Transfusion in Elective Proximal Aortic Reconstruction: Where Do We Currently Stand?

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Abstract

Aortic procedures are associated with higher risks of bleeding, yet data regarding perioperative transfusion in this patient population are lacking. We evaluated transfusion patterns in patients undergoing proximal aortic surgery to provide a benchmark against which future standards can be assessed.

Between June 2014 and July 2017, 247 patients underwent elective aortic reconstruction for aneurysm. Patients with acute aortic syndrome, endocarditis, and/or prior cardiac surgery were excluded. Transfusion data were analyzed by type of operation: ascending aorta replacement ± aortic valve procedure (group 1, $n = 122$, 49.4%); aortic root replacement with a composite valve–graft conduit ± ascending aorta replacement (group 2, $n = 93$, 37.7%); valve-sparing aortic root replacement (VSARR) ± ascending aorta replacement (group 3, $n = 32$, 13.0%).

Thirty-day mortality for the entire cohort was 2.02% (5 deaths). Overall, 75 patients (30.4%) did not require any transfusion of blood or other products. Patients in groups 1 and 3 were significantly more likely to avoid transfusion than those in group 2. Mean transfusion volume for any individual patient was modest; those who underwent VSARR (group 3) required less intraoperative red blood cells (RBC) than others. Intraoperative transfusion of RBC was independently associated with an increased risk of death at 30 days.

Elective proximal aortic reconstruction can be performed without the need for excessive utilization of blood products. Composite root replacement is associated with a greater need for transfusion than either VSARR or isolated replacement of the ascending aorta.

Keywords

- ascending aortic dilation
- cardiac surgery
- aneurysm
- aortic valve disease
- cardiovascular disease
- cardiovascular risk factors
- dissection

Cardiac surgery represents a fraction of all surgical procedures performed worldwide, yet is responsible for consuming ~20% of all blood products available in the United States annually.[1] A substantial body of evidence has advocated for change in transfusion policy in the cardiac surgical arena,[2–7] however, despite published consensus guidelines from the Society of Thoracic Surgeons (STS) and other professional associations,[8–11] significant variations in clinical practice are still prevalent, not only between different institutions, but also amongst individual practitioners within the same center.

Aortic procedures tend to be associated with higher inherent risks of bleeding, yet specific information regarding perioperative transfusion requirements in this patient

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population is lacking. Data from aortic procedures have often been excluded from several those studies examining blood product utilization in cardiac surgery, such that relevant transfusion data has to be extrapolated from non-aortic operations.[12] Consequently, to better provide a benchmark against which future quality metrics can be assessed, we sought to evaluate our current transfusion patterns in patients undergoing elective proximal aortic surgery.

Patient and Methods

Study Population and Definitions

A comprehensive retrospective review was undertaken of all patients who underwent elective primary proximal aortic surgery at two institutions, aged 18 years or older, between July 2014 and June 2017. Data were collected regarding all blood products that the patients may have received at any time during their hospital stay, be it red blood cells (RBC), fresh frozen plasma (FFP), platelets, or cryoprecipitate.

Exclusion criteria included all patients who underwent surgery for an acute aortic syndrome or infectious endocarditis, as well as those who had undergone prior cardiac surgery. Patients who required extensive distal aortic reconstruction, such as an arch replacement of thoracoabdominal procedure, in conjunction with their proximal aortic operation, were also excluded from analysis.

This study was conducted with the approval of the Northwell Health institutional review board (November 6, 2017; IRB approval #17–0763); consent was waived.

Data Analysis

Definitions of patient demographic characteristics, perioperative variables, and postoperative outcomes, were obtained from the New York State Cardiac Surgery Reporting System and from the Society of Thoracic Surgeons Adult Cardiac Surgery Database, version 2.81.

Study data were collected and managed using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at Lenox Hill Hospital.[13] REDCap is a secure, web-based application designed to support data capture for research studies, providing (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages; and (4) procedures for importing data from external sources.

