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Blood Utilization in Revision vs. First-time Cardiac Surgery: An Update in the Era of Patient Blood Management

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Abstract

Background: Relative to first time (primary) cardiac surgery, revision cardiac surgery is associated with increased transfusion requirements, but studies comparing these cohorts were done before patient blood management (PBM) and blood conservation measures were commonplace. The current study was done as an update to determine if this finding is still evident in the PBM era.

Methods: Primary and revision cardiac surgery cases were compared in a retrospective database analysis at a single tertiary care referral center. Two groups of patients were assessed: 1) Those having isolated coronary artery bypass (CAB) or valve surgery, and 2) all other cardiac surgeries.

Intraoperative and whole hospital transfusion requirements were assessed for the 4 major blood components.

Results: Compared to the primary cardiac surgery patients, the revision surgery patients required ≈ 2 -fold more transfused units intraoperatively ($P < 0.0001$), and ≈ 2 to 3-fold more transfused units for the whole hospital stay ($P < 0.0001$). Intraoperative massive transfusion (> 10 red blood cell units) was substantially more frequent with revision vs. primary cardiac surgery; 2.6 vs. 0.1%; $P < 0.0001$ for isolated CAB or valve, and 6.1% vs. 1.9%; $P < 0.0001$ for all other cardiac surgeries. Revision surgery was an independent risk factor for both moderate (6–10 red blood cell units) and massive intraoperative transfusion.

Conclusions: In the era of PBM, with restrictive transfusion strategies and a variety of methods for blood conservation, revision cardiac surgery patients continue to have substantially greater transfusion requirements relative to primary cardiac surgery patients. This difference in transfusion requirement was greater than what has been previously reported in the pre-PBM era.

Introduction:

With increased longevity, more patients are having revision cardiac surgery, which presents additional challenges relative to first-time (primary) cardiac surgeries. Blood loss and transfusion requirements are both increased with revision cardiac surgery, likely due to scar tissue, adhesions, and increased operative time. Bracey and colleagues reported a 75% increase in blood components transfused with revision compared to primary coronary artery bypass (CAB) surgery, however this was more than 20 years ago, before patient blood management (PBM) programs were commonplace.¹ Since then, new studies supporting lower hemoglobin (Hb) transfusion triggers and new methods of intraoperative blood conservation have been introduced, both of which may influence overall blood utilization.^{2,3}

The purpose of the current study was to assess transfusion requirements for patients undergoing revision compared to primary cardiac surgery in the era of patient blood management. In this retrospective database review, we included both isolated CAB or valve (aortic or mitral) and all other cardiac surgery patients, and evaluated both intraoperative and whole hospital transfusion requirements for all four major blood components. Our hypothesis was that revision cardiac surgery patients continue to have greater transfusion requirements relative to primary surgery patients, despite newer methods of blood conservation and patient blood management techniques. Our findings should be clinically relevant by allowing appropriate planning and preparation for blood availability, as well as targeted methods of blood conservation in these most challenging cases.

Methods:

After approval by the institutional review board, we acquired electronic medical record data for cardiac surgery cases at a single tertiary care center (Johns Hopkins Hospital) from April 2010 until June 2016. We used three sources: a web-based intelligence portal (IMPACT Online; Haemonetics Corp, USA), our anesthesia information management system (AIMS) (MetaVision; iMDsoft Corp, USA), and the Society of Thoracic Surgeons (STS) National Database. We excluded patients with missing data from any of these datasets. We also

excluded pediatric cardiac cases (age <18 years old) and trans-aortic valvular replacement (TAVR) procedures. During the time frame of the study, the methods of blood conservation, many of which have been adopted at our institution, are listed in Table 1. Although these were not universally used in all cardiac surgery patients, these methods have been used with increasing frequency at our institution over the past 7 years.

