

Quality of Red Blood Cells Using Autotransfusion Devices: A Comparative Analysis

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Abstract: Cell salvage devices are routinely used to process and wash red blood cells (RBCs) shed during surgical interventions. Although the principle theory of cell saving is the same, the actual process to achieve this is very different from one device to another. The purpose of this study was to compare the quality of washed, concentrated RBC produced by five very different cell-saving devices, specifically the Cobe BRAT 2, Medtronic Sequestra 1000, Haemonetics Cell Saver 5, Medtronic Autolog, and the Fresenius CATS. Reservoir and washed red blood cells were analyzed for hematocrit (Hct), platelets (PLT), leukocytes (WBC), potassium (K+), heparin, plasma-free hemoglobin

(PFH), RBC mass recovery and recovery rate. The Haemonetics and BRAT 2 had the highest RBC recovery. All devices adequately removed heparin and potassium. The Medtronic Autolog had the highest removal of platelets and PFH; whereas, the BRAT had the lowest. Although the Autolog had the highest leukocyte removal, leukocytes were not adequately washed out by any of the autotransfusion devices. In conclusion, although all cell-saving devices use the same theory of centrifugation, the actual quality of the washed RBC product differs widely from one device to another. **Keywords:** cell savers, autotransfusion device, quality, washed, red blood cells. *JECT. 2003;35:28-34*

Autotransfusion of shed blood was first proposed by Dr. James Blundell in 1818. He postulated that the salvage and reinfusion of shed patient blood during surgery could potentially be a valuable resource in surgical procedures. However, it wasn't until 1885 that the first clinical cases were reported (1). This eventually led to the increased acceptance of autotransfusion throughout North America and Europe during the early 1900s. However, with the introduction of modern blood banking in the 1950s, the use of salvaged blood quickly declined (2). Within the last decade, the increased cost and shortages of banked blood, along with the concerns of transfusion reactions and disease transmission using homologous blood, has again pushed autotransfusion of salvaged blood to the forefront.

Presently, the autotransfusion of shed blood is accomplished with very sophisticated machinery. These cell salvage devices are routinely used to process and wash red blood cells (RBCs) shed during surgical interventions. There are several commercially available cell-saving devices; however, the specific advantages or disadvantages of each are still debatable. All salvage devices operate by separating anticoagulated whole blood into its individual

components through centrifugation. Blood is an ideal biologic mixture for such a technique because it is a suspension of heterogeneous elements of significantly different densities and, thus, is easy to separate. When subjected to a centrifugal force, the components will migrate relative to their respective density, with the higher density components moving farther from the axis of rotation than less dense components. As blood continues to enter a spinning chamber, the high-density red cell pack begins to occupy more of the chamber volume, and excess plasma is pushed ahead of the red cells. When the total liquid volume of the chamber has been exceeded, the excess plasma is expelled through the effluent fluid outlet into a waste bag. Thus, red blood cells from the operative field are spun down in the centrifuge, discarding waste materials and lysed red blood cells. To clear the red cell pack of contaminants, it is washed with isotonic saline (0.9% sodium chloride solution). At the termination of washing, the clean, packed red cells are transferred to a holding bag, which can then be transfused into the patient. The final concentrated RBC product is a cleaner, compacted and a more safely transfusable RBC product. However, it is still recommended that a 40- μ m filter be used to rid the RBC product of high-density debris that may be left, even after washing (3). This is especially true during orthopedic cases, where high-density bone fragments may be generated.

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A variety of contaminants are intentionally or unintentionally added or aspirated with the blood. Some of these include heparin or other anticoagulants, antibiotics, and irrigants such as saline, and also such debris as clot, fat, and bone fragments. Autotransfusion systems should be able to remove at least 90% of these contaminants (4).

Although the principle theory of cell salvaging and washing is the same, the actual process to achieve this varies from one device to another. This variation between the different types of cell-saving devices may also result in differences in the quality of the concentrated RBC product. The purpose of this study was to compare the quality of washed, concentrated RBC produced by five very different cell-saving devices specifically the Medtronic Autolog, Cobe BRAT 2, Medtronic Sequestra 1000, Haemonetics Cell Saver 5, and the Fresenius Continuous Autotransfusion System (CATS). All devices produce washed, packed red blood cells by centrifugal cell salvage.

