
Survey of Blood Conservation Techniques During Open Heart Surgery

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Abstract

The shortage of a safe and adequate blood supply for open heart surgery has prompted the development and institution of numerous blood conservation and autotransfusion techniques. A survey was conducted of 60 hospitals in the Northeastern United States to determine the frequency of application as well as the resultant effect on banked blood usage.

A total of 37 surveys were returned for a response rate of 62%. This represents an annual caseload of 23449 open heart procedures which is more than 10% of the total number performed annually in the U.S.

The following techniques were used during adult cases to conserve blood:

| | |
|------------------------------------|-----|
| No blood in prime | 95% |
| Membrane oxygenator | 67% |
| Chest drainage autotransfusion | 40% |
| Autotransfusion of suctioned blood | 40% |
| Pre-bypass volume removal | 18% |
| Hemoconcentrator | 8% |

Post bypass techniques for recovery of residual pump volume were also surveyed. The following techniques were employed:

| | |
|----------------------|-----|
| Centrifugation | 54% |
| Blood bag collection | 31% |
| Discarded | 11% |
| Hemoconcentration | 4% |

Kendall's Tau-b correlation coefficients showed a significant association between autotransfusion of suctioned blood ($p < .05$) and decreasing reported blood use, as well as priming volume and blood use ($p < .05$), although correlations were of small magnitude. When usage was compared across units of

packed red cells, for several blood conservation techniques greater usage was reported in the groups that used the smallest amount of blood.

Introduction

The demand for blood products for use during or following open heart surgery continues to increase despite the use of various blood conservation techniques. The increase in caseload, although not as rapid as in the late seventies and early eighties, continues to rise as well as the increase in complexity of operations due to a more elderly patient population. The introduction of coronary angioplasty techniques has further selected the patient group, and the most difficult cases are delegated to the cardiac surgery team.

The average number of packed red cells (PRC) per patient during cardiac surgery has decreased because of technological advances in cardiopulmonary bypass.¹ These advances are a product of the need to reduce blood consumption, as well as patient exposure to homologous blood. The use of these blood conservation techniques was surveyed to evaluate their effectiveness in reduction of bank blood requirements.

Various techniques of blood conservation have been shown to reduce demand. Hemodilution is responsible for more than half of the saving.^{4,7} Autotransfusion techniques such as pre-bypass withdrawal of blood, collection of suctioned blood and centrifugation in a cell washer, and post-bypass collections of chest drainage are probably the most cost-effective and further reduce consumption of blood products from 18–50%.^{1,8} Table 1 shows the percentage reduction of blood products reported with the use of these blood conservation techniques.

Of historical interest is a method of blood conservation that was reported in 1967 by Repogle.² A series of 193 patients underwent open heart surgery using disc oxygenators with "paired perfusions." This technique of using the same blood and perfusion circuit for two patients in a row was necessary due to the large demand for blood products for priming the per-

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Table 1.
% Reduction in Bank Blood Requirements

| | | |
|---|--------------|------------|
| Autologous Blood Withdrawal Prior To Bypass | | |
| 50% | Lawson (11) | |
| 25% | Hallowel (5) | |
| 18% | Kaplan (8) | |
| 0% | Pliam (12) | |
| Salvage of Suctioned Blood With a Cell Washer Device | | |
| 46% | Pelley (9) | |
| 35% | Breyer (3) | |
| 32% | Vertrees (4) | |
| 17% | Moran (10) | |
| 0% | Winton (11) | |
| Centrifugation of Oxygenator Contents | | |
| 25% | Moran (10) | |
| Combined Techniques | | |
| pre-bypass collection | 77% | Moran (10) |
| autotransfusion of suction blood | | |
| centrifugation of pump contents | | |
| pre-bypass collection | 20% | Cohn (7) |
| post-bypass | | |

fusion circuit. This "recycling" of blood was extremely successful in an era that is far removed from present day concerns regarding transmission of AIDS and hepatitis.³ Fortunately, the development of the modern disposable oxygenator has contributed much to the reduced demand for blood products.

Materials and Methods

A questionnaire regarding the use of blood conservation techniques was sent to 60 perfusionists in the Northeastern United States in July 1987. The list of perfusionists was supplied by a local distributor of cardiopulmonary bypass products. 37 surveys were received within the next month for a response rate of 61.6%. The survey was divided into adult and pediatric sections. The results represent the practice of conservation techniques in hospitals performing a combined total of 23,449 open heart procedures annually. This is approximately 10% of the total number of operations performed in the United States in 1987. The various questions relate to the frequency that a specific technique was used. The frequency was multiplied by the number of adult or pediatric cases reported to calculate the percentage of time that a technique was used in the total case population.

The average number of packed red cells per patient

from day of surgery until discharge was also questioned, as well as the average number of units collected and autotransfused by a cell washing device if used.