Classification of Surgery and Transfusion

Utilizing the AIMS data, we searched for the procedure “redo sternotomy”, which is the designation for any revision cardiac surgery at our institution. We then used the STS database to classify surgical procedures into four groups: 1) primary isolated CAB or valve (mitral or aortic), 2) revision isolated CAB or valve (mitral or aortic), 3) primary other cardiac surgery, and 4) revision other cardiac surgery. A CAB combined with any other major cardiac procedure (e.g. valve) was included in the “other cardiac surgery” category.

We examined allogeneic blood requirements in both intraoperative and whole hospital time periods for red blood cell (RBC), fresh frozen plasma (FFP), platelets (PLTS), and cryoprecipitate (CRYO). One unit of PLTS was considered to be an apheresis single donor bag, and one unit of CRYO was considered to be one dose (5 pooled units). CRYO data were not available for the intraoperative period, but intraoperative CRYO units were included in the whole hospital data. Based on total number of intraoperative RBC units transfused, we further stratified transfusion requirements into moderate transfusion (6–10 RBC units) and massive transfusion (>10 RBC units) patients based on prior literature.⁴

Statistical analysis

Results are reported as proportions, mean $\pm$ SD, and median (interquartile range). Proportions were compared by Chi-squared tests and/or Fisher’s Exact tests where appropriate. Normally distributed continuous data were compared by unpaired student’s t-tests, and non-normally distributed continuous data by Mann-Whitney U tests. In particular, mean $\pm$ SD are reported for transfusion requirements to allow comparison with prior literature on this topic, which reported transfusion requirements in mean $\pm$ SD. A multinomial logistic regression model was used to examine whether revision cardiac surgery (relative to primary surgery) was independently associated with increased whole hospital transfusion requirements. Variables to include in the model were considered a priori based on parameters known to influence transfusion rates (preoperative hemoglobin, body mass, gender, duration of surgery, P2Y12 inhibitors, patient age, Charlson Comorbidity Index). Data were analyzed using JMP version 12.0.2 (SAS Institute, Cary North Carolina) and Stata 12.0 (StataCorp; College Station, TX). $P < 0.05$ defined significance.

Results:

Patients Characteristics

Data were available on 5800 patients. Patient characteristics for the four cohorts (primary vs. revision; isolated CAB or valve vs. other cardiac surgery) are shown in Table 2. The procedures in the “other cardiac surgery” category are listed in Table 3. Of note, 284/5800 (4.9%) patients underwent procedures through a minimally invasive thoracotomy approach.

As expected, there were differences in patient characteristics between the primary and the revision groups. Mean age was increased in the primary surgery patients in the other cardiac surgery group. Coagulopathy was more prevalent in the revision group, for both the isolated CAB or valve, and the other cardiac surgery patients. P2Y12 inhibitors were taken in equal proportions in the primary and the revision groups. As expected, duration of surgery, duration of bypass, and duration of cross-clamp were increased with revision surgery in both the isolated CAB or valve and the other cardiac surgery groups. There were small but significant differences as the preoperative hemoglobin was lower, the INR higher, and the platelet count lower in the revision groups.

Patients that were brought back to the operating room after their initial cardiac surgery were included in the analysis. The vast majority of the time, these patients are brought back due to excessive bleeding in the cardiac surgical ICU. There were 307 patients brought back for excessive bleeding out of 5800 total patients, or 5.3%. There were 4.85% in the primary sternotomy group (259/5336) versus 10.3% (48/464) of the revision sternotomy patients ($P<0.001$).

Incidence of Transfusion

As shown in Figure 1, for all patients (both the isolated CAB/valve group and the other cardiac surgery group), the percentage of patients requiring transfusion over the whole hospital stay and intraoperatively was greater in the revision than the primary surgery group for RBCs, FFP, PLTS, and CRYO ($P<0.01$ for all blood components). The greater incidence of transfusion in the revision patients ranged from a ≈ 30 –50% increase (for RBCs) to ≈ 60 –100% increase (for FFP, PLTS, and CRYO).

