The Operating Surgeon Is an Independent Predictor of Chest Tube Drainage Following Cardiac Surgery ☆

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Objectives: **Bleeding into the chest is a major cause of blood transfusion and adverse outcomes following cardiac surgery. The authors investigated predictors of bleeding following cardiac surgery to identify potentially correctable factors.**

Design: **Data were retrieved from the medical records of patients undergoing cardiac surgery over the period of 2002 to 2008. Multivariate analysis was used to identify the independent predictors of chest tube drainage.**

Setting: **Tertiary hospital.**

Participants: **Two thousand five hundred seventy-five patients.**

Interventions: **Cardiac surgery.**

Results: **The individual operating surgeon was independently associated with the extent of chest tube drainage. Other independent factors included internal mammary artery grafting, cardiopulmonary bypass time, urgency of surgery, tricuspid valve surgery, redo surgery, left ventricular impairment, male gender, lower body mass index and higher preoperative hemoglobin levels. Both a history of diabetes and administration of aprotinin were associated with reduced levels of chest tube drainage.**

Conclusions: **The individual operating surgeon was an independent predictor of the extent of chest tube drainage. Attention to surgeon-specific factors offers the possibility of reduced bleeding, fewer transfusions, and improved patient outcomes.**

KEY WORDS: chest tube, bleeding, cardiac surgery, surgeon, blood transfusion

EVERY YEAR AN estimated 1 million to 1.25 million patients worldwide undergo cardiac surgery. For these patients, excessive bleeding into the chest remains a common and serious complication. A large multicenter study of patients undergoing high-risk surgery found 66% required a blood transfusion and 12% had massive bleeding.[1] Excessive bleeding results in increased blood transfusions, higher redo-thoracotomy rates, prolonged mechanical ventilation, prolonged intensive care, and hospital stays, higher risk of death, and increased costs.[2,3] A safe level of bleeding has not been established, but the authors previously reported that as little as 1,000 mL of chest tube drainage in the first 24 hours was independently associated with a 4-fold higher risk of death.[2] The aim of the current study was to identify potentially correctable factors associated with bleeding. Reduced bleeding could lead to fewer blood transfusions and better clinical outcomes.

METHODS

The study was undertaken at St. Vincent's Hospital, Melbourne, a large inner city tertiary university referral hospital in Melbourne, Australia. The authors analyzed data from 2,575 consecutive patients who underwent cardiac surgery requiring cardiopulmonary bypass between January 1, 2002 and February 12, 2008. Data were retrieved from the patients' electronic medical records (CareVue, Philips, Eindhoven, Netherlands). Patients undergoing salvage surgery (undergoing cardiopulmonary resuscitation en route to the operating room, n = 7) and Jehovah's Witness patients (n = 17) were excluded.

This was a retrospective, observational, cohort study of patient data. The St. Vincent's Health Human Research Ethics Committee approved the use of deidentified data for this study and waived the need for individual patient consent. The anesthetic, surgical, and intensive care management and associations between chest tube drainage and adverse outcomes previously have been described.[2]

Chest tubes were placed just prior to sternal closure. Chest tube drainage was recorded as the chest drain level at 24 hours following admission to the intensive care unit (ICU). If the patient was discharged from the ICU before 24 hours, the last recorded level was used. Potentially life-threatening bleeding was defined as >1,000 mL of chest tube drainage over 24 hours.[2] Packed red blood cell transfusion was defined as administration of red cells in the 24 hours following admission to the ICU. Type of surgery was classified as 1 of 3 categories: Coronary artery bypass grafting (CABG), valve surgery (repair or replacement of valve), or complex surgery (multiple valve surgery or coronary artery bypass grafting with valve surgery or surgery involving the aortic arch). Urgency of surgery was classified as 1 of 3 categories: Elective (the procedure could be deferred without risk), urgent (surgery indicated within 72 hours of angiography or of unplanned admission), and emergency (surgery required same day). Redo surgery was defined by the patient having undergone cardiac surgery on a previous admission.

In the ICU, packed red cells were transfused to maintain the hemoglobin >80 g/L. A combination of red cells, platelets, and plasma products were considered for administration if chest tube losses were >200 mL/hour for 2 consecutive hours. Redo-operation was considered if the patient had sustained hemodynamic instability not responding to intravenous fluids with escalating requirement for inotropic support in the setting of excessive chest bleeding (>400 mL over 1 hour) or evidence of cardiac tamponade on transthoracic echocardiogram.

