating the benefits of preoperative cessation of smoking and ethanol use in preparation for nonemergent surgery. Respiratory complications have a median hospital cost/patient of as much as $62,704 *versus* $5,015 in patients without respiratory complications[8]; cigarette smoking and ethanol use may represent potential modifiable risk factors during the preoperative period. However, the definition of current smoker (up to 1 year before surgery) makes it difficult to comment on residual risk in smokers who stop smoking before surgery.

Our data also demonstrate that UEPI is independently associated with a 9-fold increase in 30-day all-cause mortality. One of the important findings of the current study was the effect size of UEPI on mortality in the low risk classes, with unadjusted odds of mortality as high as 69.1 in risk class I and 32.2 for risk class II. Subjects in risk class V had 30-day mortality of 30.6%. Although preoperative risk discussions typically encompass usual anesthesia-related complications, our current data support the need for more robust discussion of risks and implications of respiratory failure during the early postoperative period. In addition, these data may provide an opportunity to target patients with high risk class for identification of specific interventions that may improve outcomes. This may involve developing triggers for early postoperative noninvasive ventilation, as demonstrated by a 10-fold reduction in tracheal intubation by early application of continuous positive airway pressure after abdominal surgery.[18]

There are several limitations to our study, as described before.[16] First, the ACS-NSQIP database does not enable specific, detailed data collection on patients with UEPI, limiting our ability to provide additional descriptive information on indications for tracheal intubation and causes of mortality. Second, although UEPI events were classed as unanticipated, we cannot comment with confidence that all of these patients were extubated at the end of surgery. Pertinent perioperative anesthesia management data were not collected and cannot be retrospectively acquired. Such data would include preoperative diagnosis of sleep apnea, anesthetic techniques, analgesic medications, and postoperative medical management. Additional work is needed to identify intraoperative risk factors for UEPI. We did not use any external validation methodology. We employed Harrell's methodology to assess for internal validity using a 2:1 split database, a technique that has been used by others.[19–21] This technique carries with it the potential risk of exposing both the derivation and validation cohorts to the same biases. The ACS-NSQIP database has some generic limitations. Although it is widely considered the most robust noncardiac surgical outcomes database, the ACS-NSQIP cannot technically be considered a nationally representative database. It is a purely voluntary database, and statistically, it does not employ any weighting design to prevent case clustering. The latter, in particular, may weaken summary data by potentially masking case clustering at the facility level. Finally, the ACS-NSQIP participant use data file lacks any regional- or facility-specific information. As a result, we are not able to comment on specific practice patterns or regional factors and their impact on the risk of UEPI.

In summary, unanticipated respiratory failure occurs with an incidence of 0.83–0.9% in the first 72 h after nonemergent, noncardiac surgery, with an independent 9-fold increase in mortality. Importantly, one half of 30-day unanticipated respiratory failure occurs within the first 3 days after nonemergent, noncardiac surgery. We have created and validated a simple UEPI risk classification that can be used for prospective research to reduce the risk of early postoperative respiratory failure.

Appendix 1: Definitions of Outcome and Study Covariates

Unplanned intubation: Placement of an endotracheal tube and mechanical or assisted ventilation because of the onset of respiratory or cardiac failure manifested by severe respiratory distress, hypoxia, hypercapnia, or respiratory acidosis within 30 days of the operation. In patients who were intubated for surgery, unplanned intubation occurred at any time after they had been extubated after surgery. In patients who were not intubated during surgery, intubation at any time after surgery was considered unplanned.

Unanticipated early postoperative intubation: unplanned tracheal intubation (as defined above) occurring within 3 days after surgery.

Alcohol use: The patient admits to drinking more than 2 oz of hard liquor or more than two 12-oz cans of beer or more than two 6-oz glasses of wine per day in the 2 weeks before admission. If the patient is a binge drinker, the number of drinks during the binge are divided by 7 days and the definition is applied.

Current smoker: Patient has smoked cigarettes in the year before admission for surgery.

Dyspnea: Patient described difficult, painful, or labored breathing with moderate exertion or at rest.

