Blood Conservation Strategies Can Be Applied Safely to High-Risk Complex Aortic Surgery

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Objective: **The present study aimed to evaluate the effect of blood conservation strategies on patient outcomes after aortic surgery.**

Design: **Retrospective cohort analysis of prospective data.**

Setting: **University hospital.**

Participants: **Patients undergoing thoracic aortic surgery.**

Interventions: **One hundred thirty-two consecutive high-risk patients (mean EuroSCORE 10.4%) underwent thoracic aortic aneurysm or dissection repair from January 2010 to September 2011. A blood conservation strategy (BCS) focused on limitation of hemodilution and tolerance of perioperative anemia was used in 57 patients (43.2%); the remaining 75 (56.8%) patients were managed by traditional methods. Mortality, major complications, and red blood cell transfusion requirements were assessed. Independent risk factors for clinical outcomes were determined by multivariate analyses.**

Measurements and Main Results: **Hospital mortality was 9.8% (13 of 132). Lower preoperative hemoglobin was an independent predictor of mortality ($p < 0.01$, odds ratio [OR] 1.7). Major complications were associated with perioperative transfusion: 0% complication rate in patients receiving <2 units of packed red blood cells versus 32.3% (20 of 62) in patients receiving ≥2 units. The blood conservation strategy had no significant impact on mortality ($p = 0.4$) or major complications ($p = 0.9$) despite the blood conservation patients having a higher incidence of aortic dissection and urgent/emergent procedures and lower preoperative and discharge hemoglobin. In patients with aortic aneurysms, BCS patients received 1.5 fewer units of red blood cells (58% reduction) than non-BCS patients ($p = 0.01$). Independent risk factors for transfusion were lower preoperative hemoglobin ($p < 0.01$, OR 1.5) and lack of BCS ($p = 0.02$, OR 3.6).**

Conclusions: **Clinical practice guidelines for blood conservation should be considered for high-risk complex aortic surgery patients.**

KEY WORDS: aortic surgery, blood conservation, anemia, transfusion

APPROXIMATELY 50% of cardiac surgery patients receive perioperative blood products,[1] with transfusion rates as high as 95% in some series.[2] Cardiac surgery uses up to 20% of the blood supply in the United States[3,4] and worldwide[2,5,6] despite evidence that blood transfusions are associated with worsened short-term and long-term outcomes[2,6,7] and increased medical costs.[4,8] In addition, while the number of blood transfusions has risen,[9] the blood donor pool has stabilized or decreased,[9,10] resulting in blood product shortages and increased transfusion costs.[11]

The Society of Thoracic Surgeons and the Society of Cardiovascular Anesthesiologists (STS/SCA) blood conservation clinical practice guidelines recommend a multidisciplinary, multimodality approach to blood conservation for patients undergoing cardiac surgery, with recommendations ranging from preoperative pharmacologic approaches to intraoperative surgical, perfusion, and transfusion strategies and postoperative management.[5] However, there is a paucity of data in the literature concerning the safety and efficacy of using a blood conservation strategy (BCS) in complex aortic surgery patients, with most data arising from case reports of patients who are Jehovah's Witnesses.[12–17]

Thoracic aortic surgery often involves complex aortic reconstructions with multiple suture lines and frequently is associated with urgent or emergent presentations, prolonged cardiopulmonary bypass times, hypothermia, platelet dysfunction, and coagulopathy, putting these patients at higher risk for receiving allogeneic blood transfusion.[1,18–24] With 80% of the blood transfusions in cardiac surgery going to only 10% to 20% of cardiac surgical patients,[5,25] it may be possible to significantly reduce the amount of blood transfused[26] by focusing on these high-risk patients.[12]

Clinical outcomes and transfusion records of patients undergoing complex thoracic aortic surgery, with and without implementation of a simplified, low-cost BCS, were compared to determine the impact of a BCS on morbidity, mortality, and blood product use in this higher risk population.

METHODS

Institutional review board exemption for deidentified patient outcome data analysis was obtained, and the requirement for written informed consent was waived. Perioperative non-blood bank data were obtained from the New York State Adult Cardiac Surgery Database. Between January 2010 and September 2011, 132 consecutive high-risk patients (mean EuroSCORE 10.4% ± 10%) underwent complex thoracic aortic surgery involving repair or replacement of the thoracic aorta for the treatment of thoracic aortic aneurysm or dissection. All patients who underwent thoracic aortic surgery during this time period were included in the analysis. A single surgeon instituted a BCS protocol in his first 57 (43.2%) consecutive thoracic aortic patients. The remaining 75 (56.8%) patients were managed with existing traditional methods by the remaining 8 surgeons in the group and served as the control group. These surgeons performed a median of 8.5 (range 2-15) aneurysm repairs and 1.5 (range 0-3) dissections each. The resident physicians managing perioperative care were the same