METHOD

Cardiac surgery patients for whom cell salvage was required were divided into five groups based upon the type of autotransfusion device. Although this is an adult study, only the low-volume bowls were used for all the autotransfusion devices to avoid unnecessary waste. All devices were evaluated using the manufacturers recommended protocols in the automatic mode.

1. Medtronic Autolog: The Medtronic Autolog (Medtronic Inc., Minneapolis, MN) uses a tall cylindrical bowl with two indentations in the sides to increase mixing of cells. It operates at a speed of 10,000 rpm with a volume of 135 mL. Initially, the bowl fills at 600 mL/min, slowing down to 250 mL/min during the secondary bowl fill. During the wash cycle, wash fluid is pulsed through the bowl, which, along with the indentations, increases turbulence and, thus, the washing efficiency. The wash volume used is 250 mL.
2. Cobe Baylor Rapid Autotransfusion Device (BRAT): The BRAT 2 (COBE Cardiovascular, Denver, CO) uses the Baylor 135 mL cylindrical centrifuge bowl at a speed of 4400 rpm. The bowl is filled at a recommended rate of 200 mL/min, washed at 400 mL/min, and emptied at 200 mL/min. The recommended wash volume using this bowl is 1000 mL.
3. Medtronic Sequestra 1000: The Sequestra 1000 (Medtronic Inc., Minneapolis, MN) uses the Latham type bell-shaped bowl. The bowl size used was 125 mL. It operates at a centrifugal speed of 5600 rpm. Both fill, wash and empty rates are standard at 300 mL/min. The recommended wash volume for cardiac cases is 1000 mL.
4. Fresenius CATS: The Fresenius CATS (Fresenius HemoCare, Inc., Germany) uses a closed spiral-

washing chamber for a continuous washing process. The centrifuge speed varies from 1400–2400 rpm with a prime volume of 210 mL. The protocol used in this study was the Quality Wash in which there is a 5:1 wash solution to blood ratio.

5. Haemonetics Cell Saver 5: The Cell Saver 5 (Haemonetics Corp., Braintree, MA) also uses the Latham bowl technology; however, the bottom of the bowl has impellers to improve mixing. The bowl size used was the low volume 125 mL bowl. The centrifuge spins at 5650 rpm, fills, and washes at 300 mL/min, then empties at 500 mL/min. The wash volume was 750 mL.

Operators were limited to those who have been properly trained to use the autotransfusion devices. The same device was used for each case throughout the study. Each autotransfusion machine was set up according to manufacturers' specifications using the recommended fill, wash, and empty rates in the automatic mode, with a maximum controlled suction of 150 mmHg. The cell saver was set up as per usual protocol with a 150- μ m reservoir. Two luer connectors with stopcocks were placed; first, after the reservoir; and second, before the blood bag for sampling. Before processing, the reservoir was agitated to ensure adequate mixing. The fill cycle was started, and the time was recorded. Blood was withdrawn from the reservoir line and placed in appropriate containers without using needles to avoid hemolysis. Once the cycle was completed (i.e., start of fill to end of empty), the time was recorded, and the blood was withdrawn from the holding bag through a stopcock. Reservoir and process volumes were recorded, and samples were sent to the lab.

If there were not enough RBCs to perform an effective wash (i.e., bowl is not completely filled), the contents were returned to the reservoir until enough blood had been salvaged from the operating field. This procedure was repeated each time a bowl was processed.

Analysis of Blood Samples

Complete Blood Count: 3 mL samples were placed in EDTA vacuum containers and labeled. The blood was then analyzed for platelets, white blood cells (WBC), total red blood cells and hematocrit (Hct) using a coulter counter.

Potassium: 3 mL of blood was collected in a dry heparinized blood gas syringe and analyzed for potassium levels using the Nova pHox (Nova Biomedical Corp., Waltham, MA) blood gas analyzer.

