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Impact of acute postoperative limb ischemia after cardiac and thoracic aortic surgery

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ABSTRACT

Objective: Acute limb ischemia (ALI) is the cause of significant morbidity and mortality. Although ALI after cardiac surgery is associated with high rates of morbidity and mortality, there are no robust, controlled analyses of the risk factors and outcomes of ALI in this setting. We aimed to identify risk factors for and to delineate outcomes after ALI in patients undergoing cardiac surgery.

Methods: We performed a retrospective review of prospectively collected data on patients undergoing cardiac surgery at our institution between 2002 and 2012.

Results: Between 2002 and 2012, there were 11,343 patients who underwent major open cardiac surgery, with 156 cases of ALI for an incidence of 1.4%. In a multivariable model, significant risk factors for ALI included body surface area (odds ratio [OR], 0.41; 95% confidence interval [CI], 0.18-0.92), current smoking status (OR, 2.2; 95% CI, 1.3-3.7), peripheral arterial disease (OR, 2.5; 95% CI, 1.6-3.7), nonelective operative status (OR, 1.9-5.0; 95% CI, 1.2-19.7), use of extracorporeal membrane oxygenation (OR, 5.6; 95% CI, 2.5-11.6) or intra-aortic balloon pump (OR, 4.7; 95% CI, 2.9-7.5), and valve operation (OR, 2.1; 95% CI, 1.1-4.0). There were 105 (67%) patients who developed ALI who required an operation, and 27 (17%) required an amputation on the index admission. ALI was associated with a significant reduction in long-term survival (hazard ratio, 3.72; 95% CI, 2.97-4.65; $P < .0001$).

Conclusions: ALI is associated with significant morbidity and mortality, and it is also associated with reduced long-term survival. Those patients with the risk factors described require extra vigilance to limit the risk of ALI and should be managed in accordance with the patient's overall clinical condition and goals of care. (J Vasc Surg 2018;67:1530-6.)

Acute limb ischemia (ALI) is the cause of significant morbidity and mortality; patients with ALI have a 10% to 30% amputation rate and a 15% to 20% rate of short-term mortality.[1] In some series, 5-year overall mortality after ALI has been shown to be close to 50%.[2] When it occurs in the immediate postoperative period after cardiac surgery, the development of ALI is highly predictive of adverse events, with mortality rates reaching 45% in two separate cohorts.[3,4] Despite the high rates of morbidity and mortality associated with ALI in these studies, there is no robust, controlled analysis of risk factors and outcomes. Because of this, it is difficult to draw meaningful conclusions about the risk factors for development of ALI, the appropriate treatment of ALI, or the expected outcomes in patients with ALI after cardiac surgery.

Numerous studies, including one from our institution, have, however, examined the risk factors and outcomes of ALI in a subgroup of cardiac surgery patients requiring either an intra-aortic balloon pump (IABP) or extracorporeal membrane oxygenation (ECMO) support.[5-11] In these patients, major ischemic complications have been reported at a rate of 8% to 25% with IABP use and 17% to 21% with ECMO support. Risk factors for ALI included pre-existing peripheral arterial disease, tobacco use, female gender, young age, and small body surface area; these factors portray a scenario in which the instrumentation of chronically diseased or small vessels leads to acute ischemic complications.[5-7,10,11] Mortality has been reported to be as high as 28% to 80%, although the occurrence of ALI has not been shown to significantly affect mortality or limb survival in these subgroups. Even though these studies are well done and

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appropriately controlled, they have small sample sizes, especially in the setting of ECMO, with between seven and 18 cases and between 36 and 157 controls per study, and lack statistical power. In addition, given that these patients all had femoral artery instrumentation, the findings cannot be extrapolated to the broader cardiac surgery population.

In this analysis, we sought to further elucidate the independent risk factors for development of ALI after cardiac surgery and to investigate the outcomes of patients who suffer from ALI after open cardiac and thoracic aortic surgery.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of single-center prospectively collected registry data
- **Take Home Message:** In 156 patients who developed acute limb ischemia after open cardiac surgery, 105 (67%) required an operation, 27 (17%) required an amputation, and long-term survival was significantly reduced (hazard ratio, 3.72; 95% confidence interval, 2.97-4.65).
- **Recommendation:** This study suggests that acute limb ischemia after open cardiac operations is associated with a significant risk of amputation and decreased long-term survival.