Patient characteristics and outcomes were compared using chi-square, Fisher's exact test, student's *t*-test, or Wilcoxon–Mann–Whitney test, as appropriate. A chi-square test was used for categorical variables where the expected value for each cell was 5 or higher; if this assumption was not met, then we used Fisher's exact test. A *p*-value of less than 0.05 was considered to be statistically significant.

Predictive regression analysis was performed to determine any relationship between intraoperative administration of blood products and perioperative mortality. The Hosmer–Lemeshow test was used to test the goodness of fit of the predictive model; the R^2 was 0.72.

Statistical analyses were performed with the IBM Statistical Package for the Social Sciences (SPSS) for Windows, version 22.0 (IBM Corporation, Armonk, New York, United States).

Results

Patient Demographics and Operative Data

Over the time period of the study, 247 patients underwent elective first-time proximal aortic reconstruction, primarily for aneurysmal disease. These patients were stratified into three groups according to type of operation performed, namely, ascending aorta replacement ± aortic valve procedure (group 1, $n = 122$, 49.4%); aortic root replacement with a composite valve–graft conduit ± ascending aorta replacement (group 2, $n = 93$, 37.7%); and valve-sparing aortic root replacement (VSARR) ± ascending aorta replacement (group 3, $n = 32$, 13.0%).

Patient demographics are summarized in ►**Table 1**.

Major intraoperative variables are reported in ►**Table 2**. Aortic cross-clamp time was significantly longer in Group 3 than in the other two groups, and these patients also tended to have longer overall cardiopulmonary bypass times. Antegrade cerebral perfusion was utilized in the overwhelming majority of patients who underwent a period of hypothermic circulatory arrest.

Transfusion Requirements

Overall, 75 patients (30.4%) did not require transfusion of blood or other products at any time during their hospital stay. Patients in groups 1 ($n = 44$, 36.1%) and 3 ($n = 12$, 37.5%) were significantly more likely to avoid transfusion of RBC and/or other blood products than those in group 2 ($n = 19$, 20.4%) (►**Table 3**, ►**Fig. 1**).

Of the entire study cohort, 97 patients (39.3%) did not receive any RBC during their hospital stay, although they did require other blood products. Avoidance of RBC transfusion by patient group is summarized in ►**Table 3** and ►**Fig. 2**.

For those patients that did require RBC or other blood products, volume of transfusion per patient was modest (►**Table 3**). VSARR cases (group 3) required less RBC intraoperatively than did the other patient cohorts. Those individuals who underwent aortic root replacement with a composite valve–graft conduit (group 2) received more platelets and cryoprecipitate in the operating room than did those patients in the other two groups, and they were more likely to require fresh frozen plasma postoperatively.

Patients who underwent root replacement with a composite valve–graft conduit (group 2) required more clotting factors ($n = 23$, 24.7%) than individuals in either group 1 ($n = 9$, 7.4%) or group 3 ($n = 2$, 6.3%).

Clinical Outcomes

For the entire cohort, 30-day mortality was 2.02% (5 deaths) (►**Table 4**), not significantly different between patient groups. Major perioperative complications were comparable between all three cohorts.

Intraoperative transfusion of RBC was independently associated with an increased risk of death at 30 days (►**Table 5**).