Heparin Analysis: 4.5 mL samples were collected in citrate containers and centrifuged twice for 20 minutes each. After centrifugation the citrated plasma was then frozen at -70°C . Once enough samples were collected they were analyzed for heparin using a chromogenic assay utilizing Anti-Factor 10a.

Plasma Hemoglobin: 5 mL of blood was collected in the heparinized tubes and centrifuged twice for 20 minutes. Plasma was then taken off and analyzed for plasma free hemoglobin (FH) utilizing a spectrometric assay.

Processing Time: The processing time for all devices was also recorded. The times were measured from the start of processing to the production of the final product (i.e., start of filling to the end of the empty cycle).

Red Blood Cell Recovery: The red blood cell mass recovery in terms of a percentage value, as well as the red blood cell mass-processing rate was calculated. The starting and ending hematocrits and liquid volumes in the collection reservoir and holding bag were recorded and the recovery calculated using the following equation:

$$\text{RBC Recovery (\%)} = (V_{\text{HB}} \times \text{Hct}_{\text{HB}}) / (V_{\text{R}} \times \text{Hct}_{\text{R}}) \times 100\%$$

Where V_{HB} = Holding Bag volume

Hct_{HB} = Holding Bag hematocrit

V_{R} = Reservoir Volume

Hct_{R} = Reservoir hematocrit

Statistical Analysis

Statistical analysis of all data was done using the single factor ANOVA. A two-tailed p value of less than 0.05 was considered statistically significant.

RESULTS

A total of 65 cardiac operations were entered in the study. None of the patients were on drugs that directly affect red blood cell integrity such as sulphonamide. Table 1 shows the number of patients and process procedures for each of the autotransfusion devices. All findings are summarized in Tables 2 and 3.

Red Blood Cell Recovery

There were no significant differences between the various autotransfusion devices with regards to the starting Hct. However, the CATS gave a significantly higher Hct than all the other devices ($p < 0.05$) with a mean of $66\% \pm 7\%$ while the Haemonetics Cell Saver 5 had a significantly lower Hct than all the rest ($46 \pm 4.6\%$, $p < 0.05$). Also the Autolog had a significantly higher Hct than both the BRAT and the Sequestra (Figure 1).

Table 1. Number of patients included in the study and the actual number of processes done with each cell saver.

	Cases	Processes
Sequestra	12	22
BRAT 2	11	21
Haemonetics	11	21
Autolog	11	17
CATS	20	20

When looking at the percentage of RBCs recovered using the equation:

$$\text{RBC Recovery (\%)} = (V_{\text{HB}} \times \text{Hct}_{\text{HB}}) / (V_{\text{R}} \times \text{Hct}_{\text{R}}) \times 100\%$$

Where V_{HB} = Holding Bag volume

Hct_{HB} = Holding Bag hematocrit

V_{R} = Reservoir Volume

Hct_{R} = Reservoir hematocrit

a totally different picture arises (Figure 2). Haemonetics has a significantly higher RBC recovery than the CATS, Autolog or Sequestra ($94 \pm 16\%$, $p < 0.05$) while the BRAT 2 had a significantly higher RBC recovery than the Autolog and Sequestra ($94 \pm 18\%$, $p < 0.05$).

Processing Times and Volumes:

The processing times and volumes are summarized in Table 4. Since the CATS system is a continuous system, only the devices that use bowl technology were used in this comparison. The Sequestra and BRAT 2 had the longest process times at 6.1 ± 0.7 min and 6.1 ± 2.1 min respectively ($p < 0.05$). There was no significant difference between the Haemonetics and the Autolog. The Haemonetics had the lowest processing volumes of all the devices (437 ± 114 ml, $p < 0.02$).

RBC Mass Recovery Rate:

To compare all the autotransfusion machines the RBC mass recovery rate was used. This was calculated by dividing the volume of RBCs recovered by the time it took to process the RBCs as expressed in the following equation:

$$\text{RBC Mass Recovery} = V_{\text{HB}} \times \text{Hct}_{\text{HB}} / \text{Process Time}$$

Where: V_{HB} = Volume of RBCs in the holding bag,

Hct_{HB} = Hct of the blood in the holding bag.

