

## Original Article

# *Comparative Analysis of Recovery of Cardiopulmonary Bypass Residual Blood: Cell Saver vs. Hemoconcentrator*

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### ABSTRACT

For surgical bleeding problems, the cell saver has been used to return shed blood; however, overuse can lead to a deficit in coagulation factors. Its usefulness has gained widespread use in many surgical settings.

The hemoconcentrator can aid in raising the hematocrit level while reducing blood utilization where large blood volume and/or large amounts of irrigation are returned to the perfusion circuit. The hemoconcentrator returns red blood cells without removing coagulation factors, unlike the cell saver.

In order to determine which method of returning residual blood from the cardiopulmonary bypass circuit is more desirable, blood samples were drawn both pre and post transfusion from 15 cell saver patients, and 14 hemoconcentrator patients. Twelve hour blood loss was recorded in 40 patients within each group.

The fibrinogen, platelet count, total protein, albumin and white blood cell count were similar between the two groups, as was the blood loss. The only significant differences found were the post red blood cell count, post hemoglobin, and the delta hematocrit, all being higher in autotransfusion group.

In conclusion, returning blood through the hemoconcentrator in the average adult perfusion circuit was not able to significantly raise certain coagulation parameters, nor reduce postoperative bleeding.

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## INTRODUCTION

The desire to minimize blood use and yet still provide satisfactory oxygen delivery with hemodilution has allowed the need for homologous blood utilization to be reduced, as well as reducing the risk of blood transmitted diseases. With hemodilution, capillary perfusion is improved within the microcirculation; however, the oxygen carrying capacity associated with hemodilution is reduced, necessitating hypothermia and/or increased flow rates to counteract the reduction of oxygen delivery. Hemodilution with the associated reduction in colloid osmotic pressure can lead to post-operative edema and fluid overload.

Utley (1) described important predictors of blood volume (BV), plasma volume (PV), and red blood cell count (RBC) in patients having coronary artery bypass grafting. While body surface area does have a strong influence on BV, smoking, sex of the patient, and emergency procedure can also influence BV, PV, and RBC. Cosgrove (2) also described principal determinants of blood volume and blood utilization.

The perfusionist has had several options to help minimize blood requirements:

- 1) Low priming oxygenators and circuits
- 2) Diuretics
- 3) Cell savers
- 4) Hemoconcentrators
- 5) Blood cardioplegia
- 6) Careful and discrete monitoring of blood samples

The hemoconcentrator and the cell saver have been valuable tools in removing excess water, but they have not been without some inherent problems. The hemoconcentrator has been shown to preserve factors necessary for colloid osmotic pressure as well as coagulation factors (3-6). While the clotting factors are retained, heparin is retained as well. During CPB the heparin retained does not cause a problem. On the contrary, one must monitor the patient's anticoagulation status if excessive water is removed because some heparin may actually be removed. If the hemoconcentrator is used following CPB as well as after the administration of protamine to salvage blood from the CPB circuit for packed red blood cells, then the clinician must bear in mind that while the clotting factors are being returned to the patient, so is heparin, and additional protamine may be required.

Naik (7) found that using the hemoconcentrator on children during CPB did not significantly reduce the total body water (TBW) amount; however, there was a significant reduction in TBW when the hemoconcentrator was used following CPB. Their results however do not show any results comparing the cell saver.

The Cell Saver uses a wash solution to remove heparin which will unfortunately also remove clotting factors. The clinician must then take into consideration that if large amounts of cell saver blood are used, clotting components may be needed to

maintain hemostasis.

Following CPB, one must decide which method is best to employ in returning the blood within the extracorporeal circuit to the patient. Hemoconcentration and cell saving both have their advantages and disadvantages (8). The principles of hemoconcentration and their practical applications have been described elsewhere (9). It is the purpose of this study to show if returning the coagulation factors from the extracorporeal circuit via the hemoconcentrator does indeed raise the patient's blood level of necessary clotting components, as well as lower blood loss post-operatively.