Magnitude of Transfusion Requirements

As shown in Figure 2, all types of revision surgeries had an approximate 2-fold increase in the mean number of units transfused intraoperatively for all blood components ($P<0.0001$ for all comparisons). For the whole hospital course, all types of revision surgeries had an approximate 2 to 3-fold increase in mean number of units transfused for all blood components ($P<0.0001$ for all comparisons).

The relative incidence of moderate (6–10 RBC units) and massive (>10 RBC units) intraoperative transfusions was also examined, as shown in Figure 3. Moderate transfusion during surgery was substantially more frequent with revision vs. primary cardiac surgery, for both isolated CAB/valves (10.4 vs. 1.5%; $P<0.0001$), and for all other cardiac surgeries (14.5% vs. 5.8%; $P<0.0001$). Similarly, massive transfusion during surgery was substantially more frequent with revision vs. primary cardiac surgery for isolated CAB/valves (2.6 vs. 0.1%; $P<0.0001$) and for all other cardiac surgeries (6.1% vs. 1.9%; $P<0.0001$).

The independent contribution of revision surgery to moderate and massive intraoperative transfusion was examined using multivariable multinomial logistic regression, with risk adjustment for age, weight, gender, operative time, first hemoglobin, Charlson score, and anti-platelet medications (Table 4). Revision surgery independently increased the risk of both moderate and massive transfusions. The magnitude of increased risk was greater among CAB/valve patients, compared with other surgeries.

Discussion:

The primary findings in our study are that revision cardiac surgery patients have a substantially greater transfusion requirement relative to first time (primary) cardiac surgery patients. In fact, the difference between revision and primary surgery in the current study with regard to transfusion requirements was greater than was reported over 20 years ago by Bracey et al. before current PBM practices were commonplace, and prior to the randomized trials supporting restrictive transfusion strategies.^{1-3,5} In general, our findings demonstrate a 2–3 fold greater transfusion requirement for patients having revision surgery, compared to a 75% increase previously reported.¹

This increased transfusion requirement for revision surgeries suggests that the newer methods of blood management may not be very effective in reducing transfusion requirements in revision surgeries. Revision cardiac surgery may require more blood than we are able to save by using blood management methods, such as cell salvage, hemoconcentrators, acute normovolemic hemodilution (ANH), lower hemoglobin triggers and targets, smaller phlebotomy tubes, complete rewarming, and viscoelastic point of care testing. However, we are hopeful that continuing these blood conservation methods along with modifying our surgical strategies, may help us eventually to achieve less blood utilization for these challenging patients.

Routine use of anti-fibrinolytics is one of many strategies to decrease blood product utilization in cardiac surgery. Epsilon-aminocaproic (EACA) and its pharmacologic mechanism was first discovered in the early 1960's but did not become clinically recognized and used until the late 1980's.⁶ Due to cardiopulmonary bypass causing accelerated thrombin generation, dysfunctional platelets and fibrinolysis, aprotinin and lysine-analogs (EACA and tranexamic acid) became popular to attenuate bleeding.⁷ In a Cochrane review by Henry et al., the relative risk of needing an allogeneic RBC transfusion with tranexamic acid and EACA compared to controls were 0.61 (95% confidence interval [CI] 0.53 to 0.70) and 0.81, respectively (95% CI 0.67 to 0.99). Our institution started routinely using EACA in the late 1990's, and it remains the routine practice today.⁸

Additionally, in this new era of patient blood management, many anesthesiologists use viscoelastometry to help guide transfusion of plasma, platelets, and cryoprecipitate. There have been algorithms developed specifically targeting cardiac surgical patients.⁹ A recent meta-analyses by Wikkelsø et al. of trials utilizing viscoelastometry (TEG and ROTEM) algorithms found a significant reduction in bleeding and transfusion.¹⁰ Such algorithms were published in 1999, and used sporadically in our institution until the past decade, when a formal algorithm was adopted as routine practice.