Correlation coefficients and corresponding tests of significance using the Kendall tau-b method were computed between the percentage usage of each blood conservation technique and the reported use of PRC. This non-parametric statistic can be computed if the variables are measured on at least an ordinal scale and yields a measure of the degree of association or correlation between the two sets of ranks. It has the added advantage of statistical control via its generalizability to a partial correlation coefficient. No assumptions are necessary about the distribution of the population scores.

The centers were divided into four groups to visualize the reported use of red cells ($N =$ units of PRC). Group I $N \leq 1$, Group II $1 < N \leq 2$, Group III $2 < N \leq 3$, and Group IV $N > 3$. The median percentage of time that each technique was performed was calculated for each of the four blood use groups.

A review of the first 25 coronary artery bypass graft (CABG) patients of 1988 and 1978 at Montefiore Medical Center was conducted to determine demographic changes in the patient population regarding age, weight, and preoperative hematocrit. The Wilcoxon rank sum test for independent samples was used to test for the statistically significant differences in this data.

Results

Adult Blood Conservation Techniques

Of the 35 hospitals that reported the percentage of use of the adult conservation techniques, two did not report blood use. Therefore Table 2 displays the percentage of use in this sample of 22,052 adult cases in the remaining 33 hospitals. No blood in the prime was used in 95% of the cases. Membrane oxygenators were

Table 2.
Adult Blood Conservation Survey Results

| | |
|------------------------------------|-------------------------------|
| No. of hospitals = 33 | |
| Total no. of adult cases = 22052 | |
| <i>Technique</i> | <i>% of Total Adult Cases</i> |
| No Blood in Prime | 95% |
| Membrane Oxygenator | 67% |
| Chest Drainage Autotransfusion | 40% |
| Autotransfusion of Suctioned Blood | 40% |
| Autologous Pre-Bypass Collection | 18% |
| Hemoconcentration | 8% |

used 67% of the time. Chest drainage autotransfusion and cell washer during bypass for collection of suctioned blood were both used in 40% of the cases.

Pre-bypass volume removal was performed in 18% of the cases, and hemoconcentrators were used only 8% of the time. For those sites who reported that blood was removed pre-bypass, the median volume removed was 500 ml. (range 300–1250). The median priming volume reported was 2000 ml. (range 1200–2500). The median lowest acceptable hematocrit on bypass was 18% with a range of 12–30% (Table 3).

The salvaging techniques used for blood remaining in the perfusion circuit at the end of bypass are shown in Table 4. 54% of the cases used centrifugation, 31% collected the volume in the circuit in a blood bag for transfusion after bypass without any processing. In 11% of the cases the blood was discarded, and in 4% a hemoconcentrator to remove excess fluid before transfusion was used. The reported median number of packed red cells used per patient was 2 units with a range of 0.3-8 units.

The only blood conservation technique for which the Kendall rank correlation coefficients showed a significant correlation with reported blood usage was the

use of a cell washer autotransfusion system, $p < .05$. The magnitude of the correlation was low however ($\tau = -.286$) (Table 5). Use of a membrane oxygenator had the second highest correlation ($\tau = -.223$). Another parameter, priming volume, was also significantly associated with blood usage, $p < .05$. Of the post-bypass disposal techniques, centrifugation and the collection of blood without processing had significant associations with reported blood use. The former showed an inverse relationship with blood use ($\tau = -.353$) and the latter was positively correlated ($\tau = +.308$) with PRC.

Dividing the hospitals by the reported average number of PRC/patient and examining the median percentage use of various blood conservation techniques showed some interesting trends (Table 6). The median percent of volume removed was highest in the group of hospitals that reported the use of less than 1 unit PRC/patient. Membrane oxygenator use was highest in the groups with the lower blood use. The median percent of cell washer autotransfusion use was highest in the centers that reported averages of less than 1 and between 1 and 2 units of blood/patient. Acceptance of a lower hematocrit on bypass was more prevalent in the lower blood use groups.

The disposal techniques for the blood remaining in the oxygenator showed that the highest blood usage group reported the lowest average of centrifugation

Table 3.
Adult Blood Conservation Survey Results

| (n = 33 hospitals) | | |
|---------------------------------|----------|---------------|
| | Median | Range |
| Autologous Blood Removed* | 500 ml. | 300–1250 ml. |
| Priming Volume | 2000 ml. | 1400–2500 ml. |
| Lower Limit of HCT. on Bypass | 18% | 12–30% |
| # of PRC/Patient Till Discharge | 2 units | 0.3–8 units |

*16 hospitals reported blood removed pre-bypass

Table 4
Salvage of Blood in the Perfusion Circuit at the End of Bypass

| N = 33 hospitals | |
|--------------------------------|------------------|
| Total # of adult cases = 22052 | |
| | % of Adult Cases |
| Centrifugation | 54% |
| Blood Bag Collection | 31% |
| Discarded | 11% |
| Hemoconcentration | 4% |

