Annals of Medicine and Surgery 33 (2018) 16–23

Contents lists available at ScienceDirect

Annals of Medicine and Surgery

journal homepage: www.elsevier.com/locate/amsu

Risk factors contributing to cardiac events following general and vascular surgery

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ARTICLE INFO

Keywords:
Cardiac events
Risk factors
Noncardiac surgery
General surgery
Vascular surgery

ABSTRACT

Background: Cardiac events (CE) following surgery have been associated with morbidity and mortality. Defining risk factors that contribute to CE is essential to improve surgical outcomes.

Study design: This was a retrospective study at a large urban teaching hospital for surgery performed from 2013 to 2015. Adult patients (≥18 years) that underwent general and vascular surgery were analyzed. Patients were grouped into those who experienced postoperative CE and those who did not. Univariate and multivariate regression analyses were used to identify predictors of postoperative CE, and association of CE with adverse postoperative outcomes. Separate subgroup analyses were also conducted for general and vascular surgery patients to assess predictors of CE.

Results: Out of 8441 patients, 157 (1.9%) experienced CE after major general and vascular surgery. Underlying predictors for CE included age > 65 years(OR 4.9, 95%CI 3.4–6.9,p < 0.01), ASA > 3(OR 12.0, 95%CI 8.5–16.9,p < 0.01), emergency surgery(OR 3.7, 95%CI 2.7–5.1,p = 0.01), CHF(OR 11.2, 95%CI 6.4–16.7,p = 0.02), COPD(OR 3.9, 95%CI 2.4–6.4,p = 0.04), acute renal failure or dialysis(OR 8.0, 95%CI 5.2–12.1,p = 0.04), weight loss(OR 3.3, 95%CI 1.7–6.7,p < 0.01), preoperative creatinine > 1.2 mg/dL(OR 5.1, 95%CI 3.7–7.1,p = 0.01), hematocrit < 34%(OR 4.0, 95%CI 2.8–5.7,p < 0.01), and operative time > 240 min(OR 2.0, 95%CI 1.3–3.3,p = 0.02). Following surgery, CE was associated with increased mortality(OR 3.5, 95%CI 1.2–6.5,p < 0.01), pulmonary complications(OR 5.0, 95%CI 3.1–8.9,p < 0.01), renal complications(OR 2.3, 95%CI 1.9–4.5,p < 0.01), neurologic complications(OR 2.5, 95%CI 1.4–5.2,p < 0.01), systemic sepsis(OR 2.2, 95%CI 1.7–4.0,p < 0.01), postoperative RBC transfusion(OR 4.4, 95%CI 2.7–6.5,p < 0.01), unplanned return to operating room(OR 4.0, 95%CI 2.3–6.9,p < 0.01), and prolonged hospitalization (OR 5.5, 95%CI 3.1–8.8,p = 0.03). There was no statistical difference in incidence of CE between general and vascular surgery patients (p = 0.44); however, predictors of CE differed between the two surgical groups.

Conclusion: Postoperative CE are associated with significant morbidity and mortality. Identified predictors of CE should allow for adequate risk stratification and optimization of perioperative surgical management.

1. Introduction

Postoperative cardiac events (CE) are associated with significant morbidity and mortality [1–4]. It is estimated that of the 100, 000, 000 patients undergoing noncardiac surgery worldwide, approximately 500,000 to 900,000 experience perioperative CE [2]. In-hospital mortality rates have ranged from 15% to 25% for myocardial infarction [2,3], and as high as 65% for cardiac arrest [4]. The high mortality and morbidity rates associated with postoperative CE make it a necessity to improve surgical outcomes through risk stratification and optimal perioperative management.

Previous studies have proposed cardiac risk indices in patients undergoing noncardiac surgery [5–15]; however, their application and generalizability is debatable. For example, the first substantiated cardiac risk index, published by Goldman and colleagues [5] in 1977, has been criticized for having a low positive predictive value of 21.6% [3]. Similarly, the revised cardiac index by Lee and colleagues [6] over-represents patients who underwent thoracic and orthopedic surgery [3] and has insufficient likelihood ratio for identifying patients with greater cardiac risks [16], limiting its accurate prediction of CE in general or

Abbreviations: CE, cardiac events; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; MI, myocardial infarction

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https://doi.org/10.1016/j.amsu.2018.08.001
Received 13 February 2018; Received in revised form 2 July 2018; Accepted 1 August 2018