METHODS

Study design. This is a retrospective analysis of prospectively collected data designed to examine the risk factors for development of ALI after open cardiac surgery and to identify the outcomes of this group of patients compared with those who did not develop ALI. As such, the primary outcome of interest was the development of ALI after cardiac surgery. ALI was defined as any ischemic event of the arterial system of the upper or lower limbs. Secondary outcomes included death within 30 days of surgery or during the index admission and long-term survival. This study was approved by the Institutional Review Board of the University of Pennsylvania, and a waiver of participant consent was obtained.

Data source. We performed a retrospective review of prospectively collected data from our institution using the Society of Thoracic Surgeons (STS) database. The STS database, established in 1989, prospectively collects data from cardiothoracic surgeons and anesthesiologists for the purposes of quality improvement and improved patient safety.[12]

Population of patients. Adult patients who underwent open cardiac or thoracic aortic surgery and who were enrolled in the University of Pennsylvania STS database were considered eligible. Those patients who had primary endovascular or catheter-based therapies (thoracic endovascular aortic repair or transcatheter aortic valve replacement) were excluded, as were those who suffered intraoperative death.

Statistics. All analyses were performed using R 3.2.3 "Wooden Christmas Tree" (R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2015. http://www.R-project.org). The χ^2 test was used for the analysis of categorical data and the Wilcoxon rank sum test for continuous variables. Generalized linear models with binomial distributions were used to assess the bivariate relationship between preoperative, operative, and postoperative variables in all patients as well as in the subgroup of patients who required ECMO or IABP. Clinically significant variables (sex, age, race, ethnicity, body surface area, smoking status, cardiovascular disease, peripheral arterial disease, chronic kidney disease, hemodialysis status, left ventricular ejection fraction, presence of IABP, use of ECMO, shock, cardiac bypass time, operative status [urgent, emergent, or elective], and procedure) were included in a multivariable model to independently assess their relationship with the development of ALI. A Cox proportional hazards model was used to model long-term survival, controlling for the following clinically significant variables: sex, age, race, ethnicity, body surface area, smoking status, diabetes, cerebrovascular disease, peripheral arterial disease, chronic kidney disease, hemodialysis status, left ventricular ejection fraction, presence of IABP, use of ECMO, shock, procedure status (urgent, emergent, or elective), procedure performed, and cardiac bypass time.

RESULTS

Study cohort. Between 2002 and 2012, there were 11,343 patients who underwent major open cardiac surgery and were eligible for this study. There were 156 cases of ALI for an incidence of 1.4%; this was stable across all years of the study. Patients with ALI were 53% male, with a median age of 66 years; 82% of patients with ALI were white, and 51% were never smokers. Demographics, comorbidities, and operations performed are demonstrated in Table I.

Risk factors for development of ALI. Numerous patient and operative characteristics were associated with an increased risk for development of postoperative ALI (Supplementary Table I, online only) on bivariate analysis. The highest risks were seen with female gender (odds ratio [OR], 1.7; 95% confidence interval [CI], 1.2-2.4), current smoking status (OR, 2.3; 95% CI, 1.4-3.5), myocardial infarction within 21 days of surgery (OR, 3.2; 95% CI, 2.0-4.8), cerebrovascular disease (OR, 2.0; 95% CI, 1.4-2.8), peripheral vascular disease (OR, 2.9; 95% CI, 2.1-4.0), chronic kidney disease (OR, 2.3; 95% CI, 1.5-3.5), preoperative shock (OR, 5.0; 95% CI, 3.3-7.4), and preoperative