Table 5.
Kendall Tau-B Correlation Coefficients Between the Use of a Blood Conservation Techniques and the Average Number of Packed Red Cells Used

| (N = 33 hospitals) | | |
|------------------------------------|------------|----|
| Autotransfusion of Suctioned Blood | -.286 | * |
| Membrane Oxygenator | -.223 | |
| Lower Limit of Hematocrit | +.215 | |
| Autologous Pre-Bypass Collection | -.137 | |
| Chest Drainage Autotransfusion | +.135 | |
| No. of Open Heart Cases | +.122 | |
| % Blood Prime | +.078 | |
| Blood Cardioplegia | +.038 | |
| Priming Volume | -.272 | * |
| <i>Disposal Techniques</i> | | |
| Centrifugation | -.353 | * |
| Blood Bag Collection | +.308 | ** |
| Discard | +.128 | |
| Hemoconcentrate | -.023 | |
| Statistical Significance | * p < .05 | |
| | ** p < .01 | |

Table 6.
Median Percentage Used of Selected Blood Conservation Techniques by Reported Blood Use

| # OF UNITS OF PRC | N (hospitals) | Autotransfusion of Suctioned Blood | Membrane Oxygenator |
|-------------------|---------------|------------------------------------|-------------------------|
| N <= 1 | 6 | 100% | 100% |
| 1 < N <= 2 | 12 | 100% | 100% |
| 2 < N <= 3 | 5 | 1% | 100% |
| N > 3 | 10 | 10% | 50% |
| | | Hematocrit Lower Limit | % Autologous Collection |
| N <= 1 | 6 | 17% | 23% |
| 1 < N <= 2 | 12 | 17% | 3% |
| 2 < N <= 3 | 5 | 20% | 0% |
| N > 3 | 10 | 19% | 0% |

use (Table 7). Collection of the entire blood volume in a bag was used more often in the highest blood use group.

Pediatric Blood Conservation Techniques

The perfusion techniques in the pediatric section were reported from seven centers with a total annual caseload of 1397 open heart procedures. In contrast to the adult cases, bubble oxygenators were used 67% of the time. Crystalloid cardioplegia was the preferred method and used 56% of the time. Blood was used in the pump prime 88%, a cell washer for autotransfusion only 12%. In the majority of cases (58%), the blood remaining in the perfusion circuit was discarded. The reported median number of PRC/patient was 3.0 units with a range of 1.5–4.5.

Discussion

The warning by Roche and Stengle¹³ that “without significant and effective efforts toward blood conservation, the entire national blood resource would be consumed by patients undergoing heart surgery” has been heeded, and perfusionists employ a variety of

blood conservation techniques as demonstrated by this survey. Although the correlation coefficients are low, the display of median percentage of the time that the various conservation techniques were used does indicate the effectiveness in reducing the demand for homologous blood.

In a review of a sample of patients at Montefiore Medical Center consisting of the first 25 CABG patients in 1988 vs. the first 25 patients in 1977, the trend towards older patients, with lower average body weight and lower pre-op hematocrits is evident (Table 8). The average CABG patient in 1988 is 13 years older ($p < .0005$), 10 kg. less, and the pre-op Hct is 4% lower. Based on the indicators developed by Cosgrove et al.³ using multivariate logistic regression analysis, the only two predictors of increased blood requirements in CABG patients were age and red cell volume. Therefore, the use of blood conservation techniques should become more cost-effective, as this “changed” patient population’s need for homologous blood increases. The need for blood replacement is determined by many factors. Although affected by each individual hospital’s surgical and perfusion techniques, a trend can be seen by generating data from a number of Open Heart centers.

Table 7.
Median Percentage of Blood Disposal Techniques by Reported Blood Use

| # of Units of PRC | N (hospitals) | Centrifuge | Bag | Hemoc. | Discard |
|-------------------|---------------|------------|-----|--------|---------|
| N <= 1 | 6 | 100% | 0% | 0% | 0% |
| 1 < N <= 2 | 12 | 97% | 2% | 0% | 0% |
| 2 < N <= 3 | 5 | 98% | 0% | 0% | 0% |
| N > 3 | 10 | 10% | 67% | 0% | 0% |

Table 8.**Comparison of the First 25 Patients Undergoing CABG at Montefiore Medical Center**

| Year | median (range) | | |
|------|----------------|-------------|------------|
| | Age (yrs.)* | Wt. (kg.) | Hct. (%) |
| 1978 | 54 (35-70) | 83 (52-102) | 41 (34-44) |
| 1988 | 67 (45-80) | 73 (52-99) | 37 (27-48) |

*p<.005

Dr. Cosgrove in his editorial commentary concludes that "Strict cost accounting methods fail to take into account the huge expense of the mortality and morbidity of transfusion transmitted disease."³ The avoidance of homologous blood use during open heart surgery will continue to be a challenge to the perfusionist. The use of blood products is an important quality indicator of perfusion and surgical techniques that are utilized by each individual open heart team, and the efficient use of blood conservation techniques appears to have an impact on reducing the demand for blood.

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