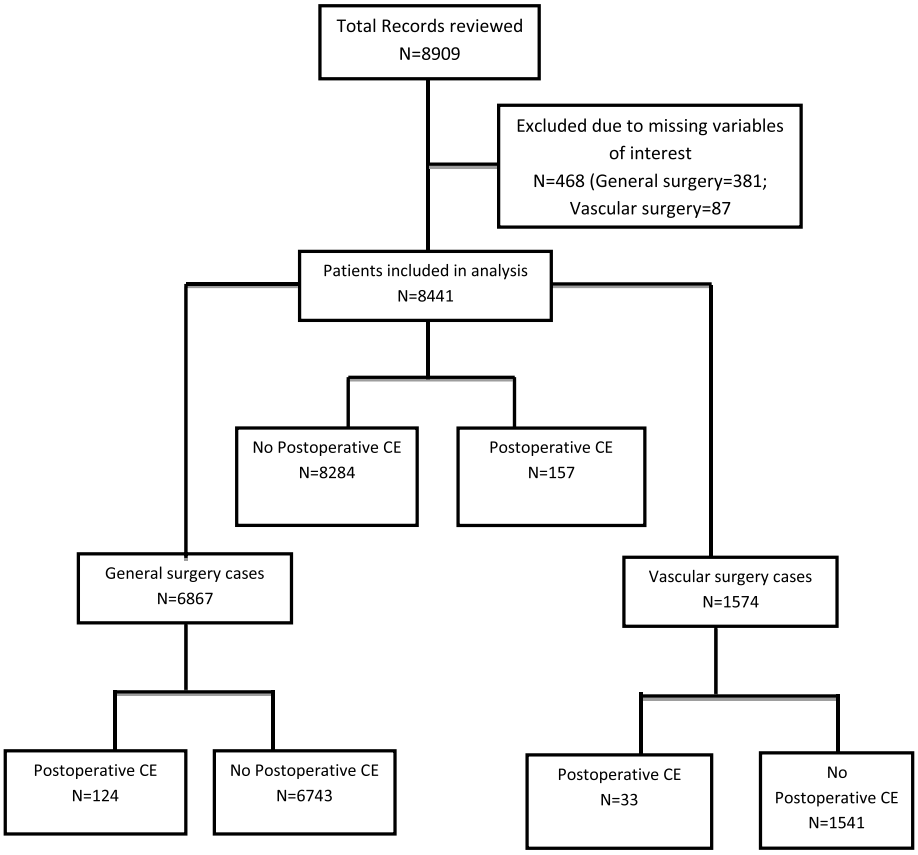

Fig. 1. Flow chart of inclusion and exclusion of patients.

vascular surgery patients. In fact, even the accepted revised cardiac risk index by the American Heart Association and the American College of Cardiologists has been noted to underestimate the risk of CE in patients undergoing major noncardiac surgery [7].

In view of limitations of previous CE risk indices, the present study seeks to understand and define in greater depth risk factors that accurately predict postoperative CE after major general and vascular surgery to allow for appropriate preoperative optimization, surgical management and informed consent. It is the hope of the authors that tailored perioperative management that targets identified risk factors will be employed to decrease CE-associated morbidity and mortality.

2. Methods

Adult patients, aged 18 years and older, who underwent major surgery from 2013 to 2016 at an urban teaching hospital were retrospectively reviewed. Patients who had general or vascular surgery were included. The list of types of operations included in the study and their current procedural terminology (CPT) codes is shown in Table 7. Patients excluded were those with missing variables of interest. Fig. 1 shows a flow chart for patients included and excluded in the study.

The primary outcome in this analysis was 30-day postoperative CE, defined as myocardial infarction or cardiac arrest within the 30-day postoperative period.

Preoperative and operative variables analyzed included age, gender, body mass index, race, American Society of Anesthesiologists (ASA) status, emergency surgery, diabetes, smoking history, dyspnea, dependent functional status, ventilator dependence, congestive heart failure, chronic obstructive pulmonary disease, hypertension, acute renal failure or dialysis, disseminated cancer, wound infection, steroid use, weight loss, bleeding disorder, preoperative red blood cell (RBC) transfusion, systemic sepsis, serum sodium, blood urea nitrogen, creatinine, albumin, total bilirubin, aspartate aminotransferase (SGOT), alkaline phosphatase, white blood count, hematocrit, platelet count, partial thromboplastin time, international normalized ratio, and operative time.

Thirty-day outcomes analyzed included mortality, pulmonary complications (pneumonia, unplanned reintubation, prolonged mechanical ventilation), renal failure, neurological complications (stroke or cerebrovascular accidents), thrombotic complications (deep venous thrombosis, pulmonary embolism), wound infection, postoperative RBC transfusion, readmission, unplanned return to operating room, and prolonged hospitalization (length of hospital stay > 8 days).

3. Statistical analysis

Statistical analyses were performed using SPSS software (Version 22, Chicago, IL, USA). Patients were classified into those who experienced at least one postoperative CE and those who did not. Univariate analysis was performed on patient demographics, preoperative variables and postoperative outcomes. Baseline characteristics were compared using X^2 tests for categorical variables and two-tailed *t*-test for continuous variables. Variables with P values less than 0.05 in the univariate analysis were included in a stepwise multivariate regression model. The stepwise multivariate regression models were utilized to identify predictors of UPR and the associations between CE and other postoperative outcomes. Additional subgroup analyses were conducted by classifying patients into surgical specialties-general or vascular surgery. All regression models were assessed using the Hosmer-Lemeshow test and *C* statistic for excellent goodness-of-fit and discrimination.