## MATERIALS AND METHODS

Prior to terminating CPB 80 male patients having coronary artery bypass grafting without transfusion (including left internal mammary graft) were divided into two groups: Group H (hemoconcentrator) had all the remaining blood within the CPB circuit concentrated with a hemoconcentrator following termination of CPB. Group C (Cell Saver) had all remaining blood within the CPB circuit processed with the cell saver (patient profile listed in Table One). Just prior to weaning each patient from CPB a final ACT was done and the protamine dose was derived from the heparin dose response curve.

Group H patients had the recirculation line coming off the Sarns Adult Membrane Oxygenator<sup>a</sup> connected to the blood inlet of the Minntech Hemocor Hemoconcentrator HP-950<sup>b</sup>, while the blood outlet of the hemoconcentrator was connected to the Gish ATR-2900F Cardiotomy<sup>c</sup>. Flow was initiated through the hemoconcentrator just prior to terminating CPB and the unit was debubbled. Once the hemoconcentrator was debubbled, recirculation through the hemoconcentrator continued without vacuum until the patient was weaned from CPB.

Once the patients in Group H were weaned from CPB and hemostasis was achieved with satisfactory hemodynamics, protamine was then administered. At this time, vacuum was applied to the hemoconcentrator at 300 mmHg while the inlet pressure was maintained at 150 mmHg. Excess fluid within the venous reservoir was allowed to recirculate through the hemoconcentrator with vacuum applied while the protamine was being administered. The "packed red blood cells" reconstituted from the hemoconcentrator continued to circulate back into the cardiotomy reservoir and into the venous reservoir until the venous reservoir bag was empty.

Once the protamine infusion was complete, the arterial and venous cannulae were removed and the volume within the arterial and venous lines was drained back into the venous reservoir. The blood drained from the arterial and venous lines was then also allowed to recirculate through the hemoconcentrator to remove excess fluid.

a Sarns, 3M Health Care, Ann Arbor, MI 48106

b Minntech, Minneapolis, MN 55441

c Gish Biomedical Inc., Santa Ana, CA 92705

**Table 1**

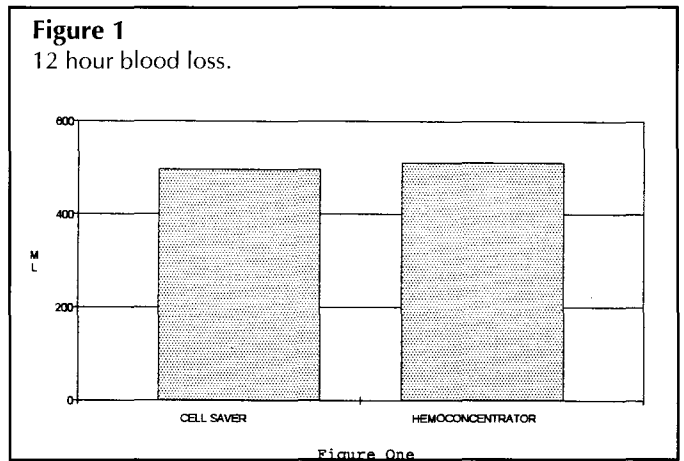
	MEAN (SD) GROUP C	MEAN (SD) GROUP H	
WEIGHT (kg)	85.47 (SD 12.35)	83.64 (SD 14.72)	NS
AGE (years)	61.55 (SD 10.96)	59.47 (SD 10.53)	NS
# OF GRAFTS	3.05 (SD 1.011)	3.075 (SD 1.095)	NS
BSA (m <sup>2</sup> )	2.01 (SD 0.20)	2.04 (SD 0.14)	NS
CPB TIME (min)	78.5 (SD 29.72)	77.0 (SD 23.93)	NS
AUTOLOGOUS BLOOD TRANSFUSED (ml)	722.5 (SD 200.3)	901.3 (SD 182.39)	NS

Once the venous reservoir bag was again emptied, the outlet of the hemoconcentrator was connected to a collection bag for the collection of autologous packed red blood cells. To remove the blood remaining within the oxygenator and pump header tubing, 1000 ml of Plasmalyte A<sup>d</sup> was infused into the cardiotomy and then into the venous reservoir bag. This fluid was then pumped into the circuit to "force" blood out of the pump header tubing and oxygenator and into the hemoconcentrator at an inlet pressure of 150 mmHg. This "flushing" technique was done so that the CPB circuit would still be primed and free of air if CPB had to be reinstated.

