
Cost-Effectiveness of Blood Conservation

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Introduction

The geometric growth rate of coronary artery bypass procedures has strained blood bank resources. This is becoming increasingly evident in small communities with rapidly expanding cardiac surgical programs. Four technical advances in use today can help the perfusionist and the surgeon alleviate this problem.

1) Hemodilution is a widely accepted practice, and it has been estimated that this technique has reduced blood bank requirements by as much as 50%. In addition, it has reduced the incidence of serum hepatitis and transfusion reactions.¹⁻⁵ This, in turn, has led to the acceptance of a lower post-operative hematocrit in these patients. 2) The use of blood component therapy for post-operative oozing and bleeding has been shown to be more effective than the use of fresh whole blood.⁶ 3) Careful monitoring of activated clotting times and lowered protamine to heparin ratios for heparin reversal has also reduced the need for additional blood due to bleeding from heparin-protamine imbalance.⁷ 4) Autotransfusion has been used intermittently for over 100 years, with the first reported use in 1818.⁸ Procedures such as pre-bleeding days before surgery or immediately prior to cardiopulmonary bypass have not gained wide acceptance.⁹⁻¹⁰ Autotransfusion of waste blood has been difficult due to the complexities of the return systems used.

The introduction of the Haemonetics Cell Saver* has alleviated many of the problems with autotransfusion. The Cell Saver was introduced for the purpose of centrifugation and washing of oxygenator contents after bypass. This step reduces the incidence of left ven-

tricular failure due to volume overload of the heart by returning remaining perfusate directly to the patient.⁶ This study expands our use of the Cell Saver for total blood recovery and processing to determine if the methods used were cost effective.

Materials and Methods

During a one month period from 7 November to 7 December 1979, twenty consecutive adult patients having cardiac surgery with the aid of cardiopulmonary bypass (CPB), underwent total blood conservation during surgery with the use of the Haemonetics Intraoperative Autotransfusion System. This group was compared retrospectively to twenty other adult patients having had cardiac surgery with CPB in the previous six months. The patients in both groups had placement of arterial and central venous lines for pressure monitoring, prior to induction with morphine anesthesia. Leads II and V5 were monitored on all patients. All patients had a median sternotomy and were cannulated for bypass through both cavae and the ascending aorta. The CPB circuit contained a bubble oxygenator** which was primed with 2 Liters of Isolyte E***. Seventy-five Grams of salt-poor albumin**** was added prior to going on bypass. Pump flow was calculated to 2.4 L/M² body surface area (BSA) with actual flows ranging from 2.2 to 3.0 L/M² BSA. All patients were cooled to an esophageal temperature of 28 degrees Centigrade. All patients received an initial dose of beef

* Haemonetics Corporation, Braintree, Massachusetts, 02184.

** S100A Shiley Sales Corporation, Irvine, California, 92714.

*** McGaw Laboratories, Irvine, California, 92714.

**** Travenol Laboratories, Glendale, California, 91202.

lung heparin***** equaling 3 mg/kg of body weight. Activated clotting times (ACT) were monitored every 20 minutes during CPB utilizing Hattersley's method for ACT determination.⁷ The ACT was maintained at 600 seconds or greater. Prior to coming off CPB, an automated protamine titration test***** was done to identify the amount of protamine needed to reduce existing circulating heparin to a normal ACT of 100 ± 15 seconds. All patients had direct aortic root injection of cryocardioplegia during continuous aortic crossclamp during CPB.

Arterial blood gases, potassium levels, hemoglobin, and urine output were measured after induction of anesthesia, pre-bypass, every 20 minutes during bypass, post-protamine administration, and upon arrival in the surgical intensive care unit. Chest tube drainage was recorded after 24 hours. A complete blood count (CBC) was obtained prior to discharge from the hospital. The amount of whole blood and packed cells given in the operating room and during the hospital stay was recorded. All patients had immediate centrifugation of oxygenator contents after bypass with a Cell Saver.