Strategies to reduce transfusion have been driven by the results of both randomized and observational studies. The two most recent trials supporting restrictive transfusion strategies in cardiac surgery add to the evidence from an earlier study (also by Bracey and colleagues), that giving more blood than is necessary to cardiac surgery patients does not improve outcomes⁵. The TRACS and TITRe2 trials, in 2010 and 2015 respectively, demonstrated noninferiority in the primary outcomes between a restrictive vs. liberal postoperative

transfusion strategy.^{2,3} In revision cardiac surgery, specifically, George et al. found that revision sternotomy heart transplant recipients had increased blood product usage, and that increased transfusion of products was independently associated with short and long-term mortality.¹¹ Many other observational studies have reported the increased morbidity and mortality associated with incremental amounts of blood transfusion.^{4,12,13} Although the results of observational studies must be interpreted with caution, the 2011 Update to the Society of Thoracic Surgeons and Society of Cardiovascular Anesthesiologists Blood Conservation Guidelines noted that transfusing beyond the recommended guidelines only increases risk and cost for cardiac surgery patients.¹⁴

Surgeons also approach revision sternotomy cases differently from primary cases. First, a decision is made whether to commence cardiopulmonary bypass (CPB) prior to sternotomy. The disadvantage to this conservative approach is a longer time on CPB. Secondly, surgeons may use different equipment, including an oscillating saw to try and prevent entering into a large vessel or anterior cardiac chamber. Thirdly, hemostatic agents, such as Floseal™ (Baxter International, Deerfield IL) may be used for both primary and revision sternotomy cases. Although the surgical technique may be different for revision cases, we have not been able to identify techniques that we feel could improve outcomes; indeed many of the differences in techniques were developed specifically to improve safety in this population. Thus, newer strategies in transfusion and surgical practice warranted a new look at whether revision cardiac surgery patients continue to require more transfused blood components relative to primary cardiac surgery patients, as was shown two decades ago.

Not surprisingly, there was a significantly increased duration of surgery and duration of cardiopulmonary bypass for revision cardiac surgery relative to primary surgery. Increased time on CPB may result in more inflammation, leading to impaired hemostasis and increased blood loss, and consequently increased transfusion requirements. As mentioned previously, CPB can increase fibrinolysis, cause a consumptive coagulopathy, and lead to dysfunctional platelets. Increasing duration of CPB and its' associated risk of more allogeneic blood units transfused is a common finding.^{12,15,16} Parr et al. found that increased CPB time had an adjusted odds ratio (OR) of 1.33 (95% CI 1.14–1.54) in their primary outcome of transfusion of >2 units of RBCs and an adjusted OR of 1.36 (95% CI 1.16–1.60) of needing mediastinal re-exploration or receipt of cryoprecipitate, FFP, or platelets during hospitalization.¹⁵ Although viscoelastic point-of-care testing, antifibrinolytic drugs, acute normovolemic hemodilution, cell salvage and use of hemoconcentrators have been effective in reducing transfusions overall in cardiac surgery, the increased duration of CPB in revision cases is likely an contributing cause of increased transfusion requirements.

In addition to examining average transfusion, we also examined the incidence of moderate (6–10 RBC units) and massive (>10 RBC units) transfusion intraoperatively. It is paramount to know how best to prepare for revision cardiac surgery cases, specifically quantities of blood components to prepare, and how quickly these units can be obtained. In our data, 13.0% of the revision isolated CAB or valves and 20.6% of the revision other cardiac surgeries required moderate or massive transfusion. Commonly, slow bleeding occurs at the microvascular level in revision cardiac cases. Uncommonly, these are cases with rapid blood loss upon entering the patient's chest. Even when using extreme caution, a large vessel, such

as the aorta or pulmonary artery or even an anterior heart chamber, such as the right ventricle, can be accidentally punctured. In those moments of rapid bleeding, having a container of RBCs and/or FFP in the operating room helps to facilitate giving blood during sudden hemorrhage. Our data also suggest that plasma and platelets should be rapidly obtainable for revision cardiac surgery cases.