Table I. Cohort characteristics

	No ischemia (n = 11,187)	Ischemia (n = 156)	*P* value
Patient factors			
Male	7315 (66)	83 (53)	.0008
Body surface area, m^2	1.98 (1.79-2.15)	1.86 (1.67-2.10)	<.0001
Body mass index, kg/m^2	27.44 (24.28-31.25)	26.30 (22.58-31.01)	.02
Smoking			.001
Never	6640 (60)	78 (51)	
Former	3370 (30)	47 (31)	
Current	977 (8.9)	26 (17)	
Coronary artery disease	2398 (22)	16 (11)	.0008
Myocardial infarction			<.0001
No	8386 (76)	92 (61)	
>21 days	1813 (17)	32 (21)	
≤21 days	803 (7.3)	28 (18)	
Cerebrovascular disease	1802 (16)	42 (28)	.0002
Peripheral arterial disease	1810 (17)	55 (36)	<.0001
Chronic kidney disease	839 (7.6)	24 (16)	.0001
Preoperative hemodialysis	274 (2.5)	8 (5.4)	.03
Preoperative creatinine level	1.00 (0.90-1.30)	1.05 (0.90-1.50)	.05
Left ventricular ejection fraction, %	55 (40-62)	45 (30-60)	<.0001
Preoperative shock	556 (5.1)	32 (21)	<.0001
Preoperative resuscitation	138 (1.3)	9 (5.9)	<.0001
Operative factors			
Operative status			<.0001
Elective	6933 (63)	50 (32)	
Urgent	3252 (30)	64 (41)	
Emergent	815 (7.4)	37 (24)	
Emergent salvage	36 (0.3)	5 (3.2)	
ECMO	90 (0.8)	13 (8.3)	<.0001
IABP	737 (6.7)	52 (33)	<.0001
Isolated coronary bypass	2096 (19)	19 (12)	.03
Isolated valve surgery	432 (40)	40 (26)	.0003
Thoracic aortic procedure	2052 (19)	42 (27)	.008
Ventricular assist device implantation	110 (1.0)	4 (2.6)	.05
Cardiopulmonary bypass time, minutes	136.0 (92.0-192.0)	181.0 (120.0-185.2)	<.0001
Femoral artery cannulation for bypass	437 (4.0)	12 (7.8)	.02

ECMO, Extracorporeal membrane oxygenation; *IABP*, intra-aortic balloon pump.
Categorical variables are presented as number (%). Continuous variables are presented as median (range).

resuscitation (OR, 5.0; 95% CI, 2.3-9.4). Significant operative factors included urgent (OR, 2.7; 95% CI, 1.9-4.0), emergent (OR, 6.3; 95% CI, 4.1-9.7), and emergent salvage surgery (OR, 19.3; 95% CI, 6.4-47.0) as well as IABP (OR, 7.0; 95% CI, 4.9-9.8), mechanical circulatory assistance (OR, 7.5; 95% CI, 5.4-10.5), ECMO (OR, 11.1; 95% CI, 5.8-19.6), and femoral artery cannulation (OR, 2.0; 95% CI, 1.1-3.6).

A multivariable model was developed to assess the independent association of clinically and statistically significant factors with the development of ALI (Table II). ECMO (OR, 5.6; 95% CI, 2.5-11.6; $P < .0001$), emergent salvage operative status (OR, 5.0; 95% CI, 1.0-19.7; $P < .03$), IABP (OR, 4.7; 95% CI, 2.9-7.5; $P < .0001$), heart transplantation (OR, 2.6; 95% CI, 1.0-6.6; $P < .05$), emergent operative status (OR, 2.6; 95% CI, 1.4-4.7; $P < .003$), peripheral arterial disease (OR, 2.5; 95% CI, 1.6-3.7; $P < .0001$), current smoker status (OR, 2.2; 95% CI, 1.3-3.7; $P < .004$), urgent operative status (OR, 1.9; 95% CI, 1.2-2.9; $P < .006$), any valve surgery (OR, 2.1; 95% CI, 1.1-4.0; $P < .02$), and cerebrovascular disease (OR, 1.5; 95% CI, 1.0-2.3; $P < .05$) were all independently associated with an increased risk for development of

Table II. Multivariable model for the development of postoperative acute limb ischemia (ALI)