The calculated RBC mass processing rate, as depicted in Figure 3, shows that the Haemonetics had a significantly higher RBC recovery rate than that of all the other devices (22 ± 7 ml/min, $p < 0.05$) while the Sequestra had the poorest recovery rate (10 ± 2 ml/min, $p < 0.05$). The Autolog had a significantly higher recovery rate than the BRAT 2 and CATS (18 ± 5 ml/min vs. 14 ± 5 and 14 ± 5 ml/min respectively, $p < 0.05$).

Quality of Wash

The Quality of the washed blood was assessed by calculating the percent removal of the contaminants of leukocytes, platelets, plasma free hemoglobin, heparin and potassium using the following equation:

Table 2. Summary of complete blood count for all cell savers.

	Pre Hct (%)	Post Hct (%)	Pre Plt (×10 ⁹ /L)	Post Plt (×10 ⁹ /L)	Pre WBC (×10 ⁹ /L)	Post WBC (×10 ⁹ /L)
Sequestra	15 ± 3.7	57 ± 6.1	65.1 ± 47.2	24.7 ± 44.2	4.27 ± 1.52	7.1 ± 2.9
BRAT 2	15 ± 3.8	54 ± 8.0	79.9 ± 28.4	89.2 ± 70.9	5.98 ± 3.37	15.1 ± 5.45
CATS	14 ± 4.6	66 ± 7.0	67.6 ± 38.3	28.0 ± 25.6	3.37 ± 1.23	9.7 ± 4.2
Haemonetics	15 ± 4.2	46 ± 4.6	63.9 ± 27.7	24.6 ± 21.0	3.71 ± 1.41	8.1 ± 3.4
Autolog	17 ± 2.9	62 ± 2.2	61.2 ± 22.8	3.7 ± 2.1	4.78 ± 1.5	4.9 ± 2.7

Table 3. Summary of heparin, potassium, and plasma-free hemoglobin in the reservoir (pre) and holding bag (post) of the various cell savers.

	Pre Heparin (units/mL)	Post Heparin (units/mL)	Pre K+ (mmol/L)	Post K+ (mmol/L)	Pre PFH (mg/L)	Post PFH (mg/L)
Sequestra	11.8 ± 5.0	0.61 ± 0.36	4.7 ± 1.4	1.7 ± 0.31	3078 ± 1508	1476 ± 793
BRAT 2	11.4 ± 6.2	0.80 ± 0.65	5.2 ± 2.0	2.0 ± 0.71	1788 ± 1288	3093 ± 2803
CATS	11.5 ± 7.9	0.73 ± 0.86	4.9 ± 2.2	2.6 ± 0.47	2322 ± 1031	2942 ± 2716
Haemonetics	13.0 ± 11.5	0.19 ± 0.17	4.9 ± 1.5	1.4 ± 0.39	2386 ± 952	1224 ± 797
Autolog	7.75 ± 5.0	0.39 ± 0.33	5.6 ± 1.8	2.2 ± 0.15	3640 ± 1341	1324 ± 466

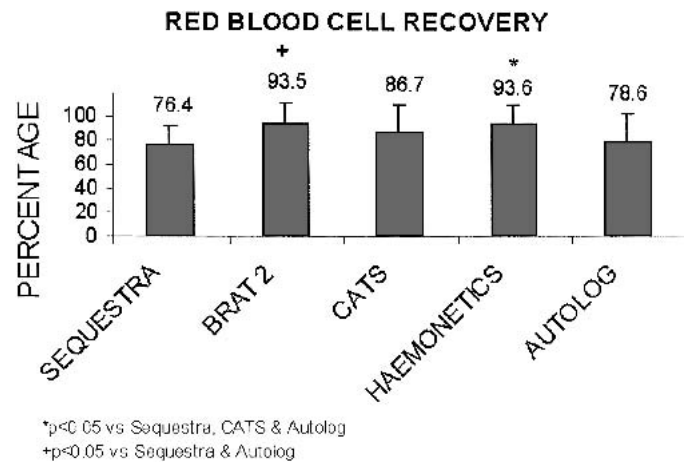
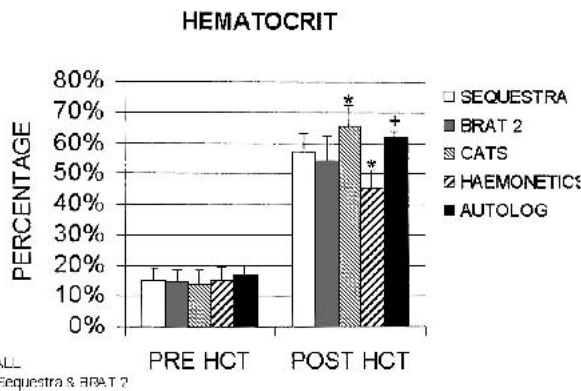


