

## Cell Salvage Systems

### History

- The first recorded uses of autologous transfusion was documented in late 1800's when an English surgeon James Highmore proposed the use of "autotransfusion" (autologous transfusion) and suggested that a patient's own shed blood was an overlooked source which could be used to great advantage. His article, published in *The Lancet* in 1874, advocated intraoperative autotransfusion specifically in the case of postpartum hemorrhage.
- In early 1900's, techniques for typing and matching blood were developed and the first blood bank was established at Cook County Hospital (Chicago) in 1937. During WWII and the following Korean and Vietnam wars there were a continued high demand for donor pool. The shortages of donor blood during the Vietnam War revived the interest in autotransfusion. An American surgeon named Klebanoff began using open heart pump to capture, anticoagulate, filter, and reinfuse the blood lose in surgery. His device was introduced commercially in the 1970's by Bentley Laboratories. The Bentley device was the first attempt to modernize autologous blood recovery in decades.

### What is cell salvage?

- it consists of scavenging of blood from operative fields or wound for reinfusion into the patient, typically after noncellular matter is reduced by saline dilution followed by centrifugation, a process termed "washing."
- best suited for cases in which medium to large volume, rapid blood loss into a clean surgical field is anticipated, as these factors maximize the quality of the salvaged blood, and minimize the risks of hemolysis and contamination.
- Recent Cochrane review indicated that cell salvage is efficacious in reducing the need for allogeneic red cell transfusion in adult elective cardiac and orthopaedic surgery and that the use of cell salvage did not appear to impact adversely on clinical outcomes.

### Benefits of cell salvage

- General benefits of autologous transfusion (reduced risk of disease transmission and transfusion reactions, minimal compatibility testing, reduced demand on blood bank inventory)
- Removal of red cell stroma, plasma free hemoglobin, activated clotting factors, extracellular potassium, possible acceptance by Jehovah's witness

### Potential risks include

- air embolism
- nephrotoxicity
- coagulation disorders
- leukocyte activation with resulting lung damage
- dissemination of microaggregates, infectious matter, cytokines, and malignant cells

The risk/benefit ratio and cost-effectiveness of blood salvage must be determined on an individual basis by surgeons, anaesthetists, and transfusion specialists involved in patient care.

- The presence of any of the following criteria may be an indication for blood salvage:
  - Anticipated blood loss of > 1000 mls or > 20% estimated blood volume
  - Patient with a low Hb or increased risk factors for bleeding
  - Patients with multiple antibodies or rare blood types
  - Patients with objections to receiving allogenic blood
- Specific types of surgery for which the technique is especially useful include
  - Open heart and vascular surgery
  - Total joint replacement and spinal surgery
  - Liver transplantation
  - Ruptured ectopic pregnancy
  - Selected neurosurgical procedures
- Postoperative salvage is employed most often following cardiac and certain types of orthopedic procedures

### Steps involved in cell salvage:

Shed blood collection and anticoagulation:

- The system is continually anticoagulated with heparinized saline, to prevent clotting during collection or processing.
- To minimize hemolysis, blood should be aspirated from the surgical field, ideally with carefully modulated suction force and a large-diameter suction catheter tip submerged in a pool of blood. These measures reduce the formation of air bubbles that increase the surface area of the air-water interface, where hemolysis tends to occur.