During the operation in the autotransfused group, all blood and irrigation in the operative field was aspirated through a harness system, which heparinized the blood, and was collected in a cardiotomy reservoir. When a sufficient amount was collected, the blood was centrifuged to a packed cell concentration of 65 – 75% as indicated in the manufacturer's operators manual. The packed cells were then washed with 400 milliliters (ml) to 750 ml. of normal saline. The washed, packed cells were then placed in a transfer pack for later reinfusion into the patient at the conclusion of CPB.

All statistical evaluations were performed utilizing Student's T-Test for matched pairs, analysis of variance and descriptive statistics programs created for the Radio Shack TRS-80*****. A significance level of 0.05 was selected.

Results

There were twenty patients in each group (Figures 1 and 2). Group A represents the blood conservation group while Group B represents the retrospectively

***** Upjohn Company, Kalamazoo, Michigan, 49001.

***** A-10 Hepcon, Hemotec, Incorporated, Englewood, Colorado, 80110.

***** Tandy Corporation, Fort Worth, Texas, 76102.

Figure 1. Patient Data

	Group A	Group B
Sex	16 Male 4 Female	16 Male 4 Female
Age	59.4 ± 6.7	60.1 ± 9.1
Pump Time	105.6 ± 39.9	105.3 ± 34.3
AXC Time*	66.1 ± 23.1	71.7 ± 23.2

* Aortic CrossClamp.

compared group of patients. There were four patients in Group B who needed intra-aortic balloon assist (IABP) whereas only one patient in Group A needed the IABP. One patient in Group A required re-exploration for bleeding. There was one death due to bi-ventricular failure in the early postoperative course in Group B.

There were no differences in age, sex, procedures, bypass time, aortic crossclamp time, operative and postoperative blood gases, potassium levels, or urine output. There were no differences in postoperative ACT's, including those patients having IABP assist, since we do not anticoagulate those patients having IABP assist for less than 36 hours.

The only significant difference in hemoglobin levels (Figure 3) was in the post-protamine measurement period. This was due to the infusion of the washed, packed cells collected during CPB.

The patients in Group B received a total of 84 units of whole blood and 32 units of packed cells (Figure 4). In addition, each patient received the equivalent of one unit of packed cells from the immediate centrifugation of the oxygenator contents following CPB (250 ml). The average cost to the patient for bank blood was \$179.80, excluding laboratory charges for typing and crossmatch.

The Patients in Group A received a total of 35 units of whole blood and 18 units of packed cells. They also

Figure 2. Procedures

	Group A	Group B
1 CAB*	1	1
2 CAB	3	1
3 CAB	7	4
4 CAB	3	4
5 CAB	4	7
6 CAB	0	1
MVC* 3 CAB	1	1
MVR*	1	1

* Coronary Artery Bypass (CAB), Mitral Valve Commissurotomy (MVC), Mitral Valve Replacement (MVR).

Figure 3. Hemoglobin Level (mean Gms \pm SD)

	Pre-Bypass	Bypass	Post Protamine*	Surgical Intensive Care	Discharge
Group A	13.4 \pm 1.5	7.7 \pm 1.3	10.7 \pm 1.4	12.5 \pm 1.4	11.7 \pm 1.4
Group B	12.9 \pm 1.9	7.2 \pm 1	9.7 \pm 1	11.6 \pm 1.6	11.3 \pm 2.2

* t = 2.25, p less than .05.

received a total of 72 units of autotransfused blood. The average cost for bank blood was \$83.70, excluding laboratory charges for type and crossmatch. The cost for additional disposable supplies for autotransfusion was \$37.50 regardless of the number of units of blood processed. This represents a total charge of \$121.20. Even though the patients in Group A received more blood (Figure 4), their total cost was less than Group B.

There were no significant differences in chest tube drainage after 24 hours in the two groups.