Chronic obstructive pulmonary disease: Chronic obstructive pulmonary disease (such as emphysema and/or chronic bronchitis) resulting in any one or more of the following: functional disability from chronic obstructive pulmonary disease (*e.g.*, dyspnea, inability to perform activities of daily living), hospitalization in the past for treatment of chronic obstructive pulmonary disease, or requires chronic bronchodilator therapy with oral or inhaled agents or a forced expiratory volume in 1 s of less than 75% of predicted on pulmonary function testing. Patients are not included whose only pulmonary disease is asthma, an acute and chronic inflammatory disease of the airways resulting in bronchospasm. Patients are not included with diffuse interstitial fibrosis or sarcoidosis.

Pneumonia: Patients who have evidence of pneumonia when brought to the operating room. Patients with pneumonia must meet one of the following two criteria. Criterion 1: Rales or dullness to percussion on physical examination of chest and any of the following: (a) new onset of purulent sputum or change in character of sputum, (b) organism isolated from blood culture, (c) isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy. Criterion 2: Chest radiographic examination shows new or progressive infiltrate, consolidation, cavitation, or pleural effusion, and any of the following: (a) new onset of purulent sputum or change in character of sputum, (b) organism isolated from blood culture, (c) isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy, (d) isolation of virus or detection of viral antigen in respiratory secretions, (e) diagnostic single antibody titer (IgM) or 4-fold increase in paired serum samples (IgG) for pathogen, or (f) histopathologic evidence of pneumonia.

Diabetes: A patient is not included if diabetes is controlled by diet alone. A diagnosis of diabetes requiring therapy with an oral hypoglycemic agent or daily insulin therapy.

History of coronary artery disease: Previous percutaneous coronary intervention or major cardiac surgery at any time (including any percutaneous coronary intervention).

Recent coronary artery disease event: History of angina in 1 month before surgery or history of myocardial infarction 6 months before surgery.

Congestive heart failure: Only newly diagnosed congestive heart failure within the previous 30 days or a diagnosis of chronic congestive heart failure with new signs or symptoms in the 30 days before surgery fulfills this definition.

Hypertension requiring medication: Persistent elevation of systolic blood pressure more than 140 mmHg or a diastolic blood pressure more than 90 mmHg or requires an antihypertensive treatment (*e.g.*, diuretics, β blockers, angiotensin converting enzyme inhibitors, calcium channel blockers) at the time the patient is being considered as a candidate for surgery (which should be no longer than 30 days before surgery).

Liver function abnormality: Presence of liver disease as manifested by ascites or esophageal varices.

Renal failure: Acute renal failure should be noted within 24 h before surgery and/or dialysis (acute or chronic renal failure requiring treatment with peritoneal dialysis, hemodialysis, hemofiltration, hemodiafiltration, or ultrafiltration within 2 weeks before surgery).

Altered sensorium or coma: Patient is acutely confused and/or delirious and responds to verbal and/or mild tactile stimulation. Patient is noted to have developed an impaired sensorium if he/she has mental status changes and/or delirium in the context of the current illness. Patients with chronic or long-standing mental status changes secondary to chronic mental illness (*e.g.*, schizophrenia) or chronic dementing illnesses (*e.g.*, multiinfarct dementia, senile dementia of the Alzheimer's type) are not included. This assessment of the patient's mental status is within 48 h before the surgical procedure. Coma is defined if patient is unconscious, postures to painful stimuli, or is unresponsive to all stimuli entering surgery. This does not include drug-induced coma.

Preexisting neurologic condition: We called this hemiplegia and/or history of transient ischemic attack and/or history of cerebrovascular accident with deficit and/or cerebrovascular accident without deficit and/or tumor in the central nervous system and/or paraplegia and/or quadriplegia.

Cancer: Patients who have cancer that (a) has spread to one site or more sites in addition to the primary site and (b) in whom the presence of multiple metastases indicate the cancer is widespread, fulminant, or near terminal.

Previous hospitalization: Transfer status coded as acute or chronic care hospital transfer and/or any days in hospital before operation.

Steroid use: Patient who required regular administration of oral or parenteral corticosteroid medications (*e.g.*, Prednisone, Decadron) in the 30 days before surgery for a chronic medical condition.

Weight loss: >10% loss body weight in last 6 months.

Transfusion: Transfusion of more than 4 units packed erythrocytes in the 72 h before surgery.

Sepsis: Systemic inflammatory response syndrome.

Prior operation within the past 30 days.

Preoperative ventilator dependence: Patient required ventilator-assisted respiration at any time during the 48 h before surgery. This does not include the treatment of sleep apnea with continuous positive airway pressure.