Exposure	OR	95% CI	*P* value
Age	1.00	0.98-1.01	.90
Female	1.40	0.90-2.16	.13
Race			
White	0.98	0.29-6.09	.97
Black	0.95	0.25-6.23	.95
Other	0.92	0.19-6.66	.92
Hispanic	0.64	0.04-3.01	.66
Body surface area, m^2	0.41	0.18-0.92	.03
Smoking			
Never	Reference	—	—
Former	1.32	0.88-1.99	.17
Current	2.20	1.27-3.67	.004
Diabetes mellitus	1.13	0.74-1.68	.57
Cerebrovascular disease	1.52	1.00-2.28	.05
Peripheral arterial disease	2.45	1.64-3.65	<.001
Chronic kidney disease	1.35	0.72-2.37	.32
Preoperative hemodialysis	0.84	0.30-2.14	.73
Left ventricular ejection fraction, %	1.00	0.97-1.01	.60
Preoperative shock	1.04	0.57-1.85	.90
Operative status			
Elective	Reference	—	—
Urgent	1.85	1.19-2.87	.006
Emergent	2.58	1.37-4.73	.003
Emergent salvage	5.02	0.95-19.65	.03
ECMO	5.61	2.54-11.55	<.001
IABP	4.70	2.90-7.52	<.001
Any coronary bypass	1.36	0.84-2.17	.21
Any valve surgery	2.11	1.14-4.00	.02
Thoracic aortic procedure	1.24	0.70-2.14	.46
Heart transplantation	2.60	1.00-6.64	.05
Ventricular assist device implantation	0.57	0.15-1.65	.35
Cardiopulmonary bypass time, minutes	1.00	1.00-1.00	.24

CI, Confidence interval; *ECMO*, extracorporeal membrane oxygenation; *IABP*, intra-aortic balloon pump; *OR*, odds ratio.

ALI. Body surface area had an inverse relationship with ALI risk (OR, 0.4; 95% CI, 0.2-0.9, $P < .03$), with larger body surface area protecting from ALI.

Because of the known risk of ALI associated with ECMO and IABP use, subgroup analysis was performed for these exposures (Supplementary Table II, online only). There were 103 ECMO patients included in this study, of whom 13 developed ALI (13%). In ECMO patients, significant risk factors included age (OR, 0.96; 95% CI, 0.92-0.99) and female gender (OR, 5.25; 95% CI, 1.57-20.76). There were 789 patients included with IABP, of whom 52 (7%) developed ALI. In IABP patients, significant risk factors were female gender (OR, 2.06; 95% CI, 1.15-3.63), coronary artery disease (OR, 0.20; 95% CI, 0.05-0.55), peripheral arterial disease (OR, 2.21; 95% CI, 1.19-3.98), and chronic kidney disease (OR, 2.02; 95% CI, 1.00-3.83).

Table III. Rates of operative intervention and amputation for acute limb ischemia (ALI)

Intervention	No.
Thrombectomy	43
Endarterectomy	5
Lower extremity bypass	4
Fasciotomies	20
Angioplasty or stent	6
Below-the-knee amputation	10
Above-the-knee amputation	9
Upper extremity amputation	2
Minor amputation	6

Treatment and limb outcomes in ALI. There were 105 operations performed for 156 cases of ALI. The most common operation performed for ALI was thrombectomy (43 [28%]), followed by fasciotomies (20 [13%]); percutaneous intervention (6 [4%]), endarterectomy (5 [3%]), and lower extremity bypass operations (4 [3%]) were less commonly performed (Table III). There were 21 major (13%) and six minor (4%) amputations performed on the index hospitalization, including two upper extremity amputations (Table III). The overall rate of patients with ALI who suffered limb loss was 9.8% (16/162), with five patients losing more than one limb. There were no apparent trends in the need for operative intervention or the use of endovascular procedures or amputation rates over time during the study period.