Figure 1. Cell saver comparison of hematocrit before and after final processing.

Figure 2. Comparison of the red blood cell recovery.

$$\% \text{ Removal} = \frac{[1 - (V_{HB} \times [Sub]_{HB}) / (V_R \times [Sub]_R)] \times 100\%}{}$$

where: V_{HB} = Volume in the Holding Bag
 $[Sub]_{HB}$ = Concentration of substance in the Holding Bag
 V_R = Processed volume in the reservoir
 $[Sub]_R$ = Concentration of substance in the reservoir

Results are summarized in Table 5.

Heparin Removal: All cell savers removed heparin adequately with over 98% removal (Figure 4). However, the Haemonetics had the greatest heparin removal with 99% ± 6% ($p < 0.05$ vs. all).

Potassium Removal: There were no statistically significant differences between the groups for potassium removal. (Figure 5).

Plasma Free Hemoglobin (PFH): The Autolog had the highest PFH removal of all the autotransfusion devices (92% ± 4, $p < 0.05$) (Figure 6). The Sequestra had a significantly higher removal than the BRAT 2 ($p < 0.05$). The

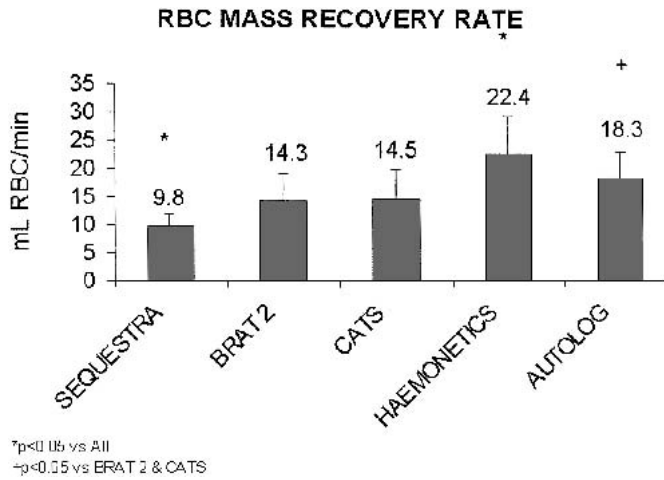
Table 4. Processing times, reservoir, and final RBC volumes.

	Reservoir (mL) Mean ± SD	RBCs (mL) Mean ± SD	Process Time (min) Mean ± SD
Sequestra	539 ± 121	105 ± 27	6.1 ± 0.7
BRAT 2	649 ± 283	146 ± 4.6	6.1 ± 2.1
Haemonetics	437 ± 114	123 ± 3.0	4.4 ± 1.7
Autolog	548 ± 148	110 ± 17	3.8 ± 0.7
CATS	1213 ± 543	241 ± 151	10 ± 3.0

PFH removal of the CATS was very inconsistent as reflected by the very large standard deviations.

Platelet Removal: As shown in Figure 7 the Autolog had a significantly higher platelet removal than all the other devices (99% ± 1%, $p < 0.05$) while the platelet removal of the BRAT 2 was significantly lower than any of the other machines (68% ± 20%, $p < 0.05$).

Leukocyte Removal: All autotransfusion devices did a very poor job of removing leukocytes (Figure 8). The



*p<0.05 vs All
 †p<0.05 vs BRAT 2 & CATS

Figure 3. RBC mass processing rate of the various autotransfusion devices.

