Postoperative Lactate Levels and Hospital Length of Stay After Cardiac Surgery

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Objectives: **The objective of this study was to characterize the association between lactate levels and hospital length of stay (LOS) after cardiac surgery.**

Design: **A retrospective study using prospectively collected data from the Society of Thoracic Surgeons adult cardiac surgery database.**

Setting: **A tertiary-care hospital.**

Participants: **Patients in the database who presented for major cardiac surgery between 2002 and 2014 and whose lactate level was measured within 3 hours after skin closure.**

Interventions: **None.**

Measurements and Main Results: **The authors performed multivariable linear regression with adjustment for more than 30 variables to assess the association between postoperative lactate levels and hospital LOS. The study included 1,208 patients whose median LOS was 6 days (quartiles: 5, 9). Median LOS in the low-, moderate-, and high-lactate groups was 5 days (quartiles: 4, 7), 6 days (quartiles: 5, 9) and 9 days (quartiles: 6, 17), respectively; $p < 0.001$. In multivariable analysis, patients with a moderate lactate level had a 1.08 times (95% CI: 1.00–1.17; $p = 0.04$) longer LOS compared with those with a low lactate level. Patients with a high lactate level had a 1.12 times (95% CI: 1.00–1.26; $p = 0.04$) longer LOS compared with those with a low lactate level. Lactate levels also were associated with intensive care unit LOS and nonsurgical postoperative complications.**

Conclusions: **Postoperative lactate levels are associated with increased hospital LOS for patients undergoing major cardiac surgery.**

KEY WORDS: lactate, cardiac surgery, length of stay, coronary artery bypass grafting, valve surgery, morbidity

MAJOR CARDIAC SURGICAL procedures, such as coronary artery bypass grafting and cardiac valve procedures, are among the most commonly performed major surgeries in the United States.[1] Even though mortality associated with these procedures is relatively low, morbidity remains substantial, with a significant risk of postoperative complications, such as atrial fibrillation, stroke, pneumonia, and bleeding, which can lead to prolonged intensive care unit (ICU) and hospital length of stay (LOS).[2–4] Prolonged ICU and hospital LOS are associated with substantial increases in cost for an already costly procedure, and therefore serve as relevant endpoints not only for patients but also for the overall healthcare economy.[3,5]

Cardiac surgery elicits a cascade of stress responses, and significant metabolic alterations occur. These changes contribute to a shift from aerobic to anaerobic metabolism, causing increased levels of pyruvate and lactate.[6,7] Previous studies of patients who underwent major cardiac surgery have shown an association between elevated postoperative lactate levels and increased morbidity and mortality.[8–12] However, the association between lactate levels and hospital LOS has not been characterized adequately in previous studies, and the independent association (ie, adjusted for important confounders) has not been described previously.

The main objective of this study was to evaluate whether postoperative lactate values were associated with hospital LOS in patients undergoing major cardiac surgery. Secondarily, the association between lactate levels and ICU LOS as well as postoperative complications were also assessed. To control for potential confounding factors, the authors performed multivariable analysis, including multiple patient and surgical characteristics.

METHODS

Design, Setting, and Data Source

The authors performed a retrospective analysis of prospectively collected data from the Society of Thoracic Surgeons (STS) adult cardiac surgery database at Beth Israel Deaconess Medical Center, a tertiary-care hospital in Boston, MA. The specifics of the database, including data collection forms, data dictionaries, and training manuals, can be found online.[13] Data for all patients undergoing cardiac surgery (with the exception of transcatheter aortic valve replacement) are entered. Data are abstracted continuously by trained nurses via inpatient medical records. Data are sent to an external, central data analysis center quarterly, and a retrospective audit and adjudication process are performed biannually. The authors only included variables that were collected consistently throughout the study period (ie, data found in all database versions from 2002-2014). The rate of missing data in the STS database was very low, except for cross-clamp time (19 patients [1.6%]) and ejection fraction (84 patients [7.0%]). Lactate levels are not part of the STS database and were obtained electronically from the hospital's electronic medical records and merged with the STS data set via unique patient medical record numbers and time of surgery. Lactate levels were measured at the discretion of the clinical team. This study was approved by the Institutional Review Board at Beth Israel Deaconess Medical Center,

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Boston, MA (protocol: 2013P-000307). The study was approved with a waiver of informed consent.

Study Population and Outcomes

The study was comprised of adult patients (≥18 years) who underwent coronary artery bypass grafting and/or cardiac valve surgery between 2002 and 2014. Only those patients whose lactate level was measured by the clinical team within 3 hours after skin closure were included in the study. If >1 lactate level was drawn in the 3-hour period, only the level drawn closest to the end of surgery was used for this study. Surgeries in which cardiac bypass was not performed ("off-pump" surgeries) were excluded because they were considered to include a significantly different patient population.