Complications and survival in patients who developed ALI. Individuals who developed ALI had more complicated postoperative courses than those who did not (Table IV). Uniformly, all of the patients who developed limb ischemia had at least one other complication compared with an overall complication rate of 58% in the individuals who did not suffer from ALI. These complications included higher rates of surgical site infection, sepsis, multisystem organ failure, stroke, pneumonia, acute kidney injury, transfer to the intensive care unit (ICU), and cardiac arrest. Notably, the rate of myocardial infarction was not different between the two groups.

The increased rate of complications translated into longer index ICU stay, overall ICU stay, and total length of stay. Patients with ALI had median and total ICU lengths of stay of 192 hours (interquartile range [IQR],

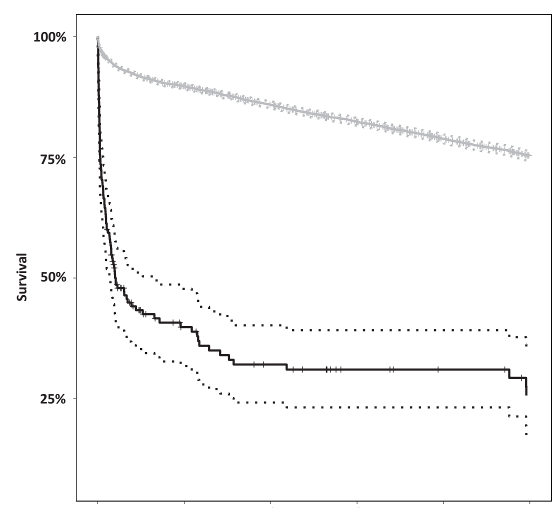
Table IV. Postoperative course and complications

	No ALI	ALI	*P* value
Index ICU length of stay, hours	48 (25-95)	192 (90-528)	<.001
Total ICU length of stay, hours	48 (26-99)	263 (131-662)	<.001
Myocardial infarction	31 (0.3)	1 (0.9)	.31
Surgical site infection	3111 (2.8)	35 (22)	<.01
Sepsis	341 (3.1)	50 (32)	<.001
Stroke	291 (2.6)	17 (11)	<.001
Pneumonia	626 (5.7)	47 (30)	<.001
AKI	822 (7.2)	77 (49)	<.001
RRT	417 (3.8)	58 (37)	<.001
Arrest	320 (2.9)	26 (17)	<.001
MSOF	407 (3.7)	74 (47)	<.001
Any complication	6467 (58)	156 (100)	<.001
Postoperative LOS, days	8 (6-13)	22 (9-53)	<.001
Operative death	555 (0.5)	71 (45)	<.001
30-Day readmission	550 (4.5)	4 (2.6)	.24

AKI, Acute kidney injury; *ALI,* acute limb ischemia; *ICU,* intensive care unit; *LOS,* length of stay; *MSOF,* multisystem organ failure; *RRT,* renal replacement therapy.
Categorical variables are presented as number (%). Continuous variables are presented as median (range).

90-528 hours) and 263 hours (IQR, 131-662 hours) compared with 48 hours (IQR, 25-95 hours) and 48 hours (IQR, 26-99 hours), respectively, for patients without ALI.

Patients who developed ALI after cardiac surgery had a significantly higher rate of short-term death, as defined by death within 30 days of the index operation if the patient was discharged from the hospital, or death on the index hospitalization; this was stable over the time of the study. The development of ALI was also independently associated with decreased long-term survival (Fig), with a hazard ratio of 3.7 (95% CI, 3.0-4.7; $P < .0001$) when controlling for other clinical factors known to have an impact on survival after cardiac surgery.



Years	1	2	3	4	5
No ALI					
At risk (n)	10,568	9,446	7,483	4,937	2,327
Survivial	89.7%	85.9%	82.3%	77.8%	75.3%
SE	0.3%	0.4%	0.4%	0.5%	0.5%
ALI					
At risk (n)	42	31	22	19	14
Survivial	39.8%	32.1%	31.0%	31.0%	25.7%
SE	0.4%	0.4%	0.4%	0.4%	0.4%

Fig. Kaplan-Meier survival plot for 11,343 patients undergoing cardiac and thoracic aortic surgery. The *black line* represents those who developed acute limb ischemia (*ALI*) postoperatively compared with those who did not, as depicted in the *gray line*. The 95% confidence intervals (CIs) are represented by the *dashed lines*. *SE,* Standard error.