Filtering

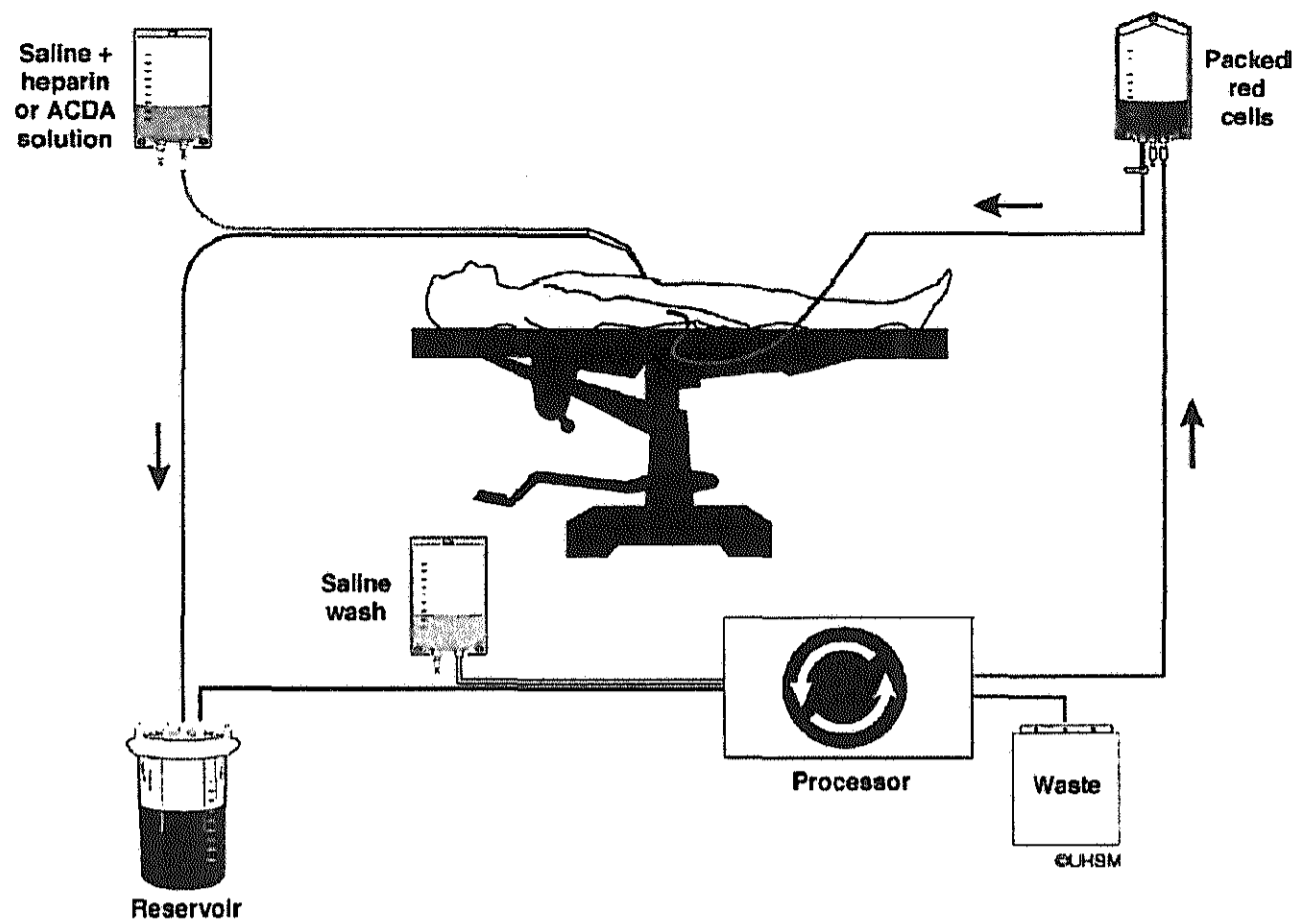
- Blood passes through a microaggregate filter (with a 20-to 40-micron effective pore size) to remove debris such as foreign matter, fibrin, and cell clumps.

Centrifugation

- Centrifugation separates the nonerythrocyte components which are channeled into a waste container.

Washing

- isotonic wash solution is introduced to carry away remaining activated coagulation factors, free hemoglobin, heparin, and proteolytic enzymes during further centrifugation.
- Once washing is complete, the red cells are pumped into an infusion bag for use, and air is evacuated from the bag.



**End-product from cell salvage system**

- A typical yield ranges from 50% to 95.8% of all RBC retrieved, with a final hematocrit typically in the 50% to 60% range
- In comparison to banked red blood cells, washed salvaged red blood cells have close to normal 2,3-diphosphoglycerate levels, and longer intravascular survival. The quality of the salvaged product reflects the collection methods and the quality of the cells collected.