In our analysis, we were unable to quantify the incidence of cardiac rupture on dissection, however we did examine the amount of cell salvage returned to patients intraoperatively. For primary sternotomy patients, a median of 500 mL (IQR 500–750 mL) was returned, while for revision sternotomy patients a median of 600 mL (IQR 500–800 mL) was returned ($P<0.01$). These estimates underscore our observation that more blood loss occurs in revision sternotomy patients, and may also be a reason for increased utilization of plasma and platelets.

Even after accounting for confounding variables, revision surgery was an independent risk factor for both moderate and massive intraoperative transfusion. Of note, the risk of moderate and massive transfusion was greater in CAB/valve patients compared with other cardiac surgery patients. This may be due to the inherent risk of bleeding associated with those cases that were classified as ‘other cardiac surgeries’, such as aortic root replacements, ascending aorta replacements, aortic arch reconstructions and emergent aortic dissections. These complex aortic surgeries will likely have increased blood utilization in the primary surgery for a variety of reasons and have been shown in other studies to have the highest degree of blood utilization compared to other cardiac surgeries.¹⁷ We did not include previous exposure to chest radiation in our analysis but studies have demonstrated increased risk of massive bleeding as well as increased long-term mortality.^{18,19}

The limitations of this study include the single centered nature of the study, and the possibility that results may differ in other centers due to differences in surgical technique or the use of patient blood management practices. Since our institution is a tertiary/quaternary referral center, it may limit the generalizability of our results. Nevertheless, it is important to point out that our results are similar in both the isolated CAB/valve patients as well as the other cardiac surgery group. In our experience, the “other” patients are often the patients who are specifically referred for tertiary/quaternary care. Additionally, the incidence of revision at our institution is similar to other sites in the literature²⁰.

Another possible limitation is the heterogeneity of the surgical cases that were in the other cardiac surgery group. For example, it has been previously noted that lowest temperature on bypass correlates with increased transfusion due to hypothermia causing dysfunctional platelets as well as the increased time for cooling and rewarming on CPB.²¹ Thus complex cardiac surgeries requiring hypothermic circulatory arrest or involving multiple combined procedures may have increased transfusion requirements. Interestingly, our findings in the isolated CAB or valve group were generally similar to the other cardiac surgery group, suggesting that revision surgery is a strong predictor of increased transfusion, regardless of the type of cardiac surgical procedure.

A final limitation is in how patient blood management (PBM) strategies are phased in over time and how that may affect a retrospective study. In 2014, our institution started to use PBM measures such as acute normovolemic hemodilution and viscoelastic testing algorithms routinely. In 2015, we started using hemoconcentrators on cardiopulmonary bypass routinely. Even though these strategies were phased in over the course of the study time period, we had an equal number of revision cases in the 2010–2013 time period when there was less PBM enacted as we did during the 2014–2016 period when more were being utilized routinely.

In summary, revision cardiac surgery, even in the era of patient blood management, remains a strong predictor of increased transfusion requirements, and the increased transfusion with revision surgery was greater in our study than was reported two decades ago. Perhaps with more aggressive blood conservation techniques, we can reduce transfusion requirements in this high-risk population. Preoperative optimization by diagnosing and treating anemia may be of benefit, as well as correction of coagulopathies prior to surgery. Intraoperative use of autologous normovolemic hemodilution and viscoelastic testing algorithms may also be beneficial. Autologous cell salvage and hemoconcentration (modified ultrafiltration), as well as complete rewarming to prevent residual hypothermia may all be useful to decrease transfusion in these complex revision surgeries.^{22,23} Our findings may allow anesthesiologists, surgeons, and transfusion medicine specialists to better plan and prepare for these challenging revision cardiac surgery cases.