DISCUSSION

This retrospective review of ALI in patients undergoing open cardiac and thoracic aortic surgery at our institution between 2002 and 2012 is, to our knowledge, the largest series of ALI in cardiac surgery patients to date. Among the 11,343 individuals in our cohort, the incidence of ALI after cardiac surgery was 1.4%. This is significantly lower than the rates reported in some other series that focused on ALI after IABP and ECMO, but it is similar to the rate of ALI reported by others focused on ALI after open cardiac surgery.[3,6,7]

Using multivariable modeling, we identified patient and operative factors associated with the development of postoperative ALI in this population. ECMO, emergent salvage or emergent operative status, IABP, heart transplantation, peripheral arterial disease, current smoking status, and body surface area were all strongly independently associated with ALI in our multivariable model. This is in keeping with what other authors have previously identified as risk factors for ALI, including peripheral arterial disease, tobacco use, female gender, young age, and small body surface area.[5-7,10,11]

Taken together, this suggests the general clinical picture that small individuals with diseased arteries who undergo emergency operations, potentially requiring the ongoing instrumentation of their arterial system with large devices, are those at the greatest risk of ALI. Extra care should be taken to avoid ALI in these individuals. Several strategies could potentially decrease the likelihood of ALI in the perioperative period in this population. Avoiding femoral artery cannulation altogether in patients with known risk factors for ALI could limit the risk for development of lower extremity ischemic complications. Alternatively, in patients undergoing elective operations, studying the femoral and iliac systems could help determine the safest site for cannula placement and decrease the risk of ALI. Selecting the appropriate cannula size for femoral access in smaller individuals is also critical. Careful postoperative monitoring and attention to the patient's pulse examination in the immediate perioperative period may help identify any ischemic complications early and limit the incidence of amputation and limb loss.

Patients who did develop ALI had more complicated postoperative courses compared with patients who did not develop ALI, including longer ICU stays and significantly higher rates of short-term death. In our analysis, ALI was associated with a short-term mortality of 45%, which is in line with the previous literature on ALI after cardiac surgery.[3,4] In patients undergoing IABP or ECMO cannulation, reported 30-day mortality rates after ALI are variable, with some as high as 79%.[9-11] Given that patients who require IABP or ECMO cannulation are generally critically ill, it is not surprising that this subset of patients suffers increased short-term mortality. Using a Cox proportional hazards model, we also found that ALI is independently associated with significantly reduced long-term survival. Despite the strong associations with mortality, we speculate that ALI serves as a marker for overall morbidity of the patient rather than as a direct cause of the patient's death.

Because of the significant morbidity and mortality associated with ALI, it has been observed that it frequently leads to the withdrawal of care in high-risk patients.[13] Our study provides a sobering account of its impact on individuals who develop this dreaded complication after cardiac surgery and provides concrete information that can be used to engage patients and families in shared decision-making regarding the treatment of these most ill patients. Conversations with patients and their families about prognosis and treatment should emphasize that ALI is associated with an elevated risk of other complications and reduced long-term survival, and as such, it should be managed in accordance with the patient's overall clinical condition and goals of care.

There are several limitations to this study. First, this is a retrospective review of prospectively collected data. Second, whereas we identified cases on the basis of the STS definition of ALI, limited data are available beyond this definition regarding details, severity, or timing of each patient's ALI. Last, we are unable to determine the timing of complications with respect to one another, preventing assessment of causality or more complex relationships between postoperative complications.

CONCLUSIONS

ALI after cardiac surgery is a rare but serious complication. Multiple patient and operative factors contribute to the risk for development of ALI, with the data supporting a model wherein patients with small or diseased arteries undergoing emergency surgery are at the greatest risk of ALI. Patients with ALI had more complicated postoperative courses and had increased short- and long-term mortality. In addition to demonstrating risk factors for development of ALI after cardiac surgery, the study suggests that ALI after cardiac surgery may also be a marker for the patient's morbidity and mortality.