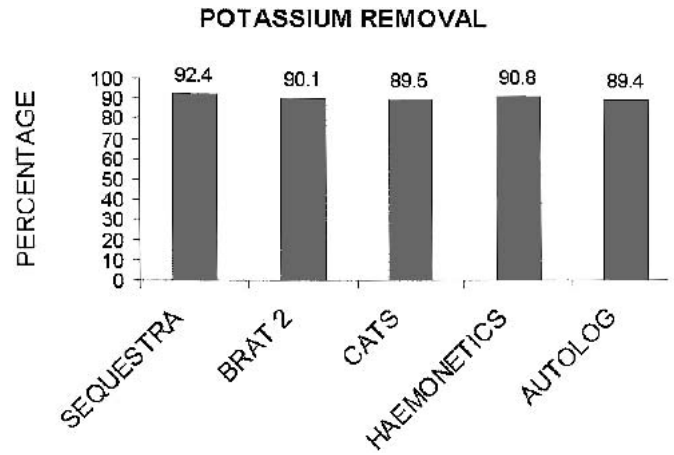
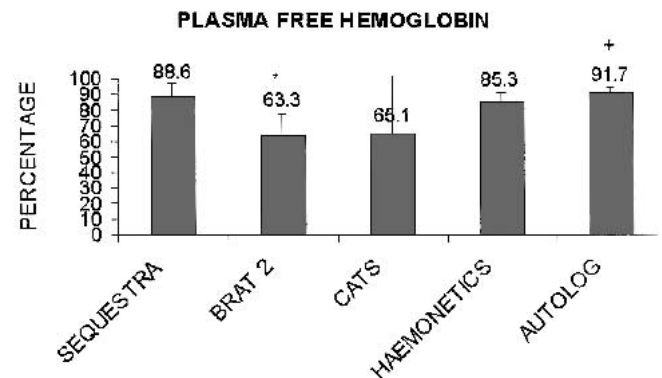


Figure 5. Percent potassium removal.

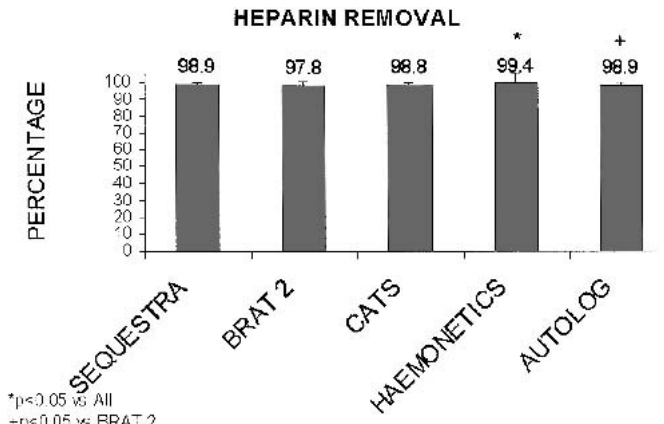
Table 5. Quality of wash.

	% Removal				
	WBC	PLT	Heparin	K+	PFH
Sequestra	66 ± 14	93 ± 12	99 ± 1	92 ± 3	89 ± 8
BRAT 2	30 ± 26	68 ± 20	98 ± 2	90 ± 3	63 ± 14
CATS	45 ± 32	93 ± 7	99 ± 1	90 ± 4	65 ± 58
Haemonetics	35 ± 17	86 ± 23	99 ± 6	91 ± 4	85 ± 6
Autolog	78 ± 11	99 ± 1	99 ± 2	89 ± 4	92 ± 4



