Reduced Transfusion Requirement With Use of Fresh Whole Blood in Pediatric Cardiac Surgical Procedures

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Background. **Pediatric patients undergoing cardiac operations are at high risk for blood loss and transfusion. A practice intended to reduce transfusion using a standard order of 2 units fresh whole blood (< 48 hours from donation) for elective cardiac operations in patients younger than 2 years of age was in place from 1995 to 2010. The objective of this study was to describe blood use in this population and to compare the results with those in published reports describing the use of blood components exclusively for transfusion.**

Methods. **Retrospective data from a surgical registry and blood bank records for 15 consecutive years were analyzed. Transfusion requirements were identified as donor exposures for the day of operation and the next postoperative day. Transfusions were fresh whole blood, packed red blood cells, platelets, and cryoprecipitate. Donor exposures for subgroups according to procedure and age were compared with those in published reports.**

Results. **The cohort consisted of 4,111 patients with a median age of 94 days and a median weight of 4.4 kg. The median donor exposure was 2 (range, 0 to 28). Younger patients having complex procedures had the most donor exposures. Fewer donor exposures were incurred in all subgroups compared with reports of component use in the literature.**

Conclusions. **The use of fresh whole blood for cardiac operations in children younger than 2 years old reduces donor exposures compared with published reports of component use.**

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Operations for complex congenital heart disease (CHD) in young patients have become common practice. Associated with the increased complexity of these surgical procedures and their use early in life, there has been an increase in significant bleeding. In the middle 1980s we observed extreme intraoperative blood loss requiring massive transfusion that depleted the immediately available blood bank inventory. In such instances we took the extraordinary measure of drawing and immediately transfusing whole blood from on-site emergency donors. A dramatic improvement in hemostasis was observed, resulting in successful outcomes that prompted interest in the planned use of fresh whole blood (FWB). Because of logistic difficulties in routinely obtaining FWB, and a belief that the use of components was equivalent or superior to the use of whole blood, a prospective study was designed to compare bleeding outcomes between FWB and components [1]. Blood loss was found to be lower in the FWB group for patients younger than 2 years of age undergoing complex procedures. On the basis of the results of that study, the Penn-Jersey American Red Cross provided a reliable supply of tested FWB, defined as up to 48 hours from donation to transfusion, and we began using this product as the routine blood support for elective cardiac operations. An optimal blood order was determined after an examination of blood use that included observations where total requirements were met with 1 or 2 units of FWB [2]. The standard preoperative blood order became 2 units of FWB and 2 units of packed red blood cells (PRBC) for all patients 2 years old or younger undergoing cardiac operations with cardiopulmonary bypass (CPB). The intent was to meet the transfusion requirements during and immediately after CPB using the FWB and to transfuse components thereafter. This approach was adopted in 1995 and continued uninterrupted to 2010. The purpose of this study is to describe the experience of this practice on the transfusion requirements for patients 2 years old and younger having elective cardiac operations with CPB.

Patients and Methods

After institutional review board approval, data were acquired from a cardiac surgery registry, blood bank, and perfusion records from1995 to 2010. Patients were identified as having CPB at age 2 years or younger. Surgical procedures, diagnoses, date of operation, age, and weight were recorded. Cases involving the use of extracorporeal

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support (extracorporeal membrane oxygenation, ventricular assist device) before or through the first postoperative day were excluded, as were patients undergoing emergency operations, tracheal reconstruction, emergency heart transplantation, or lung transplantation. Blood bank records reflected all blood products issued and presumed transfused, meaning that the product had not been returned to the blood bank or discarded unused. All transfusions were captured for the day of operation and through midnight of the day after operation. When multiple aliquots from a single donor were issued, they were identified as originating from the same donor and were counted as a single donor exposure (DE). The algorithm to enumerate DE used the unique donor identifier on blood products to account properly for those cases in which a patient received multiple aliquots from a unit of whole blood, PRBC, plasma, and single-donor platelets, and for individual units of random donor platelets and cryoprecipitate. Donor exposures incurred with pooled products such as pooled random donor platelets or pools of cryoprecipitate were estimated on the basis of the volume issued.