The study was approved by the Mount Sinai Beth Israel Hospital Institutional Review Board. This work has been reported in line with the STROCSS criteria [17].

Table 1
Patient characteristics contributing to CE following general and vascular surgery, univariate and multivariate analyses.

Patient characteristics	Univariate			Multivariate	
	CE n = 157	No CE n = 8284	P	OR (95% CI)	P
Age > 65years	72.6%	35.3%	< 0.01	4.9(3.4–6.9)	< 0.01
BMI > 30 kg/m^2	26.8%	26.0%	0.64		
Female gender	49.0%	51.0%	0.61		
Race			0.20		
White	70.1%	65.2%			
Black	21.7%	18.2%			
Asian	7.6%	12.2%			
Other	0.6%	4.3%			
ASA > 3	68.8%	15.5%	< 0.01	12.0(8.5–16.9)	< 0.01
Emergency surgery	49.0%	20.6%	< 0.01	3.7(2.7–5.1)	0.01
Diabetes	42.0%	20.4%	< 0.01	2.8(2.1–3.9)	0.53
Smoke	15.9%	16.5%	0.84	0.96(0.62–1.5)	0.39
Dyspnea	7.0%	2.5%	< 0.01	2.9(1.5–5.4)	0.20
Dependent functional status	49.0%	11.0%	< 0.01	7.8(5.7–10.7)	0.22
Ventilator Dependence	10.8%	0.4%	< 0.01	2.1(1.9–5.4)	0.76
CHF	10.2%	1.0%	< 0.01	11.2(6.4–16.7)	0.02
COPD	12.1%	3.4%	< 0.01	3.9(2.4–6.4)	0.04
Hypertension	77.7%	48.0%	< 0.01	3.8(2.6–5.5)	0.68
Acute renal failure or dialysis	19.1%	2.9%	< 0.01	8.0(5.2–12.1)	0.04
Disseminated Cancer	5.7%	2.4%	0.01	2.5(1.2–4.9)	0.59
Wound infection	19.7%	5.1%	< 0.01	4.6(3.1–6.9)	0.74
Steroid	3.8%	2.8%	0.44		0.79
Weight loss	5.7%	1.8%	< 0.01	3.3(1.7–6.7)	< 0.01
Bleeding Disorder	17.8%	5.5%	< 0.01	3.7(2.4–5.7)	0.49
Preoperative RBC transfusion	8.9%	1.1%	< 0.01	8.8(4.9–15.8)	0.92
Systemic sepsis	41.4%	8.9%	< 0.01	7.2(5.2–10.0)	0.06
Preoperative labs					
Sodium < 135mEq/L	17.8%	5.3%	< 0.01	3.9(2.6–5.9)	0.05
BUN > 23 mg/dL	52.2%	16.4%	< 0.01	5.6(4.1–7.7)	0.94
Creatinine > 1.2 mg/dL	47.1%	14.8%	< 0.01	5.1(3.7–7.1)	0.01
Albumin < 3.5 g/dL	38.7%	33.1%	0.14		
Total Bilirubin > 1.2 mg/dL	19.0%	11.4%	0.01	1.8(1.2–2.8)	0.63
SGOT > 35U/L	27.5%	13.4%	< 0.01	2.4(1.7–3.6)	0.23
Hematocrit < 34%	30.3%	9.8%	< 0.01	4.0(2.8–5.7)	< 0.01
Alkaline phosphate > 126IU/L	36.3%	15.7%	< 0.01	3.1(2.2–4.3)	0.70
WBC > 11 × 10^9/L	50.3%	18.4%	< 0.01	4.5(3.3–6.2)	0.24
Platelet < 150 × 10^9/L	15.3%	6.6%	< 0.01	2.5(1.6–4.0)	0.16
INR > 1.5	21.5%	3.5%	< 0.01	7.6(5.0–11.5)	0.13
PTT > 35 s	53.1%	20.2%	< 0.01	4.4(3.2–6.2)	0.12
Operative time > 240 min	12.1%	6.3%	< 0.01	2.0(1.3–3.3)	0.02
Type of Surgery			0.44		
General	79.0%	81.4%			
Vascular	21.0%	18.6%			

Abbreviations: CE, cardiac events; BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; RBC, red blood cell; BUN, blood urea nitrogen; SGOT, aspartate aminotransferase; WBC, white blood count; INR, international normalized ratio; PTT, partial thromboplastin time.

4. Results

This study included 8441 patients who underwent vascular and general surgeries from 2013 to 2015 at our large urban teaching hospital, 157 (1.9%) of which experienced postoperative CE. In terms of demographics, patients who experienced postoperative CE were significantly older, white, less likely to be female, and were more likely to have comorbid conditions than those who did not (Table 1).