The primary endpoint was hospital LOS—defined as the time, in days, from surgery to discharge from the hospital. Secondary outcomes included ICU LOS—defined as the total number of days in the ICU after surgery—and a composite endpoint of nonsurgical postoperative complications (cerebrovascular accident, prolonged ventilation, pneumonia, pulmonary embolism, renal failure, multiorgan failure, atrial fibrillation requiring treatment, severe gastrointestinal complications, cardiac arrest, or in-hospital death). Postoperative surgical complications were defined as any reoperation, iliac or aortic dissection, limb ischemia, or surgical site complications. The specific definitions of postoperative complications, as well as all other included variables, are provided online by the STS.[13]

Statistical Analysis

Descriptive statistics were used to summarize the study population. Data for continuous variables are presented as means with standard deviations (SD) or medians with first and third quartiles, depending on the normality of the data. Categorical data are presented as counts and frequencies. Lactate values were categorized into predefined clinically meaningful and commonly used[14–19] categories to allow for nonlinear effects: 0 to 2 mmol/L ("low"), 2 to 4 mmol/L ("moderate"), and ≥4 mmol/L ("high").

The unadjusted association between lactate group and hospital LOS was assessed with the Kruskal-Wallis test and post hoc pairwise Wilcoxon rank sum test. Multivariable linear regression was performed to assess the independent association between postoperative lactate levels and hospital LOS. Given that the distribution of hospital LOS was severely right-skewed, this variable was log-transformed before analysis. Covariates entered into the model are presented in Table 1 and were selected a priori on the basis of clinical reasoning. Because some minor changes occurred in the data set during the study period, the data set version was also included in the model to adjust for any potential minor variations. The time of lactate measurement (ie, time from skin closure to lactate measurement) was also added to the model. Severely right-skewed continuous covariates were log transformed. Quadratic terms of all continuous variables were included to allow for nonlinear effects of potential confounders. The exponents of the β-coefficients from the model (and the 95% confidence interval limits [95% CI]) were calculated to determine the ratio of the

Table 1. Patient and Surgical Characteristics*

	Low Lactate (0-2 mmol/L) n = 420 (35%)	Moderate Lactate (2-4 mmol/L) n = 584 (48%)	High Lactate (≥4 mmol/L) n = 204 (17%)
Demographics			
Female sex	91 (22)	219 (38)	76 (37)
Age (y)	64 (57, 73)	69 (61, 78)	70 (59, 77)
Race†			
White	365 (87)	510 (88)	180 (88)
Black	16 (4)	22 (4)	11 (5)
Other	38 (9)	48 (8)	13 (6)
BMI (kg/m^2)‡	28 (24, 32)	28 (24, 31)	28 (25, 31)
Comorbidities			
Diabetes	138 (33)	210 (36)	56 (27)
Dyslipidemia	317 (75)	429 (73)	132 (65)
Dialysis	15 (4)	19 (3)	6 (3)
Hypertension	322 (77)	489 (84)	164 (80)
Infectious endocarditis	23 (5)	19 (3)	17 (8)
Chronic lung disease	62 (15)	94 (16)	29 (14)
Peripheral vascular disease	58 (14)	78 (13)	38 (19)
Cerebrovascular disease	64 (15)	99 (17)	43 (21)
Previous cardiovascular intervention	114 (27)	178 (30)	75 (37)
Previous myocardial infarction	149 (35)	206 (35)	81 (40)
Cardiac characteristics			
NYHA class			
I	5 (1)	15 (3)	7 (3)
II	53 (13)	100 (17)	23 (11)
III	73 (17)	115 (20)	40 (20)
IV	31 (7)	74 (13)	50 (25)
Ejection fraction (%)§	55 (47, 60)	55 (43, 60)	55 (42, 60)
Number of diseased coronary vessels¶			
1	38 (9)	43 (7)	20 (10)
2	60 (14)	91 (16)	30 (15)
3	229 (55)	283 (49)	85 (42)
Surgical characteristics			
Year of surgery			
2002-2005	23 (5)	85 (15)	50 (25)
2006-2008	96 (23)	153 (26)	39 (19)
2009-2011	143 (34)	174 (30)	75 (37)
2012-2014	158 (38)	172 (29)	40 (20)
Surgery status			
Elective	209 (50)	313 (54)	75 (37)
Urgent	201 (48)	235 (40)	75 (35)
Emergent	10 (2)	36 (6)	54 (26)
Coronary artery bypass grafting	311 (74)	392 (67)	120 (59)
Valve surgery	180 (43)	384 (66)	156 (76)
Mitral valve procedure	137 (72)	305 (79)	137 (88)
Tricuspid valve procedure	15 (8)	24 (6)	11 (7)
Aortic valve procedure	43 (24)	92 (24)	23 (15)
Other cardiac procedure	51 (12)	88 (15)	66 (32)
Other noncardiac procedure	3 (1)	12 (2)	11 (5)