AUTHOR CONTRIBUTIONS

Conception and design: IF, PF, GW, BJ, JB, ND, RF, SD
Analysis and interpretation: IF, ND, RF, SD
Data collection: IF, SD
Writing the article: IF, SD
Critical revision of the article: IF, PF, GW, BJ, JB, ND, RF, SD
Final approval of the article: IF, PF, GW, BJ, JB, ND, RF, SD
Statistical analysis: IF, SD
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Supplementary Table I (online only). Bivariate odds ratios (*ORs*) for the development of acute limb ischemia (ALI)

Exposure	OR (95% CI)	*P* value
Age	1.01 (0.99-1.02)	.37
Female	1.71 (1.24-2.35)	.0009
Race		
White	Reference	Reference
Asian	0.88 (0.14-2.80)	.86
Black	1.16 (0.67-1.88)	.57
Other	1.70 (0.76-3.29)	.15
Hispanic	1.14 (0.28-3.04)	.82
Body surface area, m^2	0.33 (0.18-0.61)	.0004
Body mass index, kg/m^2	0.99 (0.96-1.01)	.29
Smoking		
Never	Reference	Reference
Former	1.19 (0.82-1.70)	.36
Current	2.27 (1.42-3.50)	.0004
Hyperlipidemia	0.76 (0.55-1.06)	.10
Hypertension	1.42 (0.96-2.18)	.88
Coronary artery disease	0.42 (0.24-0.69)	.001
Atrial fibrillation	1.22 (0.71-1.97)	.44
Myocardial infarction		
No	Reference	Reference
>21 days	3.18 (2.03-4.81)	<.0001
≤21 days	1.61 (1.06-2.39)	.02
Diabetes mellitus	1.36 (0.96-1.90)	.08
Cerebrovascular disease	1.95 (1.35-2.77)	.0003
Peripheral arterial disease	2.88 (2.05-4.00)	<.0001
Chronic kidney disease	2.32 (1.46-3.54)	.0002
Preoperative hemodialysis	2.22 (0.99-4.23)	.03
Preoperative creatinine level	1.11 (0.98-1.21)	.06
Left ventricular ejection fraction, %	0.98 (0.97-0.99)	<.0001
Preoperative shock	5.01 (3.31-7.37)	<.0001
Preoperative resuscitation	4.95 (2.30-9.38)	<.0001
Operative status		
Elective	Reference	Reference
Urgent	2.72 (1.88-3.97)	<.0001
Emergent	6.29 (4.07-9.66)	<.0001
Emergent salvage	19.26 (6.42-47.06)	<.0001
ECMO	11.10 (5.80-19.63)	<.0001
IABP	6.99 (4.94-9.79)	<.0001
Isolated coronary bypass	0.59 (0.36-0.94)	.03
Isolated valve surgery	0.52 (0.36-0.74)	.0003
Any coronary bypass	1.18 (0.85-1.62)	.32
Any valve surgery	1.18 (0.83-1.73)	.37
Thoracic aortic procedure	1.62 (1.12-2.30)	.008
Ventricular assist device implantation	2.62 (0.80-6.35)	.06
Heart transplantation	1.36 (0.80-2.17)	.22
Cardiopulmonary bypass time, minutes	1.01 (1.00-1.01)	<.0001
Femoral artery cannulation for cardiopulmonary bypass	2.04 (1.07-3.55)	.02

CI, Confidence interval; *ECMO*, extracorporeal membrane oxygenation; *IABP*, intra-aortic balloon pump.