## Haemonetics® Cell Saver 5+ - How this works:

### Collecting blood (figure 1)

- Blood is drawn into a collecting reservoir through an aspiration and anticoagulation (A&A) assembly
- Mixing of anticoagulant solution (in saline solution) and blood occurs in the small mixing chamber of the tube connector which is located after the suction tip which is used to remove blood and fluids from the wound
- Blood and fluids are then collected in the collection reservoir
- The recommended AC solution is 30,000 units of heparin in 1L of normal saline solution. The drip rate should be set during the procedure at 1-2 drops per second depending on the rate of blood flow being processed. Citrate can also be used as an AC solution (see manual)

#### Aspiration and Anticoagulation Assembly

1. Suction line connector
2. Cross section of A&A tubing
  - a. large lumen for anticoagulated shed blood
  - b. small lumen for solution administration
3. Saline and AC solution bag
4. Drip chamber
5. Roller clamp
6. Collection reservoir
7. Line to vacuum source
8. Reservoir drain

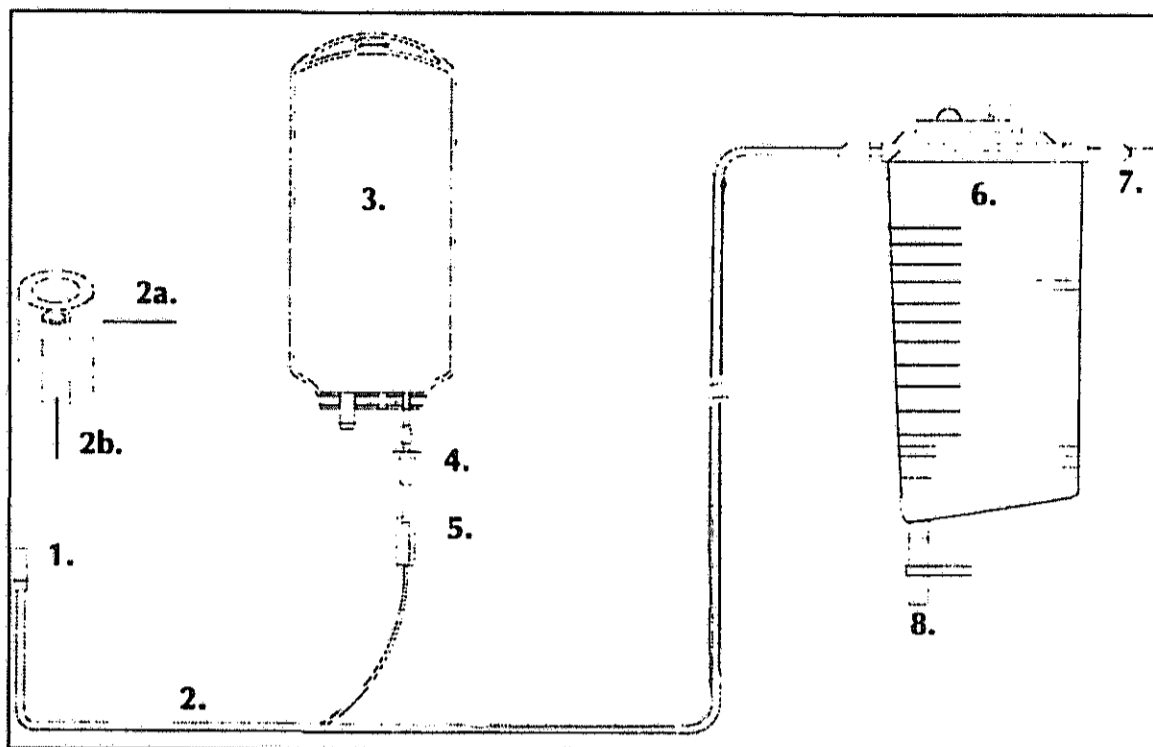
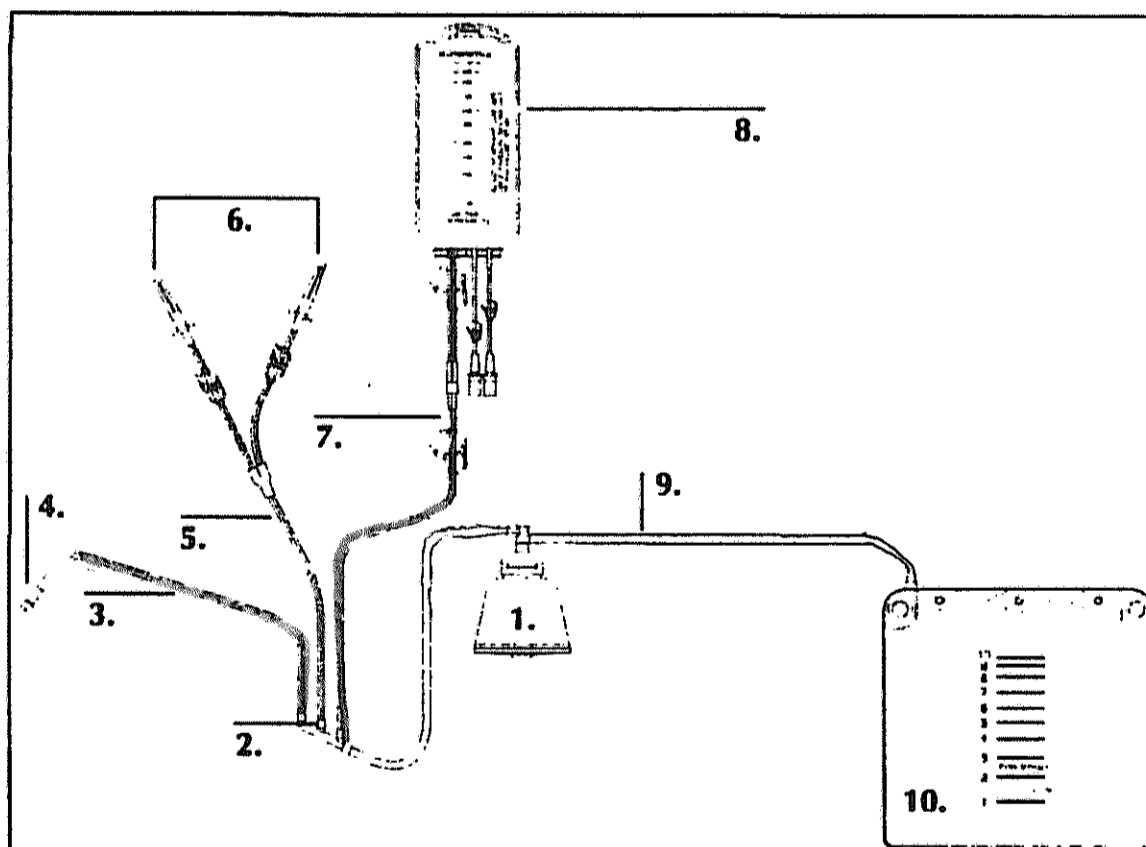