Transfusion Protocol

The patients' blood type and number of whole blood units requested were provided to the Penn-Jersey American Red Cross donor center 2 days to 1 week in advance of planned operations. Blood was obtained from daily donations 24 to 48 hours before operation, underwent standard labeling and testing for transmissible disease, was stored at 4°C, and was delivered to the hospital the evening before operation. Whole blood was added to the CPB circuit and was also used for volume replacement after CPB. The minimum hematocrit during CPB was 25% until 2002, after which it was increased to 30% when deep hypothermia or circulatory arrest was used. In the postoperative period, clinicians continued with FWB or any blood product at their discretion. Although no standardized transfusion algorithms or targets were used, the lower range of hematocrit was 25% to 35%; the highest values were observed in patients with persistently lower oxygen saturation No additional FWB was subsequently ordered for the patient's postoperative needs. If FWB was not available, components were used and included fresh-frozen plasma, cryoprecipitate, PRBC, and platelet concentrates. Platelet products were predominantly issued from a single donor (apheresis). In a few cases, pooled whole blood–derived platelets were issued. Cryoprecipitate was prepared in standard bags of 10 to 15 mL and was pooled on the basis of the volume ordered.

Data Analysis

Continuous variables were summarized with the use of descriptive statistics. A two independent samples t test was used to compare means when available between our studies and the reported studies under the strong assumption that variances are homogeneous and standard deviations could be pooled. The resulting p values were not adjusted for multiple comparisons. Analyses were performed with Stata SE10 (Stata Corporation, College Station, TX).

Results

We identified 4,246 patients younger than 2 years of age undergoing surgical procedures with CPB. Of those, 4,111 were characterized as having elective cardiac procedures. The mean ages and weights, and transfusion use by blood product, are shown in Table 1. The median age of 94 days reflects complex CHD requiring intervention very early in life. Twenty-three patients did not receive any blood products. Fresh whole blood was used in 3,836 patients, and components were exclusively used for 252 patients when no FWB was available. The wide range of DE reflects the inclusion of very complicated procedures and of problematic bleeding seen in an otherwise unselected population.

Table 2 shows the cohort by procedure listed in order of decreasing DE. The highest number of DE occurred in younger patients having complex procedures and the least in older patients having simpler procedures. The youngest patients with complex procedures in the table are those most commonly included in the published reports identified in Table 3.

Table 3 illustrates DE as reported in studies of heart operations in patients below 2 years of age. The fewest DE are found in the study groups in which FWB was used [2–4]. The DE rate was nearly identical to that in our cohort only in the study that used the same FWB strategy [3]. Many additional studies were not included because they encompassed a wide range of patient ages exceeding 2 years, or where transfusions were reported as volume of blood lost and transfused rather than as units or DE. Comparison across studies of subsets defined by factors such as surgical procedure was not possible, with the exception of age; however, younger age groups contained the highest percentage of complex surgical procedures at the highest risk for bleeding and replacement of blood loss. This is evident in Table 2.

Table 1. Demographics and Blood Use for the Entire Cohort (N = 4,111)

All Patients	Mean (SD)	Median	Min–Max
Age, days	142.8 (170.4)	94	1–729
Weight, kg	5.1 (2.4)	4.4	1–16.8
Whole blood, units	1.5 (0.6)	2	0–2
PRBC, units	1.3 (1.3)	1	0–14
FFP, units	0.1 (0.4)	0	0–6
Platelets, units[a]	0.3 (0.6)	0	0–4
Cryoprecipitate, units[a]	0.2 (0.6)	0	0–8
Total donor exposures	2.6 (1.9)	2	0–28

[a] Units from individual donors.

FFP = fresh-frozen plasma; Max = maximum; Min = minimum; PRBC = packed red blood cells; SD = standard deviation.