Group C patients had all remaining blood within the CPB circuit, which included the blood within the arterial and venous lines pumped into the Haemonetics Cell Saver<sup>e</sup> until the venous reservoir bag was emptied. At that point 1000 ml of Plasma Lyte A was infused into the cardiotomy and into the venous reservoir bag. This fluid was also used to "force" all remaining blood within the pump head tubing and oxygenator out of the circuit while maintaining a primed circuit. The blood was then packed and washed per the manufacturer's instructions.

Blood samples were drawn in 14 patients in Group H and 15 patients in Group C. There were two blood samples drawn from each patient, the first blood sample was drawn after protamine infusion was complete but just prior to the administration of the autologous packed red blood cells. This first sample served as the control, or the "pre" autologous infusion sample. After the blood sample was drawn, the autologous blood was then administered by the anesthesiologist.

Ten minutes after the arrival of the patient to the Cardiovascular Recovery Room (CVRU), another blood sample was drawn for a post autologous blood infusion test. Analysis was done for white blood cell count (WBC), red blood cell count (RBC), hemoglobin (Hgb), hematocrit (Hct), platelet count (Plt), fibrinogen (Fib), total protein (TP), and albumin (Alb). In addition to the blood samples, twelve hour blood loss was measured and recorded in 80 total patients (40 in each group).



No patients required homologous blood transfusion for low hematocrit or for excessive bleeding postoperatively. There were no re-explorations for bleeding, nor any hospital deaths.

**RESULTS**

The Levene's Test for Equality of Variances was used to analyze the significance (significance being reached when p is less than 0.05). The total and mean number of bypass grafts, age, BSA, CPB time and weight were similar between the two groups (Table 1). Group H patients received a greater amount of autologous blood (901 ml) compared to Group C (723 ml), but did not reach significance (p = 0.874)

Table 2 lists the results of the laboratory test on blood samples taken from the patient both before the autologous blood was administered (pre), and 10 minutes after arrival to the CVRU (post). In all patients, the blood infusion was completed prior to arrival to the CVRU. Any ACT greater than 125 seconds was treated with additional protamine in 25-50 mg increments.

There were no significant differences found between the two groups with respect to the fibrinogen, platelet count, total protein, albumin, and the white blood cell count both pre and post administration, as well as the difference between the specific groups pre and post infusion (Delta), nor when compared against each other. The hemoglobin pre, red blood cell pre, as well as the hematocrit pre showed no significant difference between the two groups. The blood loss between the two groups were comparable (Group H = 510 ml, Group C = 496 ml).

Significance was reached when comparing the RBC post of Group C to that of Group H (p = .05). The post-autologous infusion hemoglobin was higher in Group C (p = .031) despite having received a lower amount of volume (722.5 ml compared to 901.3 ml). This most likely was related to the higher hematocrit achieved with the cell saver. Periodic evaluation of the concentrated blood between the two groups yielded a Hct. in the range of 49-56% for the cell saver and 37-48% for the hemoconcentrator. The delta hematocrit (the difference between the pre and the post infusion in a specific group) was greater in Group C (p = .038) than that of Group H.

d Baxter Healthcare Corp., Deerfield, IL 60015  
 e Haemonetics Corp., Braintree, MA 02184