Figure 1, The Aspiration & Anticoagulation assembly

Figure 2 illustrates a typical disposable set designed for CS5+:

1. Centrifuge bowl
2. Tubing manifold
3. Red line
4. Collection reservoir connector
5. Yellow line
6. Saline bag spikes
7. Blue line
8. Reinfusion bag
9. Effluent line
10. Waste bag



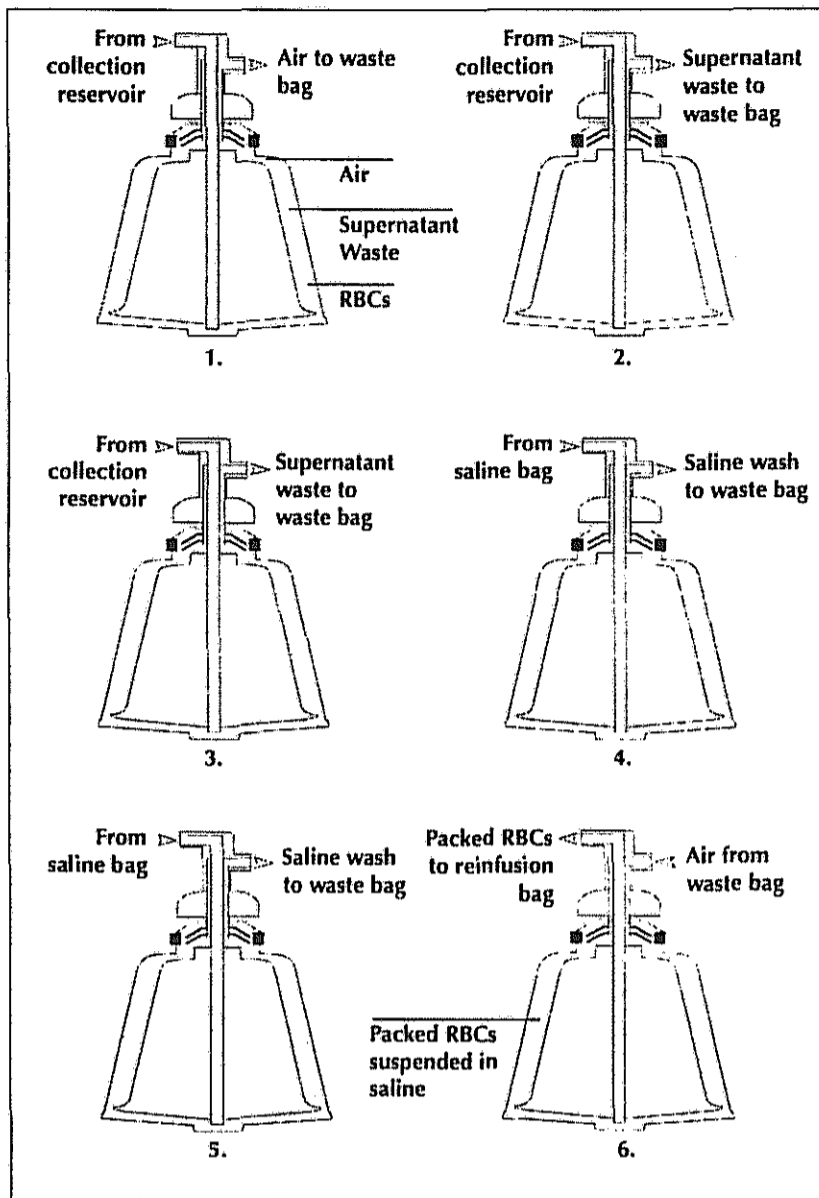
The harness consists of 3 lines

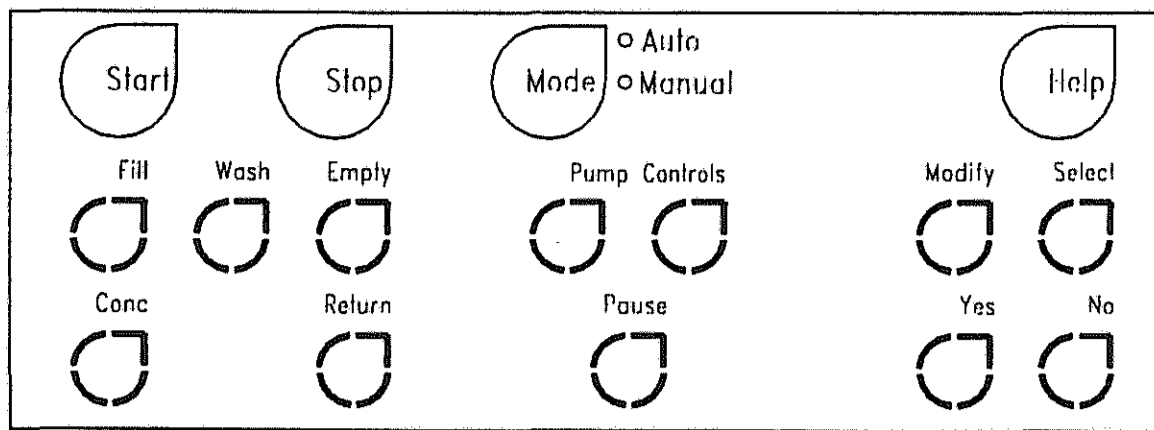
- Yellow-coded tubing connected to NS
- Red-coded tubing connected to the unprocessed blood source
- Blue-coded tubing connected to the reinfusion bag