Major predictors of CE included age > 65 years(OR 4.9, 95%CI 3.4–6.9,p < 0.01), ASA > 3(OR 12.0, 95%CI 8.5–16.9,p < 0.01), emergency surgery(OR 3.7, 95%CI 2.7–5.1,p = 0.01), CHF(OR 11.2, 95%CI 6.4–16.7,p = 0.02), COPD(OR 3.9, 95%CI 2.4–6.4,p = 0.04), Acute renal failure or dialysis(OR 8.0, 95%CI 5.2–12.1,p = 0.04), weight loss(OR 3.3, 95%CI 1.7–6.7,p < 0.01), preoperative creatinine > 1.2 mg/dL(OR 5.1, 95%CI 3.7–7.1,p = 0.01), hematocrit < 34%(OR 4.0, 95%CI 2.8–5.7,p < 0.01), and operative time > 240 min(OR 2.0, 95%CI 1.3–3.3,p = 0.02) (Table 1).

Following surgery, CE was associated with increased mortality(OR 3.5, 95%CI 1.2–6.5,p < 0.01), pulmonary complications(OR 5.0, 95%CI 3.1–8.9,p < 0.01), renal complications(OR 2.3, 95%CI 1.9–4.5,p < 0.01), neurologic complications(OR 2.5, 95%CI 1.4–5.2,p < 0.01), systemic sepsis(OR 2.2, 95%CI 1.7–4.0,p < 0.01), postoperative RBC transfusion(OR 4.4, 95%CI 2.7–6.5,p < 0.01), unplanned return to operating room(OR 4.0, 95%CI 2.3–6.9,p < 0.01), and prolonged hospitalization (OR 5.5, 95%CI 3.1–8.8,p = 0.03) (Table 2). The association between CE and postoperative outcomes were similar when patients were stratified into general and vascular surgery groups (Tables 4 and 6).

Table 2
Postoperative outcomes contributing to CE following general and vascular surgery, univariate and multivariate analyses.

Postoperative outcomes	Univariate			Multivariate	
	CE n = 157	No CE n = 8284	*P*	OR (95% CI)	*P*
Mortality	55.4%	0.9%	< 0.01	3.5(1.2–6.5)	< 0.01
Pulmonary complications	59.2%	2.6%	< 0.01	5.0(3.1–8.9)	< 0.01
Renal complications	17.2%	1.2%	< 0.01	2.3(1.9–4.5)	< 0.01
Neurologic complications	3.2%	0.1%	< 0.01	2.5(1.4–5.2)	< 0.01
Thromboembolic complications	2.5%	0.7%	< 0.01	3.8(1.4–8.6)	0.58
Systemic sepsis	33.1%	2.6%	< 0.01	2.2(1.7–4.0)	< 0.01
Wound infection	10.8%	3.5%	< 0.01	3.4(2.0–5.6)	0.59
Postoperative RBC transfusion	32.5%	4.9%	< 0.01	4.4(2.7–6.5)	< 0.01
Unplanned return to operating room	9.6%	2.6%	< 0.01	4.0(2.3–6.9)	< 0.01
Readmission	5.1%	4.0%	0.47		
Length of stay > 8days	63.1%	16.7%	< 0.01	5.5(3.1–8.8)	0.03

Abbreviation: CE, cardiac events; RBC, red blood cell.

Table 3
Patient characteristics contributing to CE following general surgery, univariate and multivariate analyses.