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across all patients. All patients (BCS and non-BCS) were managed using a standardized blood management protocol following the STS/SCA Clinical Practice Guidelines. This included but was not limited to preoperative cessation of nonaspirin antiplatelet agents when possible, use of autologous red blood cell (RBC) salvage (cell saver) techniques in all cases, routine use of antifibrinolytics (ε-aminocaproic acid) when not contraindicated, use of mechanical and/or flowable prothrombotic materials (thrombin-soaked gelatin sponges, thrombin/gelatin suspensions, fibrinogen/thrombin sealants, albumin/glutaraldehyde mixtures, or polyethylene glycol polymers) on tissue surfaces where indicated according to surgeon preference, and reversal of heparinization with protamine sulfate in all patients. Non-RBC transfusion was performed based on standardized criteria and did not differ between groups. The BCS included minimization of intraoperative hemodilution, tolerance of perioperative anemia, and education of all of the multidisciplinary cardiac surgical team members regarding this strategy. Intraoperative hemodilution was minimized by using retrograde and antegrade autologous priming of the cardiopulmonary bypass circuit and preferential use of vasopressors rather than intravenous fluids to manage anesthetic-induced hypotension. Red blood cell transfusion in the BCS group were performed for a hemoglobin <7 g/dL or for a hemoglobin of 7 to 8 g/dL if the patient demonstrated objective physiologic need, such as tachycardia, hypotension, or decreased end-organ perfusion, rather than reflexively in response to laboratory values or for empiric or prophylactic reasons. RBC transfusion in the non-BCS group was surgeon-dependent. All patients (BCS and non-BCS) received RBC transfusion for class III-IV hemorrhagic shock. There was no use of preoperative pharmacologic methods to increase RBC volume or use of autologous blood donation or other autologous transfusion techniques,[27] intraoperative normovolemic hemodilution, reinfusion of chest tube drainage, or alteration in laboratory blood draw protocols in either cohort. Point-of-care coagulation testing was not used. Coagulation factor concentrates rarely were used to achieve hemostasis. The BCS blood management protocol is available in detail as a supplementary online-only appendix.

Primary outcomes assessed were hospital mortality (death before discharge or within 30 days of surgery), major complications (a composite of postoperative respiratory failure [mechanical ventilation >72 hours], renal failure requiring dialysis, sepsis, and mortality), and RBC transfusion requirements. Secondary analyses were performed for individual complications. When differences in RBC utilization were identified, comparative cost analyses were performed. Cost savings were estimated using the following formula:

$$\text{Cost savings} = (N_{BCS})\left(\text{mean RBC}_{non\_BCS} - \text{mean RBC}_{BCS}\right)(\text{mean cost per unit of RBC})$$

where N_{BCS} was the number of BCS patients; RBC_{non_BCS} and RBC_{BCS} were the number of units of red blood cells transfused for each non-BCS and BCS patient, respectively; and mean cost per unit of RBC was $233 (simple acquisition cost of 1 unit of RBC at the authors' instituion in 2011). Transfusion requirements were monitored until hospital discharge.

Statistical analyses were performed using SPSS 20 (IBM Corp., Armonk, NY). Results are presented as mean ± standard deviation (SD) for continuous variables and incidence (percent) for categoric variables. Comparisons were performed using the Student's *t* test for continuous variables and Pearson χ^2 for categoric variables. A Mann-Whitney U test was used to compare postoperative length of stay. To minimize the effect of differences in baseline characteristics and procedure types between the 2 groups, identification of independent risk factors for mortality, major complications, and RBC transfusion was performed by multivariate analysis using stepwise logistic regression models. Variables were chosen for the multivariable analyses based on risk factors documented in the literature for other cardiac surgery as baseline differences in the 2 groups may have limited identification of significant risk factors by univariate analysis. The complete list of variables included in the regression models is available online in Appendix B. Odd ratios were determined using the equation $OR = e^b$, where b is the logistic coefficient. Values of $p < 0.05$ were considered statistically significant.

RESULTS

The mean patient age was 60.7 ± 14.0 years, with a mean logistic EuroSCORE of 10.4 ± 10.0%. Table 1 contains the preoperative characteristics of the 2 patient cohorts. The BCS patients had a higher incidence of aortic dissection and fewer aneurysms compared with the control group ($p < 0.01$). There was also a significantly greater number of emergent/urgent operations in the BCS group ($p < 0.01$). The BCS group had a higher preoperative incidence of peripheral vascular disease ($p < 0.01$) and a lower mean body mass index (BMI) ($p < 0.01$). These factors, which were more prevalent in the BCS group, are all potential risk factors for bleeding, transfusion, and adverse outcomes. Age, EuroSCORE, gender, preoperative comorbidities (Table 1) and mean cardiopulmonary bypass (CPB) and aortic cross-clamp times (Table 2) were similar between the 2 groups.

Overall mortality was 9.8% (13 of 132). There was no difference in mortality between the BCS and control groups ($p = 0.4$; Table 2). Lower preoperative hemoglobin was an independent risk factor for mortality ($p = 0.01$, OR 1.7). BCS had no effect on mortality by multivariate analysis. Mortality was higher in patients who received RBC transfusions compared with those who were not transfused (16.0% [13 of 81] versus 0% [0 of 51]; $p < 0.01$, OR 1.2), and mortality was increased in patients who received 2 or more units of RBC compared with those who received fewer than 2 units (21.0% [13 of 62] versus 0% [0 of 70]; $p < 0.01$, OR 1.3).

Major complications (a composite outcome of mortality, renal failure, respiratory failure, and sepsis) and rates of individual postoperative complications were similar between the BCS and control groups (Table 2). Independent predictors of major complications included lower BMI ($p = 0.02$, OR 1.3) and a greater mean number of RBC units transfused ($p < 0.01$, OR 3.0). Major complications were associated with any RBC transfusion (24.7% [20 of 81] versus 0% [0 of 51]; $p < 0.01$, OR 1.3) and was higher still in patients who received ≥ 2 units