Blood Conservation during Open Heart Surgery in Infants and Children

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Abstract

We studied 211 consecutive patients (age 1/12 to 18 7/12 years, median 2 3/12 years; weight 2 to 70 kg., median 11.2 kg.) undergoing cardiopulmonary bypass (CPB) for repair of congenital heart defects from September 1978 to September 1982 to determine blood used at surgery and within 48 hours of operation. There were 10/211 (4.7%) peri-operative deaths and 21 patients bled more than 500 cc from chest tubes during the first twelve hours post-op; 4 (4/211=1.9%) required re-exploration. This left 180 uncomplicated cases. From 1978 to 1982: (1) The average number of units of packed red blood cells (PRC) used per patient decreased from 4.3 to 1.9 for the entire patient population and from 4.1 to 1.2 for uncomplicated cases; (2) the average number of PRC units used for CPB prime decreased from 1.9 to 0.5; and (3) average end-CPB hematocrit decreased from 27.9 to 22.6%. All differences are highly significant (p 0.001). Peri-operative and post-operative morbidity were unchanged over the course of the study. In 1982, 23/48 (48%) cases used non-blood prime (weight 8.8 to 70 kig., median 27.0 kg.; median pre-op Hct 45.0%) and 25/48 (52%) cases used 1 unit (weight 3.5 to 16.6 kg., median 9.0 kg.; median pre-op Hct 37.1%). Through a conscious effort to conserve blood, we substantially reduced our banked blood requirements for congenital heart surgery. Blood conservation reduces cost, spares resources, and minimizes risk of transfusion reaction and infectious disease, but does not increase the morbidity of congenital heart surgery.

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Introduction

Efficient utilization of banked blood offers several advantages. Obvious benefits include decreased cost and sparing of blood bank resources. Also important is the decreased risk of hepatitis and other infectious diseases. Febrile reactions, isoimmunization, and histocompatability reactions can also be reduced in frequency by using less blood products[1]. Surgical procedures requiring cardiopulmonary bypass (CPB) accounts for a significant proportion of banked blood usage.[2] Several investigators have looked at adult populations of patients undergoing CPB in terms of blood utilization[2-11], but no one has specifically addressed the issue of blood utilization in open heart procedures for the treatment of congenital heart disease (CHD) in children. Over the last four years, an effort has been made to minimize banked blood usage in children undergoing open heart surgery for CHD at this institution. For the purpose of quantifying blood usage, a chart review of 211 consecutive CPB procedures for CHD was undertaken.

Patient Population

Between September 1978 and September 1982, 211 consecutive patients underwent CPB for surgical correction of congenital heart defects. Operative age was 1 month to 18 7/12 years (median 2 3/12 years) and weight was 2.0 to 70 kg. (median 11.2

Table 1
Blood Product Utilization

Category	Selected Group (N=180) 1978	1979	1980	1981	1982	Total Group (N=211) 1978	1979	1980	1981	1982
Avg RBC units for CPB prime	1.91	1.37	1.28	0.94	0.69	1.92	1.38	1.28	0.93	0.52
Avg RBC units intra-operatively	1.55	1.11	0.55	0.29	0.37	1.62	1.19	0.59	0.33	0.75
Avg RBC units post-operatively	0.82	0.67	0.43	0.17	0.20	0.92	1.13	0.49	0.21	0.69
Avg total RBC units used	4.27	3.15	2.25	1.40	1.26	4.46	3.74	2.37	1.46	1.96
Avg total FFP units used	1.45	1.76	1.36	1.32	1.37	1.62	2.02	1.43	1.33	2.41
Avg total platelet units used	2.27	3.07	2.95	1.40	1.66	2.31	3.97	3.15	1.66	3.10

RBC=Red Blood Cell
FFP=Fresh Frozen Plasma

kg.). There were ten (10/211=4.7% peri-operative deaths. Twenty-one (21/211=10%) patients were classified as having bled excessively after surgery (greater than 500 cc from chest tubes in the first 12 hours post-op and/or requiring re-exploration). Four (4/211=1.9%) patients were re-explored for post-op bleeding. When the 31 cases involving peri-operative death or excessive bleeding were excluded, a selected subset of 180 "uncomplicated" cases remained.

Methods

All 211 patients' hospital charts were reviewed to determine the amount and type of blood products used in the CPB pump prime, intra-operatively, and 48 hours post-operatively. Hematocrit and platelet count values were recorded from pre-op studies, final CPB studies, and at discharge from the surgical intensive care unit (SICU). Post-operative blood loss was recorded from SICU records.

The one-tail student t-test for nonpaired data was used to statistically evaluate differences in mean values of the parameters examined over the course of the study.

Results

Table 1 details blood product utilization for the study groups. The trend toward utilization of less PRC products from 1978 to 1982 was highly significant (p .001). Consumption of fresh frozen plasma (FFP) and platelets has remained relatively constant over the study period.

Table 2 details results of hematologic studies on the total patient group. Average end-CPB hematocrit was significantly (p .001) lower in 1982 than in 1978. End-CPB platelet count was significantly (p .001) lower than pre-op values, but each remained relatively constant over the course of the study.

Table 2
Hematologic Studies

Study	1978	1979	1980	1981	1982
Avg Hct: Pre-op	41.5	41.7	40.7	41.8	42.7
Avg Hct: End-CPB	27.9	27/5	25.5	23.5	22.6
Avg Hct: Discharge from SICU	37.4	37.5	37.0	37.3	34.9
Avg Plt Count: Pre-op (x1000)	-	377	284	309	274
Avg Plt Count: End-CPB (x1000)	-	92	74	83	73
Avg Plt Count: Discharge SICU (x1000)	-	177	140	130	131

Hct=heamtocrit
Plt=platelet

Table 3 shows the percentages of patients receiving non-blood CPB prime solutions along with corresponding demographic data. In 1982, 48% of cases were performed without PRC products in the pump prime solution.