Patient characteristics	Univariate			Multivariate	
	CE n = 124	No CE n = 6743	P	OR (95% CI)	P
Age > 65years	67.3%	29.5%	< 0.01	4.9(3.2–7.6)	0.38
BMI > 30 kg/m^2	24.2%	28.8%	0.34		
Female gender	48.0%	52.7%	0.35		
Race			0.48		
White	67.3%	64.2%			
Black	23.5%	16.8%			
Asian	8.2%	13.9%			
Other	1.0%	5.0%			
ASA > 3	63.3%	6.8%	< 0.01	2.5(1.4–3.8)	< 0.01
Emergency surgery	58.2%	23.2%	< 0.01	4.6(3.1–6.9)	0.87
Diabetes	24.5%	13.8%	< 0.01	2.0(1.3–2.4)	0.69
Smoke	14.3%	14.5%	0.95		
Dyspnea	7.1%	1.9%	< 0.01	4.1(1.8–8.9)	0.40
Dependent functional status	44.9%	6.6%	< 0.01	5.6(2.7–10.4)	< 0.01
Ventilator Dependence	15.3%	0.5%	< 0.01	3.1(1.9–7.9)	< 0.01
CHF	3.1%	0.4%	< 0.01	7.9(2.3–11.4)	0.06
COPD	9.2%	2.2%	< 0.01	4.4(2.2–8.9)	0.33
Hypertension	69.4%	39.9%	< 0.01	3.4(2.2–5.3)	0.68
Acute renal failure or dialysis	15.3%	1.1%	< 0.01	2.9(1.8–3.8)	< 0.01
Disseminated Cancer	9.2%	2.8%	< 0.01	3.5(1.7–7.0)	0.45
Wound infection	12.2%	1.4%	< 0.01	4.6(1.1–9.1)	0.35
Steroid	4.1%	2.8%	0.44		
Weight loss	9.2%	1.9%	< 0.01	5.1(2.5–8.4)	0.01
Bleeding Disorder	13.3%	2.2%	< 0.01	6.8(3.7–12.4)	0.27
Preoperative RBC transfusion	9.2%	0.8%	< 0.01	11.9(5.7–14.8)	0.10
Systemic sepsis	52.0%	9.2%	< 0.01	10.7(7.1–16.1)	< 0.01
Preoperative labs					
Sodium < 135mEq/L	16.3%	4.4%	< 0.01	4.3(2.5–7.4)	0.99
BUN > 23 mg/dL	45.9%	11.0%	< 0.01	6.9(4.6–9.3)	0.17
Creatinine > 1.2 mg/dL	40.8%	9.6%	< 0.01	6.5(4.3–9.8)	0.16
Albumin < 3.5 g/dL	39.1%	36.9%	0.62		
Total Bilirubin > 1.2 mg/dL	22.8%	12.2%	< 0.01	2.1(1.3–3.5)	0.32
SGOT > 35U/L	28.3%	13.1%	< 0.01	2.6(1.7–4.2)	0.68
Hematocrit < 34%	27.2%	7.9%	< 0.01	4.4(2.7–7.0)	0.04
Alkaline phosphate > 126IU/L	41.8%	15.9%	< 0.01	3.8(2.5–5.7)	0.49
WBC > 11 × 10^9/L	48.0%	13.3%	< 0.01	6.0(4.0–9.0)	0.42
Platelet < 150 × 10^9/L	17.3%	6.1%	< 0.01	3.2(1.9–5.5)	0.18
INR > 1.5	23.4%	2.4%	< 0.01	2.3(1.4–5.4)	< 0.01
PTT > 35 s	45.7%	14.0%	< 0.01	5.2(3.4–7.8)	0.03
Operative time > 240 min	10.2%	6.9%	< 0.01	1.5(0.8–3.0)	0.29

Abbreviations: CE, cardiac events; BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; RBC, red blood cell; BUN, blood urea nitrogen; SGOT, aspartate aminotransferase; WBC, white blood count; INR, international normalized ratio; PTT, partial thromboplastin time.

Table 4
Postoperative outcomes contributing to CE following general surgery, univariate and multivariate analyses.

Postoperative outcomes	Univariate			Multivariate	
	CE n = 124	No CE n = 6743	*P*	OR (95% CI)	*P*
Mortality	60.2%	0.9%		5.1(1.6–7.7)	< 0.01
Pulmonary complications	59.2%	2.6%		5.0(3.1–8.9)	< 0.01
Renal complications	16.3%	1.0%		8.7(5.4–13.5)	0.09
Neurologic complications	1.0%	0%		4.9(2.1–7.9)	0.02
Thrombotic complications	2.0%	0.7%	0.13		
Systemic sepsis	41.8%	2.7%		5.6(1.7–9.2)	< 0.01
Wound infection	12.2%	3.7%		3.6(2.0–6.7)	0.86
Postoperative RBC transfusion	29.6%	3.5%		3.5(1.3–8.1)	0.02
Unplanned return to operating room	6.1%	1.5%		4.2(1.8–9.9)	< 0.01
Readmission	4.1%	3.6%	0.80		
Length of stay > 8days	62.2%	12.8%		2.2(1.4–4.0)	0.19

Abbreviation: CE, cardiac events; RBC, red blood cell.

Table 5
Patient characteristics contributing to CE following vascular surgery, univariate and multivariate analyses.