Table 2

	MEAN (SD) GROUP C	MEAN (SD) GROUP H	
FIBRINOGEN PRE (mg/dl)	212.8 (SD41.44)	180.5 (SD 58.0)	NS
FIBRINOGEN POST (mg/dl)	206.2 (SD 53.88)	205.2 (SD 54.38)	NS
DELTA FIBRINOGEN (mg/dl)	-6.6 (SD 27.2)	24.6 (SD21.17)	NS
PLATELET PRE (k/mm <sup>3</sup> )	170,133 (SD 60.24)	177,714 (SD 73.04)	NS
PLATELET POST (k/mm <sup>3</sup> )	165,800 (SD51.72)	180,214 (SD 73.60)	NS
DELTA PLATELET (k/mm <sup>3</sup> )	- 4.333 (SD 26.90)	2.500 (SD 18.81)	NS
TOTAL PROTEIN PRE (gm/dl)	3.71 (SD 0.5)	3.82 (SD 0.42)	NS
TOTAL PROTEIN POST (gm/dl)	3.86 (SD 0.72)	4.5 (SD 0.61)	NS
DELTA PROTEIN (gm/dl)	0.17 (SD 0.61)	0.68 (SD 0.54)	NS
ALBUMIN PRE (gm/dl)	2.5 (SD 0.32)	2.55 (SD 0.28)	NS
ALBUMIN POST (gm/dl)	2.74 (SD 0.34)	3.04 (SD 0.42)	NS
DELTA ALBUMIN (gm/dl)	0.24 (SD 0.31)	0.49 (SD 0.33)	NS
WBC PRE (k/mm <sup>3</sup> )	15.11 (SD 5.68)	16.59 (SD 4.87)	NS
WBC POST (k/mm <sup>3</sup> )	16.8 (SD 5.46)	15.66 (SD 6.59)	NS
DELTA WBC (k/mm <sup>3</sup> )	1.69 (SD 5.02)	-0.93 (SD 4.13)	NS
RBC PRE (m/mm <sup>3</sup> )	3.11 (SD 0.50)	2.98 (SD 0.35)	NS
RBC POST (m/mm <sup>3</sup> )	3.78 (SD 0.56)	3.37 (SD 0.37)	p=0.05
DELTA RBC (m/mm <sup>3</sup> )	0.67 (SD 0.29)	0.39 (SD 0.26)	NS
HGB PRE (gm/dl)	9.45 (SD1.55)	9.09 (SD 1.03)	NS
HGB POST (gm/dl)	11.57 (SD 1.79)	10.43 (SD1.07)	p=0.031
DELTA HGB (gm/dl)	2.12 (SD 0.88)	1.33 (SD0.76)	NS
HCT PRE (%)	28.08 (SD 4.29)	26.87 (SD 3.11)	NS
HCT POST (%)	33.88 (SD 4.98)	27.52 (SD 8.54)	NS
DELTA HCT (%)	5.81 (SD 2.38)	0.65 (SD 7.89)	p=0.038
BLOOD LOSS (ml)	496.5 (SD 208.9)	510.78 (SD 283.65)	NS

## DISCUSSION

The cell saver has been a valuable tool in salvaging blood, reducing blood utilization in a variety of clinical situations. Its simplicity and long term success has proven its effectiveness. The main disadvantage of using a cell saver is the loss of coagulation factors. Returning moderate amounts of cell saver blood does not seem to cause any problems. However, when there is excessive blood loss, returning large amounts of cell saver blood may lead to a coagulation deficit, necessitating the need for factor replacement.

Hemoconcentrators have also been able to show their effectiveness at removing excess water both during and follow-

ing CPB, while also retaining and returning valuable factors necessary for coagulation. The value of returning coagulation factors has led many to wonder as to whether the use of the hemoconcentrator will actually reduce blood utilization following CPB, related to the reduction of blood loss postoperatively.

Following CPB in the adult patient, there may be 1,500 ml of blood remaining within the oxygenator and arterial and venous lines. The question is which method of blood salvaging is superior. After administering hemoconcentrator blood to the patient, will there be a significant rise in factors necessary to ensure coagulation, while at the same time a reduction in blood loss postoperatively when compared to the cell saver, which returns red blood cells, but no coagulation factors?

Boldt (4) and Tamari (5) were able to show an increase in the albumin following transfusion in their hemoconcentrator patients. The albumin level in our study neither increased or decreased in Group H. Group C, however, surprisingly showed a slight increase, but not significantly.