Discussion

The use of autotransfusion during cardiac surgery has enjoyed intermittent popularity over the last several years. Methods that have been used include: 1) pre-operative blood collection for storage and possible freezing for reuse at time of operation, 2) removal of one to two units of blood prior to CPB and replacement with a colloid or crystalloid solution¹¹ (With this method the blood is returned to the patient at the end of CPB.), and 3) the use of coronary suction pumps during the period the patient is heparinized.¹² This last method is used routinely by almost all cardiac surgical

teams. Other methods of autotransfusion require that the patient be fully heparinized or requires the addition of Acid Citrate Dextrose (ACD) or Citrate Phosphate Dextrose (CPD) as the blood is collected.¹³

Patients autotransfused in this manner may experience coagulation disorders, particularly following cardiac surgery. Hemolysis is very evident due to suction that is used in these systems and the blood-air interface which exists.

The principle advantages to autotransfusion are many. They include: 1) fewer transfusion reactions, 2) a decrease in blood diseases such as hepatitis and syphilis, 3) decrease of blood loss and hospital costs, and 4) a way to get around the constant demand for more blood due to an increase in cardiac surgery caseloads.¹⁴ Autologous blood has also been found to have much higher levels of 2,3-diphosphoglycerate(2,3 DPG) than bank blood which has been stored for any length of time.¹⁵⁻¹⁶

The Haemonetics Cell Saver is an outgrowth of the Haemonetics 15 Cell Washer used by many blood banking facilities. The Cell Saver was designed to be a small, quiet portable machine for use in the operating room. Its original use was to concentrate the contents of the oxygenator after CPB so that excess fluid and debris could be spun off, the cells washed, and the packed cells could then be returned to the patient and immediately raise the hematocrit. Eventually a "Y" type harness was designed to allow heparinization of blood as it passed through the leg of the "Y". This blood is then collected into a reservoir. Using the harness allows autotransfusion to be accomplished without systemic heparinization.

When a sufficient amount of blood and irrigation is collected, usually about 1000 ml., the blood is centrifuged and washed. It is then pumped to a transfer pack for later reinfusion by the anesthesiologist. In our experience, blood collection pre-bypass was negligible. One to two units of washed packed cells were usually collected during bypass while the rest was collected from oxygenator contents and from the surgical field after protamine administration and before closure of the chest.

Figure 4. Blood Loss and Blood Replacement

Loss and Replacement	Group A (mean ml \pm SD)	Group B (mean ml \pm SD)
Replacement		
Whole Blood		
In O.R.*	382 \pm 405	990 \pm 1170
Total**	742 \pm 535	1890 \pm 2511
Packed Cells		
In O.R.***	50 \pm 100	225 \pm 325
Total	262 \pm 277	400 \pm 380
Autotransfused	1012 \pm 290	\emptyset
Postoperative Chest Tube Drainage	672 \pm 335	545 \pm 363
No. of patients receiving no bank blood in O.R.	9 (45%)	2 (10%)

* t = 2.06, p less than .05.

** t = 1.89, p less than .05.

*** t = 2.33, p less than .05.

The original intent of this study was to determine if the additional disposable supplies needed was cost effective to the amount of blood being salvaged. It became apparent that we were reducing our dependence on blood bank supplies more than we had anticipated. The conservation and autotransfusion method resulted in a 46% decrease in the use of whole and packed blood.

Although the use of fresh frozen plasma and platelets did not increase in the conservation group, centrifuging and washing removes all clotting factors, hemolyzed red cells and debris.¹⁶ If large amounts of red cells are being washed, consideration should be given to infusing fresh frozen plasma and/or platelets.

The one patient who was re-explored for bleeding was in the conservation group. The bleeding was due to a side branch of a vein graft and not due to a coagulation problem.

Conclusion

The Haemonetics Cell Saver is easy to operate and an economical method for salvaging blood in the open-heart patient. While the patients in this study realized only a \$40.00 savings, the system did reduce the strain on blood bank facilities as well as possibly reducing risk factors from the use of bank blood. Therefore we consider the use of the Cell Saver as being cost-effective.

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