Patient characteristics	Univariate			Multivariate	
	CE n = 33	No CE n = 1541	P	OR (95% CI)	P
Age > 65years	81.4%	63.4%	0.01	2.5(1.3–4.9)	< 0.01
BMI > 30 kg/m^2	29.1%	23.0%	0.29		
Female gender	50.8%	43.7%	0.28		
Race			0.57		
White	74.6%	70.0%			
Black	18.6%	24.9%			
Asian	6.8%	4.4%			
Other	0%	0.7%			
ASA > 3	78.0%	56.8%	0.01	2.7(1.4–5.0)	0.82
Emergency surgery	33.9%	8.0%	< 0.01	5.9(3.3–10.4)	< 0.01
Diabetes	71.2%	52.2%	< 0.01	2.3(1.3–4.0)	0.01
Smoke	18.6%	26.1%	0.20		
Dyspnea	6.8%	5.8%	0.75		
Dependent functional status	55.9%	32.0%	< 0.01	2.7(1.6–4.6)	0.19
Ventilator Dependence	3.4%	0.1%	< 0.01	2.9(1.4–5.8)	< 0.01
CHF	22.0%	3.9%	< 0.01	7.0(3.6–13.7)	< 0.01
COPD	16.9%	8.9%	0.11		
Hypertension	91.5%	86.6%	0.28		
Acute renal failure or dialysis	25.4%	11.3%	0.01	2.7(1.5–4.9)	0.05
Disseminated Cancer	0%	0.5%	0.59		
Wound infection	32.2%	22.3%	0.18		
Steroid	3.4%	2.8%	0.84		
Weight loss	0%	1.1%	0.41		
Bleeding Disorder	25.4%	21.3%	0.57		
Preoperative RBC transfusion	8.5%	2.3%	< 0.01	3.9(1.5–10.4)	0.18
Systemic sepsis	23.7%	7.4%	< 0.01	3.9(2.1–7.3)	0.01
Preoperative labs					
Sodium < 135mEq/L	20.3%	9.5%	0.04	2.6(1.3–4.7)	0.38
BUN > 23 mg/dL	62.7%	41.7%	0.02	2.4(1.4–4.0)	0.52
Creatinine > 1.2 mg/dL	57.6%	39.3%	0.03	2.1(1.2–3.6)	0.74
Albumin < 3.5 g/dL	38.0%	37.9%	0.99		
Total Bilirubin > 1.2 mg/dL	12.0%	6.4%	0.20		
SGOT > 35U/L	26.0%	15.9%	0.12		
Hematocrit < 34%	42.4%	18.2%	< 0.01	2.6(1.3–5.3)	0.03
Alkaline phosphate > 126IU/L	36.0%	22.7%	0.07		
WBC > 11 × 10^9/L	54.2%	42.5%	0.18		
Platelet < 150 × 10^9/L	11.9%	9.2%	0.60		
INR > 1.5	18.2%	7.9%	0.03	3.1(2.8–5.4)	0.06
PTT > 35 s	66.0%	54.6%	0.01	2.2(1.4–4.3)	0.08
Operative time > 240 min	15.3%	3.5%	< 0.01	4.9(2.3–10.6)	< 0.01

Abbreviations: CE, cardiac events; BMI, body mass index; ASA, American Society of Anesthesiologists; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; RBC, red blood cell; BUN, blood urea nitrogen; SGOT, aspartate aminotransferase; WBC, white blood count; INR, international normalized ratio; PTT, partial thromboplastin time.

Table 6
Postoperative outcomes contributing to CE following vascular surgery, univariate and multivariate analyses.

Postoperative outcomes	Univariate			Multivariate	
	CE n = 33	No CE n = 1541	*P*	OR (95% CI)	*P*
Mortality	47.5%	1.1%	< 0.01	7.3(4.0–9.2)	< 0.01
Pulmonary complications	45.8%	3.2%	< 0.01	3.2(1.9–5.0)	< 0.01
Renal complications	18.6%	1.9%	< 0.01	2.8(1.5–5.2)	0.23
Neurologic complications	6.8%	0.6%	< 0.01	3.4(1.4–5.2)	0.39
Thrombotic complications	3.4%	0.5%	0.02	3.1(1.4–5.9)	< 0.01
Systemic sepsis	18.6%	2.3%	< 0.01	2.9(1.7–4.9)	0.94
Wound infection	8.5%	2.5%	0.03	3.6(1.3–9.4)	< 0.01
Postoperative RBC transfusion	37.3%	11.3%	< 0.01	4.7(2.7–8.1)	0.17
Unplanned return to operating room	15.3%	7.7%	0.10		
Readmission	6.8%	5.6%	0.77		
Length of stay > 8days	64.4%	35.4%	< 0.01	3.3(1.9–5.7)	0.13

Abbreviation: CE, cardiac events; RBC, red blood cell.

There was no significant difference between the incidence of CE among general and vascular surgery patients (p = 0.44). However, predictors of CE differed in patients who underwent general surgery compared to vascular surgery (Tables 3 and 5). Notably, ASA > 3, dependent functional status, ventilator dependence, acute renal failure or dialysis, weight loss, creatinine > 1.2 g/dL, hematocrit < 34%, INR > 1.5, and PTT > 35 s were all independent predictors of CE in patients undergoing general surgery. Significant predictors of CE after vascular surgery included age > 65 years, emergency surgery, diabetes, ventilator dependence, CHF, systemic sepsis, hematocrit < 34%, and operative time > 240 min.