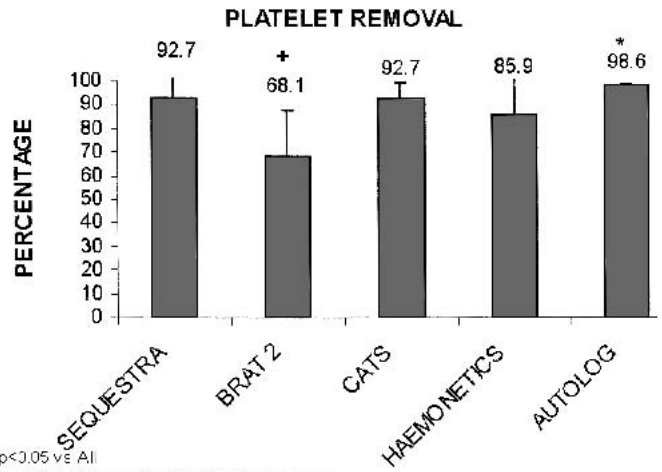
*p<0.001 vs Sequestra, Haemonetics & Autolog; †p<0.001 vs Haemonetics

Figure 6. Percent plasma free hemoglobin removal.



*p<0.05 vs All
 †p<0.05 vs BRAT 2

Figure 4. Percent heparin removal.



*p<0.05 vs All
 †p<0.05 vs Sequestra, CATS & Haemonetics

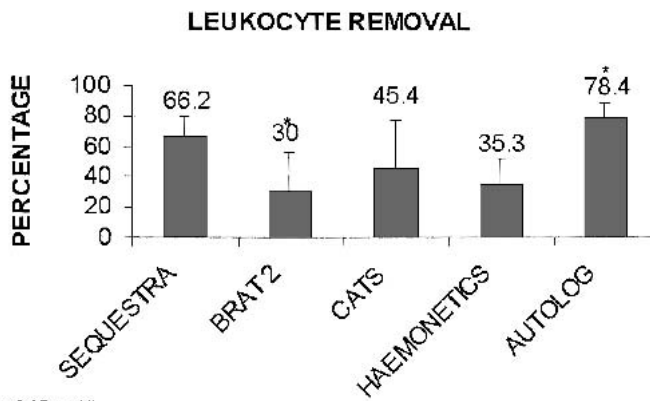
Figure 7. Percentage of platelets removed during the wash cycle.

Autolog was significantly better than the rest with 78% ± 11% ($p < 0.05$) followed by the Sequestra with 66% ± 14% ($p < 0.05$ compared to CATS, BRAT 2 and Haemonetics). The BRAT 2 had the worst removal with 30 ± 26% ($p < 0.05$).

DISCUSSION

While all cell saving devices use the same theory of centrifugation and washing this study clearly shows that the actual RBC product produced by the different cell

savers varies significantly from one device to another. The hematocrit value of blood salvaged from cases in this study varied from values as low as 10% with an average of approximately 15%. The first challenge for effective blood salvage is to raise the hematocrit value to an acceptable



*p<0.05 vs All

Figure 8. Percentage of leukocytes removed during the wash cycle.

level. By centrifugation we hope to reach hematocrit levels above 50–55%. All of the cell savers in this study easily reached this goal with the exception of the Haemonetics Cell Saver 5, which had an average hematocrit of 45%. Surprisingly, when you take into account the total RBC recovery the Haemonetics Cell Saver 5 had the highest recovery even though it had the lowest hematocrit. This is a very significant clinical finding that for the most part is ignored when comparing or evaluating cell savers. Thus inferring that the hematocrit is of little significance compared to the amount of RBCs that are recovered. Ideally all cell savers should be able to recover 100% of the RBCs with no wastage, however, the BRAT 2 and more consistently the Cell Saver 5 were the only cell savers that came close to this at approximately 94%. Therefore a lower hematocrit is clinically insignificant as long as you are retrieving most of the RBCs.

Active suctioning and air to blood interfaces can cause a high degree of hemolysis. Whole blood with hemolysed RBCs has very high levels of PFH, potassium, protein and lipid content. Electrolytes and proteins, especially potassium and albumin, are good markers or indicators of washing efficiency with at least 90% removal constituting an effective wash. Potassium concentration, a simple, rapid and reliable assay, has been advocated as a marker of washing adequacy. Values below 2 mEq/L are held to reflect sufficient cleansing (2,5) and all the autotransfusion devices in this study stayed within this range removing 90% of the potassium.