The fibrinogen level on the other hand did increase in Group H, while Group C saw a reduction. Group H started with a lower level pre-CPB and ended just slightly higher with a net gain of 24 mg/dl. Group C on the other hand had a net loss of -7 mg/dl, but the results were insignificant. These results are similar to Sutton's (10) findings except her results did reach significance. Brickley (11) on the other hand, found the cell saver patients to have a slightly higher fibrinogen level.

One would expect the total protein to increase with the hemoconcentrator (4,11), and indeed, it did. However, the total protein level surprisingly rose in Group C as well. These results are comparable to Breyers (12) where the cell saver and hemoconcentrator patients had identical levels post-transfusion.

Boldt (4) and Sutton (10) both showed higher platelet counts in the hemoconcentrator group, as did our results. The net gain for Group H was 2,000, while Group C had a net loss of 4,000, a difference of 6,000, statistically not significant. Breyer (12) on the other hand, had a lower platelet count with the cell saver group (not unexpected), but did as well with the hemoconcentrator group when comparing to the pre-CPB levels. This was something one might not expect to see within the hemoconcentrator group.

Tamari (5,6,13) has shown that the hemoconcentrator raises the WBC. The WBC rose in both the cell saver as well as the hemoconcentrator patients for Solem (14), with the increase being greater in the cell saver group, but not significantly. Our results were similar to Solem's, however the increase in the WBC was much less (3.1 vs. 0.8) with the difference between the two groups (hemoconcentrator and cell saver) not being significant.

The only areas that did reach statistical significance were the post infusion RBC, post infusion Hbg and the Delta Hct. All results were greater in Group C than in Group H, despite the total volume transfused in Group C being less than in Group H (not significantly). This is most likely due to a higher Hct. of the transfused blood coming from the cell saver. Naik's (7) study in children showed that the hemoconcentrator could lower the patient's TBW when used post-CPB; however, the cell saver was not used as a comparison. In our study, Group H received more post autologous volume from the CPB circuit (901 ml vs. 723 ml), which translates into more TBW. While the results did not reach statistical significance, the extra volume in the critical patient may impose difficulty in the already weakened myocardium.

The ability of the hemoconcentrator to remove excess water while retaining clotting factors is well known. The value in returning these factors in the average clinical setting following CPB is less defined. There are many conflicting results to verify the efficiency of returning the hemoconcentrator blood. The issue is more defined when it is compared to the overall expect-

tations, lowering blood loss.

Returning blood with higher coagulation factors via the hemoconcentrator post-CPB has not been found to lower post-operative bleeding by several authors (3,4,10). Our results showed that the 12 hour blood loss was higher in the hemoconcentrator group (despite having normal ACTs before leaving the OR), but the results were not significant (Group C = 497 ml vs. Group H = 511 ml).

This leads one to wonder if the hemoconcentrator is indeed a valuable tool for managing post-CPB blood conservation in relation to post-operative blood loss. One possible explanation for the slightly higher blood loss could be due to delayed heparin rebound. The hemoconcentrator does return coagulation factors, but heparin is included as well. All blood was administered prior to leaving the operating room with the ACT being returned to a normal level, yet it is plausible that more rebound may occur in this group over several hours postoperatively. The use of the cell saver may help alleviate some of the possible heparin rebound phenomenon as the washing mode removes heparin (15).

While the hemoconcentrator does return coagulation factors, we were not able to show that after this blood is administered to the patient, that certain specific values (protein, albumin, fibrinogen, and platelet count) will be greater, let alone significantly greater when compared to those patients receiving blood from the cell saver. This in turn leads us to expect less than exciting results for lowering blood loss.

Twelve hour blood loss was not reduced with the use of the hemoconcentrator (Figure 1), questioning the value of post-CPB use in the adult patient with an average ending blood volume remaining within the CPB circuit. One must on the other hand, exercise caution when processing large amounts of autologous blood with the cell saver. If an extreme amount of blood is returned to the patient from the cell saver, a coagulation profile may be indicated.