5. Discussion

Even though the 1.9% incidence of CE found in this study is consistent with previous reports [6,13,14,18], the observed CE-associated mortality of 55.4% was higher than expected [2,3,8]. Overall, CE was associated with significant adverse postoperative outcomes. Identified predictors of postoperative CE in general and vascular surgery included advanced age, higher ASA status, emergency surgery, CHF, COPD, ARF or dialysis, weight loss, decreased preoperative creatinine, anemia, and prolonged operative time.

Most of the identified predictors of CE in this study have been thoroughly discussed in literature; however, a few predictors notably preoperative anemia is less reported. Still, the fact that preoperative anemia contributed to CE is least surprising because its predictive prognostic values on overall postoperative adverse outcomes is well published.

Anemia is a common preoperative condition with variable etiology that has been consistently shown to impact perioperative surgical management and outcomes. It has been observed that even mild decrease in hematocrit from normal range, such as a 1% decrease, results in significant morbidity and mortality [19,20]. In a study by Musallam and colleagues [20] that analyzed 227,425 patients undergoing noncardiac surgery, they observed higher crude postoperative mortality (4.6% vs 0.8%) and morbidity (15.7% vs 5.3%) in preoperative anemic patients who underwent major noncardiac surgery. Beattie and colleagues [21] also observed a more than a two-fold increase in mortality in anemic patients undergoing noncardiac surgery, after adjusting for confounders.

A major point to note is that anemia was significantly associated with CE, irrespective of the impact of blood transfusion. It is sometimes debated that the shared interaction between anemia and RBC transfusion contributes to anemia's association with adverse outcomes [22]. However, since blood transfusion was not a significant predictor of postoperative CE, the present study provides credence to previous studies [21] that report the detrimental effects of preoperative anemia in noncardiac surgery patients, irrespective of blood transfusion.

Additionally, the present study corroborates reports studies [7] that recommend separate predictive CE risk indices and risk stratification among different surgical subspecialties. Predictors for CE greatly differed between general surgery and vascular surgery patients in our patient population. Among patients undergoing major general surgery, predictors of CE included higher ASA status, dependent functional status, ventilator dependence, acute renal failure or dialysis, weight loss, anemia, decreased serum creatinine, increased INR and increased PTT, while predictors of postoperative CE in vascular surgery included advanced age, emergency surgery, diabetes, ventilator dependence, CHF, systemic sepsis, anemia and prolonged operative time.

Findings of this study should be interpreted in the context of its strengths and limitations. First, the present study is observational in nature, which limited our ability to definitively determine causation. Second, data was obtained from a single institution, raising concerns for external validity. Last, the retrospective nature of the study did not allow us to evaluate all possible patient variables and comorbidities. It is therefore possible that some unidentified predictors may contribute to postoperative CE after general or vascular surgery. These limitations notwithstanding, this present study provides a more vigorous dataset that utilized a relatively large sample size and contained several surgical procedures in patients with different comorbidities. Results from this study can therefore be used to inform surgeons on risk stratification and optimization of perioperative surgical management.

6. Conclusion

Postoperative CE greatly increase morbidity and mortality following major general and vascular surgery. Results of this large single-center study confirm previously published predictors of CE in patients undergoing noncardiac surgery. It is the hope of the authors that results published herein provides useful information to surgeons and allows for the necessary resources to be focused on identified at-risk patients to decrease improve surgical outcomes.

Table 7
vascular and general surgery current procedural terminology (CPT) codes.