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Conflicts of Interests and Sources of Funding:

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Figure 1.

The percentage of patients requiring any transfusion of the four major blood components were compared between revision and primary cardiac surgery patients. Isolated coronary artery bypass (CAB) / valve and all other cardiac surgeries were analyzed as separate subgroups, and whole hospital and intraoperative transfusion requirements are shown. There was a clear increase in the percentage of patients requiring all the blood components when revision surgeries were compared to primary surgeries. (All P-values <0.001)

Figure 2.

Mean red blood cell (RBC), plasma (FFP), platelets (PLTS), and cryoprecipitate (CRYO) units transfused were compared between revision and primary cardiac surgery patients. Isolated coronary artery bypass (CAB)/valve and all other cardiac surgeries were analyzed as separate subgroups, and whole hospital and intraoperative transfusion requirements are shown. Revision surgery was associated with a 2 to 3-fold increase in blood utilization for isolated CAB/valve, and a 2-fold increase in other cardiac surgeries.

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Figure 3. The incidence of intraoperative moderate (6–10 RBC units) and massive (>10 RBC units) transfusion was substantially higher in the revision compared to the primary cardiac surgery patients. (All P-values < 0.001)

Table 1.

Methods of blood conservation

1. Early diagnosis and treatment of preoperative anemia
2. Discontinuing herbal supplements that interfere with coagulation
3. Judicious decision-making for when to not operate (risk exceeds benefit)
4. Minimizing laboratory testing
5. Low volume, microtainers for phlebotomy
6. In-line blood-return devices for indwelling arterial and central venous catheters
7. Tolerating lower hemoglobin levels
8. Intraoperative autologous blood salvage
9. Intraoperative autologous normovolemic hemodilution
10. Meticulous surgical technique
11. Perioperative antifibrinolytics (tranexamic acid, epsilon aminocaproic acid)
12. New methods of electrocautery
13. Topical sealants and hemostatic agents
14. Avoiding perioperative hypothermia
15. Intentional moderate hypotension
16. Point-of-care coagulation testing

Table 2.

Characteristics of Cardiac Surgery Patients^a

	Isolated CAB/Valve Surgery			Other Cardiac Surgery		
	Primary (n = 3,122)	Revision (n = 154)	P-Value	Primary (n = 2,214)	Revision (n = 310)	P-Value
Age in years, mean ± SD	64 ± 12	63 ± 15	0.396	60 ± 16	54 ± 18	< 0.0001
Male, n (%)	2,226 (71.30%)	107 (69.48%)	0.628	1,376 (62.15%)	191 (61.61%)	0.8553
Comorbidities ^b						
Hypertension, n (%)	2,065 (78.10%)	87 (65.91%)	0.0018	1,204 (63.17%)	163 (59.49%)	0.241
Pulmonary, n (%)	397 (15.02%)	19 (14.39%)	0.845	342 (17.94%)	32 (11.68%)	0.0073
Renal, n (%)	398 (15.05%)	18 (13.64%)	0.6524	294 (15.42%)	50 (18.25%)	0.2386
Coagulopathy, n (%)	150 (5.67%)	18 (13.64%)	0.0011	144 (7.56%)	34 (12.41%)	0.0095
Obesity, n (%)	484 (18.31%)	22 (16.67%)	0.6304	253 (13.27%)	22 (8.03%)	0.01
Diabetes, n (%)	771 (29.16%)	29 (21.97%)	0.0678	364 (19.10%)	41 (14.96%)	0.0921
Charlson Comorbidity Index, med (IQR)	2 (1 – 3)	2 (1 – 3)	0.65	2 (1 – 3)	2 (1 – 3)	0.4038
Weight (kg), mean ± SD	87 ± 20	86 ± 20	0.6048	85 ± 21	83 ± 21	0.1037
P2Y12 Inhibitor ^c , n (%)	412 (13.20%)	21 (13.64%)	0.9518	127 (5.74%)	15 (4.84%)	0.3193
Surgical Characteristics						
Duration of Surgery, min ± SD	257 ± 97	310 ± 106	< 0.0001	281 ± 117	358 ± 142	< 0.0001
Bypass Time, min ± SD	99 ± 40	134 ± 48	< 0.0001	134 ± 59	182 ± 82	< 0.0001
Cross Clamp Time, min ± SD	65 ± 26	72 ± 30	0.0014	86 ± 38	105 ± 49	< 0.0001
First Hb, mean ± SD	13.1 ± 2.0	12.6 ± 2.1	0.0021	13.0 ± 2.0	12.5 ± 2.4	0.0004
First Hct, mean ± SD	39.1 ± 5.3	38.0 ± 5.9	0.025	38.9 ± 5.6	37.8 ± 6.2	0.0021
First INR, mean ± SD	1.1 ± 0.4	1.3 ± 1.0	0.0034	1.3 ± 0.7	1.5 ± 1.0	< 0.0001
First PLT, mean ± SD	223 ± 80	211 ± 80	0.092	223 ± 83	208 ± 74	0.0031
% Massively Transfused						
> 5 Units RBC in OR, n (%)	52 (1.67%)	20 (12.99%)	< 0.0001	169 (7.63%)	64 (20.65%)	< 0.0001
> 10 Units RBC in OR, n (%)	4 (0.13%)	4 (2.60%)	0.0003	41 (1.85%)	19 (6.13%)	< 0.0001