We routinely use the cell saver to scavenge blood both pre and postoperatively. It has been our technique to concentrate the blood remaining within the CPB circuit following decannulation. Blood loss is always a concern, and we attempted to further minimize blood loss by concentrating the CPB volume following decannulation with the use of the hemoconcentrator. However, we were not able to show any reduction in the blood loss with the hemoconcentrator, raising the question of its value post bypass, as well as considering the added cost factor.

In conclusion, the cell saver has proven to be a valuable tool in salvaging autologous blood in a variety of clinical applications. The returned blood has been found to have an acceptable RBC life span (16), and in our investigation did not increase the blood loss over the use of the hemoconcentrator. The hemoconcentrator on the other hand, was not found to significantly increase the platelet count, fibrinogen, protein, albumin, nor to lower the post-operative blood loss when compared to the cell saver. This leads us to believe that for processing an average of 901 ml of hemoconcentrator blood will not reduce postoperative bleeding when compared to processing 3 bowls (722.5 ml in this

study) of blood from the cell saver.

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## REFERENCES

1. Utley JR, Morgan MS, Johnson HD, Wilde CM, Bell MS. Correlates of blood volume, red cell mass and plasma volume in coronary bypass patients. *Perfusion*. 1989; 4: 205-211.
2. Cosgrove DM, Loop FD, Lytle BW, et al. Determinants of blood utilization during myocardial revascularization. *Ann Thorac Surg*. 1985; 40: 380-384.
3. Nakamura Y, Masuda M, Toshima Y, et al. Comparative study of cell saver and ultrafiltration nontransfusion in cardiac surgery. *Ann Thorac Surg* 1990; 49: 973-978.
4. Boldt J, Kling D, von Bormann B, Zuge M, Scheld H, Hempelmann G. Blood conservation in cardiac operations. *J Thorac Cardiovasc Surg*. 1989; 97: 832-840.
5. Tamari Y, Nelson RL, Levy RS, et al. Effects of the hemoconcentrator on blood. *J Extra-Corpor Technol*. 1984; 16: 89-94.
6. Tamari Y, Nelson R, Levy R, et al. Conversion of dilute pump blood to whole blood by single pass ultrafiltration. *J Extra-Corpor Technol*. 1983; 15: 126-132.
7. Naik SK, Knight A, Elliott MJ. A successful modification of ultrafiltration for cardiopulmonary bypass in children. *Perfusion*. 1991; 6: 41-50
8. Page PA. Ultrafiltration versus cell washing for blood concentration. *J Extra-Corpor Technol*. 1990; 22: 142-150.
9. Wheeldon D, Bethune D. Haemofiltration during cardiopulmonary bypass. *Perfusion* 1990; 5 (suppl): 39-51.
10. Sutton RG, Kratz JM, Spinale FG, Crawford FA. Comparison of three blood-processing techniques during and after cardiopulmonary bypass. *Ann Thorac Surg*. 1993; 56: 938-943.
11. Brickley JM, Kalshoven JD, Wilds SL, Dearing JP. A comparison of two methods of post-bypass hemoconcentration. *J Extra-Corpor Technol*. 1982; 14: 431-436.
12. Breyer RH, Engelman RM, Rousou JA, Lemeshow SA. A comparison of cell saver versus ultrafilter during coronary artery bypass operations. *J Thorac Cardiovasc Surg*. 1985; 90: 736- 740.
13. Tamari Y, Nelson R, Levy R, et al. Concentration of blood in the extracorporeal circuit using ultrafiltration. *J Extra-Corpor Technol*. 1983; 15: 133-142.
14. Solem JO, Tengborn L, Lubrs C. Cell saver versus hemofilter for concentration of oxygenator blood after cardiopulmonary bypass. *Thorac Cardiovasc Surgeon* 1987; 35: 42-47.
15. Umlas J, O'Neill TP. Heparin removal in an autotransfuser device. *Transfusion*. 1981; 21: 70-72.
16. Ansell J, Parrilla N, King M, et al. Survival of autotransfused red blood cells recovered from the surgical field during cardiovascular operations. *J Thorac Cardiovasc Surg*. 1982; 84: 387-391.