Debris Elimination from Partially-Filled Cell Salvage Bowls

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Centrifuge-based cell salvage and washing systems, available since the 1970s, have decreased the use of allogeneic blood transfusions (1). Although intraoperative salvage and autotransfusion avoids the risks of allogeneic transfusion, case reports document adverse reactions to this blood, potentially related to inadequate washing (2). The cleanliness of partially filled cell salvage bowls has been questioned. Manufacturers of cell salvage devices vary in their recommendations regarding these bowls because of this concern about wash efficiency (3,4). Both discarding this blood and transfusing after a double-volume wash have been recommended. At least one company has reported that discarding this blood may be unnecessary and has recommended washing with 2000 mL of normal saline, rather than the usual 1000 mL (Haemonetics Corporation, written communication, 1996). However, this unpublished data reported only free hemoglobin (Hb) and residual heparin concentrations and ignored potentially harmful debris, including activated leukocytes (WBCs), platelets (Plts), and anaphylatoxins (C3a and C5a) (5,6). Furthermore, free Hb alone may not be significant when compared with other toxins (7). Also, the manufacturer's data did not define the level of debris remaining after a single wash volume. This study was designed to measure the residual concentrations of potential toxins after a single wash volume to help assess the safety of transfusing partially filled bowls.

Methods

After institutional approval, 4 U of expired whole blood was obtained from the blood bank (mean [± SD] age, 34.5 ± 1 days; volume ≈ 450 mL/U). The blood was sampled for WBCs, Plts, hematocrit (Hct), free Hb, C3a, and C5a. Samples were obtained from each unit before and after processing with a Sequestra® 1000 (Medtronics, Parker, CO) cell salvage device by using a 125-mL Latham bowl (fill and empty rate 300 mL/min, wash rate 250 mL/min). A full bowl and a partially filled bowl were obtained from each unit and washed with 1000 mL of 0.9% sodium chloride solution. The filling end point for the partially filled bowl was arbitrary and consistent. Hct, WBC, and Plt were measured with the GEN-S® (Beckman-Coulter Corp., Miami, FL). Free Hb was colorimetrically analyzed (Quest Diagnostics, Baltimore, MD). Complement fractions were obtained by radioimmunoassay (Specialty Labs, Santa Monica, CA). Independent samples *t*-tests compared the groups, and $P < 0.05$ was accepted as significant. Data are presented as mean ± SD.

Results

The Hcts of partially filled bowls were less than those of full bowls (34.7% ± 2.2% vs 50.5% ± 1.3%, $P < 0.001$), as were the free Hb (49.8 ± 25.5 vs 229 ± 139 mg/dL, $P = 0.045$) and C3a (749 ± 163 vs 1888 ± 823 ng/mL, $P = 0.035$) concentrations. In contrast, the WBC counts of partially filled bowls were significantly more than those of full bowls (1.2 ± 0.32 vs 0.5 ± 0.14 k/μL, $P = 0.006$). The Plt counts were also more, but this did not achieve statistical significance (46 ± 20 vs 25.5 ± 13 k/μL, $P = 0.13$). The C5a levels were similar in both groups (10.9 ± 4.1 vs 9.7 ± 6.3 ng/mL, $P = 0.77$) (Table 1).

Discussion

The hypothesis that partially filled bowls are inadequately washed is based on the physics of centrifugal cell separation. In a centrifuge, particles separate on the basis of their densities. Hence, the less dense WBCs and Plts migrate to the inner portion of the centrifuge, and the heavier erythrocytes migrate to the outer portion. In a partially filled bowl, the red cell

This study was sponsored by the Chief Navy Bureau of Medicine and Surgery, Washington, DC, Clinical Investigation Program (B99-035).

The views expressed in this manuscript are those of the author and do not reflect the Department of Defense, Department of the Navy, or the US Government.

Accepted for publication December 28, 2000.

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0003-2999/01

Table 1. Hematocrit, Leukocytes, Platelets, Free Hemoglobin, and Anaphylatoxins in Full and Partially Filled Cell Salvage Bowls

Test	Full bowl	Partial bowl	*P*
Hct (%)	50.5 ± 1.3	34.7 ± 2.2	<0.001
WBC (k/μL)	0.5 ± 0.14	1.2 ± 0.32	0.006
Plt (k/μL)	25.5 ± 13	46 ± 20	0.13
Free Hb (mg/dL)	229 ± 139	49.8 ± 20	0.045
C3a (ng/mL)	1888 ± 823	749 ± 163	0.035
C5a (ng/mL)	9.7 ± 6.3	10.9 ± 4.1	0.77

Values are expressed as mean ± SD.
Hct = hematocrit; WBC = leukocyte count; Plt = platelet count; Hb = hemoglobin.

layer does not extend to the inner wall of the centrifuge. In theory, this creates a low resistance channel for the wash solution to bypass the debris in the red cell layer and is analogous to channeling within a carbon dioxide absorber.

The smaller size of the red cell layer in a partially filled bowl explains the increased WBC and Plt counts. In these bowls, the red cell layer does not extend enough to push these cells from the centrifuge. The lower free Hb and C3a levels may be caused either by dilution with excess saline that collects in a partially filled bowl or by delivery of a smaller amount of these substances before the saline wash occurs.

That the C5a levels did not differ between the groups remains unexplained. However, the values in this study are consistent with those reported in 35-day-old stored blood (8). Bengtsson and Lisander (9) measured anaphylatoxins in full bowls during Harrington rod procedures and found no increase in C5a levels, although C3a levels were increased. They postulated the rapid degradation of C5a by neutrophils as an explanation (10,11). Alternatively, the low concentration of C5 in serum, which is approximately 5% that of C3, may play a role (12).

This study has several limitations. One was the use of expired whole blood. Older, stored blood contains more free Hb and anaphylatoxins than does fresh blood. Although this may have led to artifactual increases in these substances, this blood may contain levels of debris exceeding those seen clinically, thus placing a greater burden on the cell washing process. Another limitation was that the effect of partially filled bows on the elimination of fat, muscle, and bone fragments was not addressed. Although these contaminants are expected in surgical wounds, they were not present in the expired blood. A third weakness of this investigation was the use of only one type of cell-washing device. Variations in both wash modes and bowl designs imply that performance may not be comparable among manufacturers under these experimental conditions.

There are several alternatives to transfusing partially filled bowls. Using a 125-mL pediatric bowl, rather than a 225-mL adult bowl, requires half the red cell mass to fill, although it increases processing time and delays transfusion during rapid blood loss. A second alternative is returning blood from a partially filled bowl to the collection reservoir and awaiting further blood loss. A third solution is adding blood that has been washed but is awaiting transfusion in the holding bag. Probably the simplest and most cost-effective strategy is to estimate the red cell mass in the collection reservoir; this helps determine whether the expense of the tubing harness for the cell salvage machine is justified. Because these bowls fill to an approximate Hct of 60%, a red cell mass of 135 milliliters is needed to fill a 225-milliliter bowl.

In summary, this experiment, which used expired whole blood and a single wash volume, demonstrated that there is more whole cellular contaminant in partially filled cell salvage bowls, but chemical contaminant does not exceed that of full bowls. Transfusion of partially filled bowls may be safe, but it should be based on a prospective study measuring the quality of the blood and patient outcomes. However, designing a study that determines complications that are specific to cell salvage blood, and not to another perioperative physiologic trespass, may be very difficult.

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