Kg= kilograms; Hb = hemoglobin; Hct= hematocrit; INR= international normalized ratio; PLT= platelet

^a All values are expressed using the number of patients with non-missing data as the denominator^b ICD-9 and ICD-10 discharge codes available through the Impact Online database were used to identify comorbidities

Defined as having received P2Y12 inhibitors within 5 days of surgery

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Table 3.

Percentage of Types of Cases within Other Cardiac Surgery Category

Category	Frequency	Percentage
VAD	109	4.32
Transplant ^a	148	5.86
Aortic Arch	127	5.03
Ascending/Descending Aorta	544	21.55
Myectomy	123	4.87
Cardiac Masses	56	2.22
Congenital	86	3.41
Other valve ^b	249	9.87
CAB/Valve combined	540	21.39
Other ^c	542	21.47

VAD= ventricular assist device

^aHeart or lung transplant

^bTricuspid valve repair/replacement, pulmonic repair/replacement, and multiple valvular procedures

^cCombined procedures not easily definable or very low frequency, i.e., Ross procedure AND subaortic membrane resection

Table 4:
Relative Risk Ratio of Intraoperative Red Cell Unit Transfusion for Revision Cardiac Surgery Compared to Primary Surgery

	Unadjusted			Adjusted*		
	Relative Risk Ratio	Confidence Interval	P-value	Relative Risk Ratio	Confidence Interval	P-value
CAB/ Valve						
0 Units (reference)						
1–5 units	1.9	1.4–2.7	<0.001	1.8	1.14–2.9	0.01
6–10 units (moderate transfusion)	10.2	5.5–18.9	<0.001	8.1	3.7–17.9	<0.001
> 10 units (massive transfusion)	30.6	7.5–125.1	<0.001	22.9	3.0–174.8	0.003
Other						
0 Units (reference)						
1–5 units	2.1	1.6–2.7	<0.001	2.1	1.5–3.0	<0.001
6–10 units (moderate transfusion)	4.2	2.9–6.3	<0.001	2.5	1.5–4.4	0.001
> 10 units (massive transfusion)	5.6	3.1–10.0	<0.001	2.4	1.1–5.4	0.03

* Adjusted for age, weight, gender, surgery time, first hemoglobin, Charlson score, and anti-platelet medications