An index of hemolysis in the blood salvaged within the cardiotomy reservoir is PFH levels. PFH were higher than 400 mg/dL in some of the cardiac cases in this study and may be several times this level in orthopedic cases. Adequate washing should remove 90–98% of this free plasma hemoglobin (6). Only the Autolog consistently removed over 90% of the PFH in this study with the poorest removal being the BRAT 2 at 63%. This is surprising since the Autolog only has a wash volume of 250 mL of saline while the BRAT 2 has a wash volume of 1000 ml. The

biggest difference between the two systems is the configuration of the cell washing system. The Autolog pulses the wash and has two indentations on the side of the bowl to increase the turbulence and improve mixing and washing of the blood.

Another important indicator of how adequately the salvaged RBCs are washed is the platelets and leukocytes. A safe cell salvage product should remove most of these contaminants. Again, in this study, the Autolog had the best platelet and leukocyte removal while the BRAT 2 had the worst. Although the Autolog had a significantly higher leukocyte removal that of the other cell savers it was still inadequate (approximately 78%). Bull et al. claim that in rare circumstances, activation of leukocytes and platelets trapped on the inner wall of the disposable centrifuge chamber can release leukoattractant and thromboplastic materials, which result in a systemic syndrome called “the salvaged blood syndrome” (7). This syndrome involves elements of disseminated intravascular coagulation, capillary leak, and adult respiratory distress syndrome. Activated leukocytes circulating throughout the body can cause great tissue damage when they enter organs. Upregulation of adhesion receptors can increase their binding to endothelial cells and migration into extravascular tissues leading to edema. Activated leukocytes also release their granules, which contain destructive elements such as oxygen free radicals, elastase, and cathepsin G. The later of which are capable of degrading fibrin, potentially contributing to the instability of newly formed clots (8). There is still little evidence that leukocyte depletion of the cell-salvaged product is of clinical benefit (9), however, at this institution leukocyte/lipid reducing filters have been adopted as a standard of care.

The degree of heparin washout should also be monitored during cell salvaging. More than 95% heparin washout is expected (6). Umlas et al., have shown that the washed, concentrated salvaged blood should have heparin levels of less than 0.2 to 0.4 international units per ml of supernatant fluid after washing (10). However this study has shown levels to vary from a mean of 0.19 to 0.80 U/ml. This still is an adequate washout considering that all cell savers removed approximately 99% of all the heparin.

In conclusion, this study has shown that the variation in process between the different types of cell saving devices also results in drastic variations in the quality of concentrated RBC product. This is an important finding that the autotransfusionist must consider when providing adequate patient care.

REFERENCES

- Williamson KR and Taswell HF. Intraoperative blood salvage a review. *Transfusion*. 1991;31:662–75.
- Hood AG, Potter PS. In Perioperative autologous blood management: cell salvage, multicomponent pheresis and autotransfusion. Blundell Institute San Rafael. 1995.

3. Processing Washed Autologous Red Cells On the Cell Saver 5. In Clinical Education Series: Surgical, Haemonetics Cell Saver 5, HBSTI Publications, Tucson, 1996;7-16.
4. Emergency Care Research Institute. Autotransfusion units. Health Devices. 1988;17:219-42.
5. Yawn DH. Properties of Salvaged Blood. In: Taswell and Pinela eds. Autologous Transfusions and Hemotherapy. Boston, Boston Scientific Publishing; 1991;194-206.
6. Yawn DH. Ensuring quality during intraoperative blood salvage. Laboratory Medicine. 1994;25:626-31.
7. Bull BS, Bull MH. The salvaged blood syndrome: a sequel to mechano-chemical activation of platelets and leukocytes. Blood Cells. 1990;16:5-23.
8. Rinder CS. Hematologic Effect of Cardiopulmonary Bypass. In: Gravlee, Davis, Kurusz, Utley eds. Cardiopulmonary Bypass: Principles and Practice. Philadelphia, Lippincott, Williams & Wilkins; 2000;492-93.
9. Cross MH. Cell Salvage and Leucodepletion. Perfusion 2001; 16(Suppl):61-66.
10. Um1as J and O'Neil1 TP. Heparin removal in an autotransfusion device. Transfusion 1981;21:70-73.