Table 3
Use of Non-Blood Prime

	1978	1979	1980	1981	1982
# Pts using non-blood CPB prime	0/13	0/32	2/60	9/58	23/48
% Pts using non-blood CPB prime	0%	0%	3%	16%	48%
Weight (kg)—Range	-	-	26-35	19-66	8.8-70
Weight (kg)—Mean	-	-	30.7	37.7	29.4
Weight (kg)—Median	-	-	30.7	33.6	27.0
Pre-op Hct—Mean	-	-	48.3	45.9	45.9
Pre-op Hct—Median	-	-	48.3	44.1	45.0

Hct=hematocrit

Table 4 shows correlation coefficients for the various relationships between CPB duration, platelet

counts, and estimated blood loss (EBL). CPB duration was a good predictor of end-CPB platelet count, decrease in platelet count with CPB, and EBL. Platelet counts did not correlate well with EBL.

Table 4
Hemostatic Correlations

Predictor	Related to	r	p
CPB duration	End-CPB Plt count	-0.61	0.001
CPB duration	% drop in Plt count with CPB	+0.51	0.001
CPB duration	EBL (12 hours)	+0.50	0.001
End-CPB Plt count	EBL (12 hours)	−0.07	0.2
%drop in Plt count with CPB	EBL (12 hours)	−0.16	0.2

Plt=platelet
EBL=Estimated Blood Loss

As shown in Table 5, EBL was related to complexity of diagnosis, and consequently, complexity of surgery. The difference in mean EBL between certain diagnostic groups, (e.g., between VSD's and complex diagnoses, including transposition of the great vessels), was significant (p .01).

Table 5
Estimated Blood Loss (EBL) By Diagnosis

Diagnosis	Mean 12-hour EBL (cc)
ASD	251
VSD	216
ToF (primary repair)	512
Complex (including TGV)	548

ToF=Tetralogy of Fallot
TGV=Transposition of Great Vessels

Peri-operative mortality remained relatively constant over the four year period of study, (1978-1/13=7.7%; 1979-1/32=3.1%; 1980-2/60=3.3%; 1981-4/58=6.9%; 1982 2/48=4.2%). Similarly, there was no change in morbidity during the period studied.

Discussion

Several investigators have reported on blood utilization and conservation in open heart surgery[2-11]. These reports deal either exclusively or primarily with adult patients undergoing CPB during coronary bypass grafting procedures. Roche and Stengle[2] reported data separately from a children's hospital, but these data are only from estimates obtained by questionnaire to hospital personnel (rather than by actual chart review) and are now ten years old. They found an average of 11 units of blood were used for pediatric open heart surgery (4 units prime, 5 units intra-operatively, and 2 units post-operatively). Bayer and associates[9] reported an average of 2.8 units of blood used per pediatric open heart case. More data are available only from adult populations. Average amounts of blood used during and[4,5,7,8,10,11] immediately after CPB procedures range from 0.9 to 4.8 units. In general, more recent studies show lower utilization of banked blood as autotransfusion, non-blood priming solutions, cardiotomy suction, collection of "discard" blood and reinfusion, better control of blood loss, and acceptance of normovolemic anemia are all employed.

In 1979, we began using the Cell Saver[a] in an effort to reduce consumption of banked blood. We have also increased the frequency with which we use non-blood pump prime (see Table III) as one half of our patients now receive no PRC products in CPB prime solutions. Our end-CPB hematocrits are significantly lower (Table II) now that we are accepting normovolemic anemia.

In order to conserve blood during operation on infants, several techniques were developed to eliminate the requirement for the use of more than one unit of packed red cells. During the induction of anesthesia the pump is primed with one or two units of packed cells as necessary depending upon the patient's weight and pre-operative hematocrit. Blood can then be withdrawn from the prime for use by the anesthesiologist if volume replacement is required prior to cannulation. After heparinization, the aortic cannula is inserted first and connected to the pump tubing. This allows transfusion from the pump prime during the insertion of venous cannulae. After heparinization, any shed blood within the pericardial cavity is collected by cardiotomy suction. After discontinuation of bypass, venous decannulation is performed first to allow continued transfusion with the residual blood in the pump. After aortic decannulation, approximately 50-100cc of the perfusate is withdrawn by syringe from the oxygenator and utilized by the anesthesiologist for volume replacement while the residual volume in the oxygenator is washed and centrifuged. Using these techniques, the need for more than one or two units of packed red cells can be virtually eliminated unless unusual bleeding is encountered.

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With these measures, we have been able to lower the average amount of PRC units used per patient from 4.3 to 1.9 for the entire patient population, and from 4.1 to 1.2 for uncomplicated procedures. While these savings represent a decreased burden on the blood bank, monetary savings are modest[12, 13]. However, the conservation of a precious resource and the minimizing of the risk of infection or transfusion reaction are sound arguments for such measures.

It is well known that CPB results in a decrease in platelet counts. Our data show that the consumption of platelets does not relate to eventual blood loss. However, CPB duration does correlate well with EBL as shown previously[3]. EBL also correlates with the clinical condition of the patient prior to surgery, as coagulopathies are common in patients with cyanotic congenital heart disease[14].

In summary, substantial banked blood savings can be realized by the use of the Cell Saver, nonblood CPB prime, and normovolemic anemia. Furthermore, this is possible without any increase in morbidity or mortality. In actuality, a reduction in morbidity may be realized in that the risks of transfusion are minimized by minimizing the amount of transfused red cell products.

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