Surgical Procedure	CPT
Vascular Procedures	
Amputation	28805, 27880, 27882, 27884, 27886, 27590, 27592, 27594
Ankle disarticulation	27889
Bypass graft, with other vein (Abdominal aortic and peripheral)	35646, 35647, 35673, 35621, 35654, 35666, 35606, 35661, 35656, 35671, 35540, 35531, 35522, 35521, 35566, 35556, 35571, 35585
Fasciotomy	27600, 27602, 27496, 11044, 11043, 11042
Thrombectomy or Embolectomy	35875, 34421, 34101, 34201, 34203, 34151
Thrombendarterectomy	35331, 35361, 35371, 35372, 35355, 35341, 35302, 35305
Cerebrovascular	37215, 37216, 35301
Transluminal angioplasty of renal or visceral artery	35471
Phlebectomy of varicose veins	37765
Open upper extremity aneurysm	35011, 35045
Open abdominal aortic aneurysm	35102, 35131
Open abdominal aortic aneurysm rupture	35141,
Endovascular- abdominal aorta	34800, 34802, 34803, 34804, 34805, 34812, 34826, 34825
Endovascular- thoracic	33881, 33880
Endovascular- peripheral	34900, 37225, 37224, 37227, 37226, 37220, 37221, 37229, 37228, 37231, 37233, 27232
Open lower extremity aneurysm	35226, 33877, 35883, 35881, 35761
Open thoracic aorta	33877
Excision- abdominal graft	35907
Excision- extremity graft	35903
AV fistula	37700, 37607, 37722
Other	37799, 27301, 27603, 49561, 49560, 64818, 35860, 49010
General Surgery	
Peritoneal abscess drainage, open	49020, 49060
Ablation, radiofrequency	47380
Adrenalectomy	60545, 60540, 60650, 60660
Parathyroidectomy	60505, 60502, 60500
Appendectomy	44950, 44960, 44970,
Incisional hernia repair	49657, 49656, 49655, 49566, 49565, 49561, 49560
Ventral hernia repair	49654
Umbilical hernia repair	49653, 49652, 49587, 49585, 49582
Inguinal hernia repair	49651, 49650, 49525, 49521, 49520, 49507, 49505,
Spigelian hernia repair	49590
Epigastric hernia repair	49572, 49570
Femoral hernia repair	49555, 49553, 49550
Paraesophageal hernia repair	43282, 43281
Diaphragmatic hernia	39541
Fundoplasty	43280, 43279
Esophagectomy	43122, 43117, 43112, 43107
Hepaticojejunostomy	47760, 47780
Roux-Y cholangiojejunostomy	47785
Lymphadenectomy- axillary, cervical, transabdominal, pelvic, inguinofemoral	38745, 38740, 38724, 38780, 38770, 38765, 38760, 38570,
Splenectomy	38120, 38115, 38100
Cholecystectomy	47610, 47600, 47562, 47563,
Choledochotomy	47420
Coccygectomy	27080
Thyroidectomy	60220, 60252, 60254, 60240, 60260, 60270, 60271, 60210
Esophagectomy	43107
Breast reconstruction	19364, 19367
Enterostomy closure	44650, 44620, 44625, 44626, 44227
Enterectomy	44120, 44125, 44202
Enteroenterostomy	44130
Enterolysis	44005, 44180
Enterotomy	44020, 44021, 44110
Omentectomy	49255
Extrahepatic lesion excision	47711, 47712
Excision of breast or chest wall lesion, cyst, tumor, fibroadenoma	19125, 19271, 19120
Excision or destruction of abdominal lesions	48120, 44800, 49203, 49204, 49205, 43611
Excisions- other	25111, 55040, 49215, 45130, 51500, 15931, 25076, 27619, 27047, 27048, 27327, 24075, 24076, 48148, 45903
Laparotomy	49000, 44050, 43605
Pancreaticojejunostomy	48548
Pancreatectomy	48155, 48153, 48150, 48145, 48140, 48120, 48105, 48100
Mastectomy	19301, 19302, 19303, 19304, 19307
Mastotomy	19020
Breast reconstruction	19357, 19367
Nipple exploration	19110
Fistula (enterovesical, gastrocolic, intestinal, rectovaginal) closure	44661, 44660, 43880, 44640, 57300, 43880, 44640, 44650
Gastrectomy	43631, 43632, 43633, 43622, 43621, 43775, 43774, 43771, 43770, 43644, 43633, 43632, 43631, 43622, 43621, 43620
Gastrojejunostomy	43860, 43848, 43820
Gastrorrhaphy	43840

(*continued on next page*)

Table 7 (*continued*)

Surgical Procedure	CPT
Gastrotomy	43501, 43500
Hepatectomy	47130, 47125, 47120
Colectomy	44160, 44140, 44145, 44146, 44143, 44144, 44150, 44212, 44211, 44208, 44207, 44206, 44205, 44204, 44160, 44157, 44155, 44151, 44150
Colostomy	44320, 44340, 44345, 44346, 44188
Ileostomy or jejunostomy	44314, 44310, 44187
Debridement	11004, 11005, 11006, 11044, 11043, 11042, 11043
Fasciotomy	27892, 27497, 27600
Proctectomy	45397, 45395
Proctopexy with Sigmoid resection	45402, 45400
Duodenectomy	44010
Others	43999, 43659, 47379, 44238, 38129, 58956, 48100, 43605, 60600, 20102, 49010, 15757, 20005, 21501, 23031, 24077, 26990, 27301, 27365, 27372, 27603, 27604, 60660, 98957, 58956, 5894057300, 55175, 55040, 51500, 50240, 49425, 49422, 49402, 49325, 49324, 49322, 49321, 49215, 48500, 47300, 46060, 46045, 46040, 44900, 44850, 43659, 43520, 37722, 37700, 37228, 37227, 37226, 37224, 34201, 34203, 35301, 33661, 35571, 27880, 27590, 35761, 35800

Provenance and peer review

Not commissioned, externally peer-reviewed.

Conflicts of interest

None.

Funding

None.

Ethical approval

Exempt.

Research registration number

researchregistry3695.

Trial registrtion number – ISRCTN

None.

Author contribution

Study design: Acheampong Leitman, Lavarias, Inabnet, Mills, Pechman.

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Final approval of manuscript: Acheampong, Leitman, Guerrier, Lavarias, Pechman, Mills, Boateng, Inabnet.

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Leitman.

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