Table 1 Patient demographics

Variable	Group 1 ($n = 122$)	Group 2 ($n = 93$)	Group 3 ($n = 32$)	*p*-Value
Age, years	64.7 ± 14.0	62.3 ± 13.2	52.8 ± 15.1	<0.0001
Female gender	38 (31.1)	18 (19.4)	2 (6.3)	0.008
Body mass index, kg/m^2	30.3 ± 12.3	28.1 ± 5.2	28.5 ± 6.9	0.25
Hypertension	84 (68.9)	69 (74.2)	24 (75.0)	0.71
Dyslipidemia	70 (57.4)	56 (60.2)	11 (34.4)	0.03
Cerebrovascular disease	14 (11.5)	11 (11.8)	1 (3.1)	0.34
Peripheral vascular disease	51 (41.8)	31 (33.3)	1 (3.1)	<0.0001
Diabetes mellitus	24 (19.7)	16 (17.2)	8 (25.0)	0.63
Chronic obstructive pulmonary disease	10 (8.2)	17 (18.3)	5 (15.6)	0.08
Prior myocardial infarction	17 (13.9)	10 (10.8)	0 (0)	0.08
Preoperative hematocrit	40.5 ± 4.7	39.0 ± 5.9	41 ± 4.1	0.84
Preoperative hemoglobin (g/dL)	13.5 ± 1.9	13.5 ± 3.7	14.2 ± 1.6	0.38
Preoperative platelet count (10^9 per liter)	216.4 ± 65.8	218.3 ± 72.2	202.7 ± 54.3	0.47
Preoperative INR	1.1 ± 0.1	1.2 ± 0.5	1.0 ± 0.1	0.98
Anticoagulation use	31 (25.4)	22 (23.7)	3 (9.4)	0.15
Coumadin	5 (4.1)	1 (1.1)	0 (0.0)	0.44
Noncoumadin anticoagulation	26 (21.3)	21 (22.6)	3 (9.4)	0.13
Antiplatelet use; not aspirin	7 (5.7)	3 (3.2)	0 (0.0)	0.19
Current or prior smoking history	62 (50.8)	46 (49.5)	15 (46.9)	0.92
Dialysis-dependent renal failure	1 (0.8)	2 (2.2)	1 (3.1)	0.57
Left ventricular ejection fraction, %	57.4 ± 9.5	54.7 ± 12.2	57.5 ± 6.9	0.15

Abbreviation: INR, international normalized ratio.
Values expressed are n (%) or mean ± standard deviation.

Table 2 Operative data

Variable	Group 1 ($n = 122$)	Group 2 ($n = 93$)	Group 3 ($n = 32$)	*p*-Value
Cardiopulmonary bypass time, minutes	152.6 ± 54.6	167.9 ± 64.4	174.7 ± 38.7	0.06
Aortic cross-clamp time, minutes	114.4 ± 49.3	129.3 ± 41.9	151.1 ± 34.9	<0.0001
Lowest intraoperative temperature, °C	27.2 ± 5.2	27.9 ± 4.8	29.5 ± 2.9	0.05
Circulatory arrest	63 (51.6)	51 (54.8)	23 (71.9)	0.12
Circulatory arrest time, minutes	14.6 ± 6.6	14.5 ± 14.0	13.1 ± 4.4	0.80
Antegrade cerebral perfusion	57 (90.4)	46 (90.2)	23 (100.0)	0.30

Values expressed are *n* (%) or mean ± standard deviation.

Comment

It is well recognized that transfusion of blood and other blood products is associated with both short- and longer-term morbidity in cardiac surgery. Speiss reported the risks of an increased hematocrit in patients after cardiac surgery, finding that those with hematocrits of greater than 34% had a higher incidence of perioperative myocardial infarction.[1] Engoren and colleagues found that intraoperative and postoperative blood transfusion was associated with an increased risk of death over the ensuing 5 years after surgery.[4] Vamvakas and Taswell demonstrated that transfusion of RBC, fresh frozen plasma, and platelets were all independent predictors of long-term mortality at 10 years.[14] In a large randomized controlled clinical trial of critical care patients (not specifically limited to cardiac surgery), Hebert and associates described an increased risk of death in those patients transfused to maintain specific higher hemoglobin endpoints.[15] Our results similarly confirmed that intraoperative transfusion of RBC was independently associated with an increased risk of mortality at