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The outcome variable, chest tube drainage, was transformed to the natural logarithmic scale to adjust for skewed results and to satisfy model assumptions of normality and constant variance. A univariate analysis initially was undertaken. Due to the need to transform the outcome variable, all effects estimated from the general linear model are expressed as ratios of back-transformed medians with associated 95% confidence intervals (data supplement). A general linear model involving multiple explanatory variables was developed. Explanatory variables were added to the model in 2 blocks. In block 1, known predictors of bleeding (age, sex, type of surgery, redo surgery, urgency of surgery, preoperative creatinine, and cardiopulmonary bypass time) were fitted in the model, and a backward elimination variable selection method was used to remove nonstatistically significant variables one at a time.[4–6] In block 2, the set of other potential predictors was considered for inclusion into the model using a forward stepwise procedure; the p-value for inclusion was 0.05. Variables considered included body mass index, hemoglobin, left ventricle function, preoperative anticoagulation, history of cardiovascular accident, acute myocardial infarct, diabetes, hypertension or smoking, the Canadian Cardiovascular Society Score, the New York Heart Association Score, operating surgeon, antifibrinolytic agent used, and type and number of grafts.

RESULTS

The patient and surgical characteristics are summarized in Table 1.

Patient factors associated with increased chest tube drainage included male gender, a lower body mass index, impaired left ventricular function, previous myocardial infarct, the Canadian Cardiovascular score, the New York Heart Association score, and higher preoperative hemoglobin levels. Preoperative therapeutic anticoagulation was not associated with the extent of chest tube drainage. A history of diabetes was associated with reduced chest tube drainage (data supplement).

Surgical factors associated with increased chest tube drainage included the operating surgeon, total number of distal internal mammary artery grafts, total number of distal radial arterial grafts, increased cardiopulmonary bypass time, emergency surgery, tricuspid valve surgery, and the extent of fall in hemoglobin levels during surgery. The total number of vein grafts was not associated with the extent of chest tube drainage. Aprotinin administration and single valve surgery (other than tricuspid) were both associated with reduced chest tube drainage (data supplement).

Five surgeons operated over the study period. The number of cases per surgeon ranged from 282 to 846. On univariate analysis, the mean chest tube drainage at 24 hours varied significantly among surgeons from 759 to 967 mL ($p = 0.006$). The percentage of patients with more than 1,000 mL of chest tube drainage varied significantly from 21 to 33% ($p = 0.001$). The volume of packed red blood cells transfused also varied significantly between surgeons from 145 to 420 mL ($p < 0.0001$). Redo-thoracotomy for acute cardiac tamponade or uncontrolled bleeding did not vary significantly among the surgeons (1.4%-3.9% of patients, $p = 0.4$) (Fig 1).

On multivariate analysis, patient factors independently associated with increased chest tube drainage included male gender, a lower body mass index, impaired left ventricular function, and higher preoperative hemoglobin levels. A history of diabetes was associated with reduced chest tube drainage (Table 2).

Table 1. Patient and Surgical Characteristics

Characteristic	Value (n = 2,575)*
Age (y)	66 ± 11
Male sex, n (%)	1,868 (73)
Hemoglobin (g/dL)	137 ± 18
Creatinine (umol/L)	90 (80-110)
Hypertension, n (%)	1610 (63)
Diabetes, n (%)	691 (27)
Ever smoked, n (%)	2,137 (83)
Canadian Cardiovascular Society class 3 or 4	1,398 (54)
New York Heart Association class III or IV	1,242 (48)
Preoperative anticoagulation†	627 (24)
Left ventricle function‡, n (%)	
Normal	810 (31)
Left ventricle hypertrophy	1053 (41)
Mild impairment	493 (19)
Moderate impairment	173 (7)
Severe impairment	46 (2)
Surgical urgency, n (%)	
Elective	1,338 (52)
Urgent	1,029 (40)
Emergency	204 (8)
Surgery, n (%)	
Redo	107 (4)
Single valve	274 (11)
Coronary artery bypass grafting	1,785 (69)
Complex§	516 (20)
Aortic valve	553 (22)
Mitral valve	214 (8)
Tricuspid valve	34 (1)
Distal grafts	
Total	3 (3-4)
Arterial	2 (1-3)
Internal mammary artery	1 (1-2)
Radial	1 (0-1)
Vein	1 (0-2)
Antifibrinolytic, n (%)	
Aprotinin	1,436 (58)
ε-aminocaproic acid	747 (30)
Tranexamic acid	301 (12)
Cardiopulmonary bypass time (min)	122 ± 38
Hospital death, n (%)	60 (2.3)
Hospital stay (days)	7 (6-10)

NOTE. Data are presented as number (%) or median and (interquartile range) or plus-minus, which denotes mean and standard deviation.

*Data for surgery urgency were missing for 4 patients, for antifibrinolytic for 93 patients, cardiopulmonary bypass time for 42 patients, and cross-clamp time for 59 patients.

†Preoperative anticoagulation was defined as therapeutic levels of anticoagulation by either a heparin infusion or subcutaneous enoxaparin injections and which continued until the time of surgery.

‡Left ventricle function was based on preoperative echocardiogram or angiographic assessment of the ejection fraction (normal >50%, mild 35-50%, moderate 20-34%, and severe impairment <20%). The definition of left ventricular hypertrophy required a normal ejection fraction.

§Complex surgery was defined as multiple valve surgery or coronary artery bypass grafting with valve surgery or surgery involving the aortic arch.

On multivariate analysis surgical factors independently associated with increased chest tube drainage included operating surgeon, left or right internal mammary artery grafts,