Supplementary Table II (online only). Bivariate odds ratios (*ORs*) for the development of acute limb ischemia (ALI) in extracorporeal membrane oxygenation (*ECMO*) and intra-aortic balloon pump (*IABP*) subsets

Exposure	ECMO OR (95% CI)	*P* value	IABP OR (95% CI)	*P* value
Age	0.96 (0.92-0.99)	.03	1.00 (0.98-1.02)	.78
Female	5.25 (1.57-20.76)	.009	2.06 (1.15-3.63)	.01
Race				
White	Reference	Reference	Reference	Reference
Asian	1.83E-7 (NA)	1.00	0.95 (0.05-4.89)	.96
Black	1.79 (0.36-7.00)	.42	0.72 (0.21-1.83)	.53
Other	1.83E-7 (NA)	.99	1.26 (0.30-3.71)	.71
Hispanic	3.63 (0.16-40.75)	.31	2.19 (0.50-6.66)	.22
Body surface area, m^2	0.38 (0.06-2.45)	.32	0.57 (0.19-1.68)	.32
Body mass index, kg/m^2	0.99 (0.90-1.06)	0.72	1.00 (0.97-1.02)	0.81
Smoking				
Never	Reference	Reference	Reference	Reference
Former	0.19 (0.04-4.62)	.12	1.37 (0.72-2.55)	.33
Current	0.71 (0.04-4.62)	.76	1.67 (0.72-3.58)	.21
Hyperlipidemia	0.56 (0.17-2.00)	.35	1.00 (0.53-2.04)	.99
Hypertension	0.90 (0.25-4.33)	.89	1.37 (0.67-3.20)	.42
Coronary artery disease	4.39E-8 (NA)	.99	0.20 (0.05-0.55)	.01
Atrial fibrillation	1.42 (0.07-9.83)	.76	1.14 (0.38-2.72)	.79
Myocardial infarction				
No	Reference	Reference	Reference	Reference
>21 days	0.21 (0.10-0.41)	.15	1.02 (0.48-2.10)	.95
≤21 days	0.44 (0.06-1.85)	.31	1.08 (0.56-2.08)	.82
Diabetes mellitus	0.65 (0.17-2.18)	.51	1.47 (0.83-2.59)	.18
Cerebrovascular disease	5.19E-8 (NA)	.99	1.48 (0.77-2.71)	.22
Peripheral arterial disease	0.38 (0.02-2.12)	.36	2.21 (1.19-3.98)	.01
Chronic kidney disease	1.33 (0.28-4.96)	.69	2.02 (1.00-3.83)	.04
Preoperative hemodialysis	1.37 (0.07-9.49)	.78	0.74 (0.12-2.50)	.68
Preoperative creatinine level	0.69 (0.21-1.37)	.44	0.95 (0.68-1.23)	.73
Left ventricular ejection fraction, %	0.98 (0.96-1.01)	.99	1.01 (0.99-1.02)	.43
Preoperative shock	1.08 (0.27-3.63)	.91	1.41 (0.79-2.48)	.24
Preoperative resuscitation	2.13 (0.43-8.32)	.30	1.74 (0.64-3.99)	.23
Operative status				
Elective	Reference	Reference	Reference	Reference
Urgent	2.86 (0.64-20.1)	.21	1.15 (0.57-2.39)	.71
Emergent	3.32 (0.50-27.42)	.21	1.59 (0.76-3.43)	.22
Emergent salvage	2.58 (0.11-31.61)	.47	1.57 (0.08-9.05)	.68
Isolated coronary bypass	0.54 (0.03-3.15)	.57	0.59 (0.30-1.10)	.11
Isolated valve surgery	1.63 (0.33-6.15)	.50	0.92 (0.44-1.76)	.80
Any coronary bypass	0.43 (0.09-1.52)	.22	1.09 (0.61-2.00)	.79
Any valve surgery	0.57 (0.16-1.85)	.36	1.64 (0.92-3.05)	.10
Thoracic aortic procedure	0.45 (0.02-2.59)	.46	1.14 (0.38-2.72)	.79
Ventricular assist device implantation	0.91 (0.13-3.85)	.91	0.57 (0.09-1.93)	.45
Heart transplantation	2.23 (0.66-7.36)	.19	0.88 (0.21-2.51)	.83
Cardiopulmonary bypass time, minutes	1.00 (1.00-1.00)	.85	1.00 (1.00-1.00)	.85

CI, Confidence interval; *NA*, not applicable.