Table 3 Transfusion data

Variable	Group 1 ($n = 122$)	Group 2 ($n = 93$)	Group 3 ($n = 32$)	*p*-Value
No transfusion of RBC or other blood products				
Intraoperative	64 (52.5)	36 (38.7)	18 (56.3)	0.08
Postoperative	62 (50.8)	36 (38.7)	17 (53.1)	0.61
Total hospital stay	44 (36.1)	19 (20.4)	12 (37.5)	0.03
No transfusion of RBC				
Intraoperative	79 (64.8)	53 (57.0)	26 (81.3)	0.05
Postoperative	66 (54.1)	42 (45.2)	17 (53.1)	0.41
Total hospital stay	51 (41.8)	31 (33.3)	15 (46.9)	0.25
Volume of blood products transfused during hospital stay				
Intraoperative				
RBC, number of units	2.2 ± 1.4	3.4 ± 2.8	1.5 ± 0.8	0.03
Fresh frozen plasma, number of units	2.3 ± 1.0	2.3 ± 1.0	1.9 ± 0.5	0.44
Platelets, number of units	1.6 ± 0.7	1.5 ± 0.6	2.7 ± 5.6	0.15
Cryoprecipitate, number of units	1.4 ± 0.6	1.4 ± 0.6	1.6 ± 0.5	0.71
Postoperative				
RBC, number of units	3.4 ± 4.0	3.7 ± 2.6	2.1 ± 1.2	0.29
Fresh frozen plasma, number of units	2.2 ± 1.4	2.1 ± 1.4	1.6 ± 0.6	0.81
Platelets, number of units	2.1 ± 2.4	1.8 ± 1.2	1.0 ± 0.0	0.63
Cryoprecipitate, number of units	2.0 ± 1.1	1.5 ± 0.5	1.0 ± 0.0	0.13
Clotting factors received[a]	9 (7.4)	23 (24.7)	2 (6.3)	0.001

Abbreviation: RBC, red blood cells.
Values expressed are *n* (%) or mean ± standard deviation.
[a]Including factor eight inhibitor bypassing activity (FEIBA) and recombinant factor VIIa.

30 days. In addition to adverse impacts on short- and longer-term survival, more frequent blood transfusion is associated with an increased risk of sternal wound infection,[16] nosocomial pneumonia,[17] renal dysfunction,[18] and sepsis.[19] Despite all of this evidence, however, a low hematocrit value, in the absence of any clinical features of hemorrhagic shock, remains the most common indication for transfusion among the critically ill.[20–23]

In our study, 75 patients (30.4%) did not require any transfusion of blood or other blood products during their hospital stay, thereby confirming that transfusion in proximal aortic operations is not inevitable, despite the higher intrinsic risk of bleeding inherent in these procedures. Ninety-seven patients (39.3%) did not receive any red blood cells, a finding not dissimilar to results reported by others.[5] There is considerable literature to support the assertion that

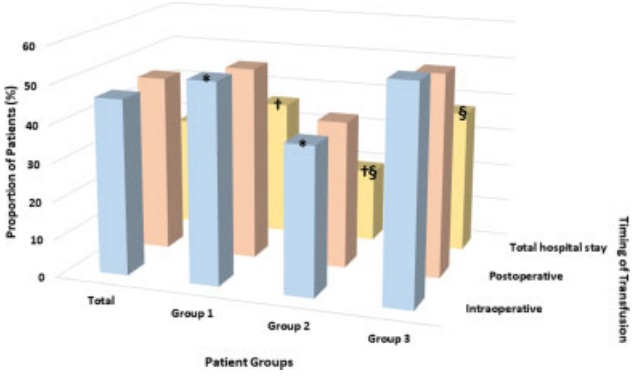

Fig. 1 Patients who did not require transfusion of red blood cells or any other blood products during their hospital stay, by patient group, and by timing of transfusion with respect to surgery. *$p = 0.05$; †$p = 0.015$; §$p = 0.062$.

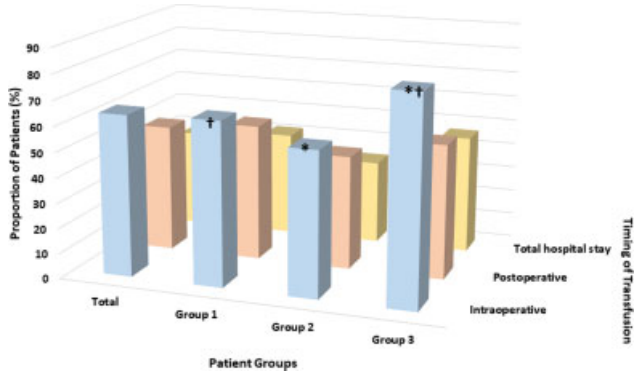

Fig. 2 Patients who did not require transfusion of red blood cells during their hospital stay, by patient group, and by timing of transfusion with respect to surgery. *$p = 0.011$; † $p = 0.05$.