Appendix 2. Surgical Procedure Classes

Surgical Procedure Classes by Secondary Buckets[14]	Procedure Count	Incidence of UEPI
Excluded procedures (less than 100 cases)		
Reconstructive surgery, lipectomy	1	0.0%
Head and neck, other	3	0.0%
Genitourinary, penile	4	0.0%
Vascular, transcatheter	18	0.0%
Head and neck, facial fractures	23	0.0%
Skin and soft tissue, wound	28	0.0%
Reconstructive Surgery, skin graft	33	0.0%
Head and neck, incision and drainage/excision	35	0.0%
Abdominal, peritoneal lavage/ centesis	45	0.0%
Genitourinary, spermatic cord/ testicle	49	0.0%
Musculoskeletal, fasciotomy/ decompression	60	1.6%
Hernia, other	72	0.0%
Skin and soft tissue, peripheral nerve	75	1.3%
Reconstructive surgery, pressure sore	85	0.0%
Low-risk surgical procedures		
PAbdominal, abdominal catheter/gastric port	196	0.0%
Anorectal, abscess	786	0.4%
Anorectal, perianal	488	0.4%
Anorectal, resection	1,137	0.4%
Breast, alteration/ reconstruction	429	0.0%
Breast, excisional	11,008	0.0%
Breast, incisional	155	0.0%
Colorectal, appendectomy	4,792	0.1%
Colorectal, low anastomosis	2,389	0.3%
Esophagogastric, bariatric	21,202	0.3%
Genitourinary, cystoscopy	226	0.4%
Genitourinary, prostate/ urethra	1,327	0.2%
Gynecology, hysterectomy	3,771	0.2%
Gynecology, nonuterine	826	0.1%
Gynecology, other	492	0.4%
Head and neck, tumor	10,591	0.5%
Hernia, inguinal/femoral (inc mesh)	2,590	0.3%
Musculoskeletal, deep/ muscle/bone/joint	595	0.0%
Musculoskeletal, fracture repair	1,106	0.5%
Musculoskeletal, hip	1,501	0.5%
Musculoskeletal, knee	2,970	0.1%
Musculoskeletal, spine	2,864	0.5%
Musculoskeletal, tumor	497	0.4%
Reconstructive surgery, skin/ muscle revision	399	0.3%
Skin and soft tissue, biopsy	296	0.0%
Skin and soft tissue, lymph	1,217	0.2%
Skin and soft tissue, simple	1,275	0.3%
Small intestine, other	168	0.0%
Vascular, access	715	0.3%
Moderate-risk surgical procedures		
Abdominal, tumor	1,614	0.9%
Adrenal, adrenalectomy	1,074	0.9%
Colorectal, abdominoperineal resection	3,539	0.6%
Colorectal, colectomy/ colostomy/stoma	31,448	1.0%
Esophagogastric, esophagus/ gastric	3,923	0.7%
Genitourinary, kidney/ureter/ bladder	968	1.0%
Hepatobiliary, biliary tree	19,402	0.7%
Hernia, ventral/umbilical/ incisional/other	12,603	0.8%
Musculoskeletal, arthroscopy	205	1.0%
Skin and soft tissue, complex	521	0.8%
Small intestine, no resection/ lysis of adhesions/incision (open)	3,442	1.0%
Vascular, abdominal vascular (nonaorta)	238	0.8%
Vascular, cerebrovascular	12,099	0.9%
Vascular, chest/extremity	12,280	1.0%
High-risk surgical procedures		
Abdominal, exploration	3,299	1.2%
Colorectal, bowel fistula management	1,004	1.1%
Colorectal, minor	221	1.4%
Esophagogastric, gastric	4,261	1.1%
Hepatobiliary, liver	3,420	1.2%
Hepatobiliary, pancreas	5,776	1.3%
Musculoskeletal, amputation	4,433	1.1%
Spleen, splenectomy/ splenorrhaphy	1,304	1.2%
Thorax, chest	690	1.4%
Thorax, diaphragm	669	1.2%
Vascular, unknown	188	1.1%
Very–high-risk surgical procedures		
Gynecology, malignancy	166	1.8%
Neurosurgery, any	579	2.6%
Reconstructive surgery, flaps	392	2.0%
Small intestine, resection/ ostomy	4,377	1.6%
Thorax, esophageal	705	8.9%
Thorax, lung resection/repair	1,656	1.9%
Vascular, aorta/iliac	8,959	2.7%

UEPI = unanticipated early postoperative intubation.

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