Table 4 Perioperative outcomes

Variable	Group 1 ($n = 122$)	Group 2 ($n = 93$)	Group 3 ($n = 32$)	*p*-Value
30-day mortality	2 (1.6)	3 (3.2)	0 (0)	0.49
Stroke	8 (6.6)	4 (4.3)	0 (0)	0.29
Reoperation for bleeding	5 (4.1)	3 (3.2)	0 (0)	0.51
Deep sternal wound infection	1 (0.8)	1 (1.1)	1 (3.2)	0.69
Sepsis of any cause	3 (2.5)	2 (2.2)	1 (3.2)	0.95
New renal failure requiring dialysis	1 (0.8)	0 (0)	0 (0)	0.84
Ventilation time, hours	27.4 ± 88.4	34.1 ± 60.8	18.1 ± 29.1	0.54
Duration of ICU stay, hours	103.3 ± 121.5	126.1 ± 119.2	97.0 ± 69.0	0.28
Postoperative length of hospital stay, days	7 ± 5.6	7 ± 6.1	5.5 ± 3.3	0.10
Postoperative length of hospital stay, days, median (IQR)	7 (5–9)	7 (6–10)	5.5 (5–7)	0.15

Abbreviations: ICU, intensive care unit; IQR, interquartile range.
Values expressed are *n* (%) or mean ± standard deviation, unless otherwise specified.

Table 5 Association between intraoperative transfusion and 30-day mortality

Variable	Odds Ratio	95% CI	*p*-Value
Red blood cells	11.27	1.02–124.95	0.05
Fresh frozen plasma	0.239	0.018–3.259	0.28
Platelets	2.88	0.179–46.315	0.46
Cryoprecipitate	0.604	0.044–8.357	0.71

Abbreviation: CI, confidence interval.

systematically implemented blood conservation strategies and thromboelastogram-directed transfusion protocols can lead to the decreased utilization of blood and to overall lower rates of total blood product consumption in proximal aortic surgery.[24–26]

VSARR continues to demonstrate excellent long-term results,[27–30] and remains preferable to a composite valve–graft conduit in appropriately selected patients.[29] Our data show that VSARR cases required less RBC intraoperatively than the other patient cohorts, an advantage of valve-sparing surgery that has not previously been widely emphasized. Intraoperative RBC transfusion has been directly and independently associated with an increased length of stay and prolonged pulmonary support in aortic root surgery, whereas VSARR has been shown to be predictive of a shorter length of stay.[30] We too found a trend toward a shorter median length of stay in VSARR cases, bearing in mind that length of stay has been used as a surrogate marker for resource allocation and efficiency.

Our study has several limitations to be acknowledged. Despite the fact that our data are comprehensive, and drawn from more than one center, our sample size remains relatively small, and our analysis is retrospective and largely observational in nature. Our patient population was highly selected, consisting of those individuals with aneurysmal disease presenting for first-time proximal aortic surgery; consequently, our results are not generalizable to patients presenting with more acute aortic pathology, such as dissection or endocarditis. Even though we reported on both intraoperative and postoperative transfusion data, we were unable to elucidate the specific trigger for transfusion in any given patient; it would be useful to know whether patients were transfused based on arbitrary hematocrit values, as has been reported by some, or whether transfusion was initiated by clinical stimuli. Our data did not stratify transfusion by individual surgeon; it remains possible that a particular surgeon's practice could potentially skew the results.

In conclusion, we found that elective proximal aortic reconstruction can be performed without the need for excessive utilization of blood products. VSARR necessitated less RBC intraoperatively as compared with ascending aorta replacement and/or aortic root replacement with a composite valve–graft conduit. Intraoperative transfusion of RBC was independently associated with an increased risk of death at 30 days, reinforcing the importance of adopting strategies to reduce perioperative transfusion requirements in proximal aortic reconstruction.

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Conflicts of Interest
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