### Filling the centrifuge bowl

- Once the disposable set has been loaded, the operator should press "START" -> CS5+ will automatically go from STANDBY state to initiate a fill cycle (when the appropriate level of fluid has been collected into the reservoir):
  - Default level is
    - 800 ml for Latham bowls (225ml / 125ml)
    - 400ml for the 70ml bowls
- A partial bowl
  - If the reservoir becomes empty before the bowl is full, the CS5+ system will revert to the STANDBY state
  - If the reservoir is filled but less than the required amount to refill the bowl automatically, the operator can
    - press the START key 2<sup>nd</sup> time to initiate a fill cycle before this level is reached (or if press FILL key if it is backlit)
    - press the backlit RETURN key to send the contents of bowl into reservoir for future processing
    - press the backlit WASH key to advance to WASH state and wash a partial bowl (see below)
- After fill cycle is initiated, the centrifuge bowl begins to spin and the red valve opens
- The bowl begins to fill as the pump transfer fluid from the reservoir while monitoring the volume of fluid being pumped

1. Blood is pumped in; separation begins as the bowl spins.
2. The supernatant wastes overflow; RBCs stay in the bowl.
3. As overflow continues, the Hct in the bowl increases to at least 50%.
4. Normal saline circulates through the RBC layer and displaces the waste.
5. The overflow runs clear. Free hemoglobin and anticoagulant are in the waste bag.
6. The bowl stops spinning. Washed, packed RBCs are pumped to the reinfusion bag.





**Separating and packing cells in the bowl**

- The spinning of the centrifuge traps the heavier RBC and cause them to be driven toward the outer wall of the centrifuge. RBC forms the outer layer while the supernatant plasma floats inward toward the core of the bowl. The lighter fraction is forced out of the effluent tubing from the bowl and into the waste bag

**Washing RBCs**

- After packing the RBCs, the optical sensors will detect that RBC content of the bowl is sufficient to warrant washing (at least 50% hematocrit)
- Optical sensor will clamp the red-coded fill line, open the yellow-coded wash line
- Saline solution enter the bowl from the yellow wash line and wash the RBC, removing unwanted components such as cell stroma, free Hb, activated clotting factors, platelets, and AC solution
- The system will automatically extend the wash (up to 2 times) according to bowl size, until the effluent line is clear.
- At the end of the WASH state, just before the system enters EMPTY or RETURN state, the red valve will open for 2 pump revolutions, then close while the blue valves open.

**Washing partial bowls**

- In general, filling the bowl to a lower hematocrit will necessitate a higher volume of wash solution to achieve adequate washout. Because the hematocrit of the bowl contents is lower, there is more supernatant in the bowl. In order to dilute the larger volume of supernatant, 2 times the normal wash solution (usually 2x 1000ml) is needed.

**Emptying the bowl**

- Once the minimum wash volume of saline has been introduced and the effluent line sensor has detected adequate washing, the wash line (yellow) will be clamped, and the reinfusion line (blue) will be opened. The pump then reverses direction, sending packed RBCs suspended in NS from bowl to the reinfusion bag

Key	Purpose
Fill	<i>Cell Saver:</i> Used to pump fluid from the reservoir into a spinning bowl. <i>Sequester:</i> Used to pump whole blood from a blood source into a spinning bowl.
Conc	<i>Cell Saver / Sequester:</i> Used to pump fluid from the product bag into a spinning bowl. Supplements "Fill" and is usually selected when the bowl is partially full and the reservoir is empty.
Wash	<i>Cell Saver:</i> Used to pump saline into a spinning bowl from the saline solution bag. <i>Sequester:</i> Not used.
Empty	<i>Cell Saver / Sequester:</i> Used to pump fluid from a stationary bowl into a product bag.
Return	<i>Cell Saver:</i> Used to pump fluid from a stationary bowl back into the reservoir or into a bypass circuit. Can be used as an alternative to the <i>Empty</i> key where the contents of the bowl are pumped back (returned) through the "Fill" line instead of being sent (emptied) to the product bag. <i>Sequester:</i> Not used.

## Complications and contraindications to perioperative blood recovery

(see attached tables)

### Notes

- The time required to process a centrifuge bowl of salvaged blood depends on
  - Salvage blood hematocrit
  - Bowl volume
  - Bowl filling rate
  - Wash volume
  - Wash flow rate
  - Empty flow rate
  
- Risk of hemolysis – working with blood pump against a severe flow restriction may cause hemolysis. Since the presence of free Hb in the reinfusion bag may not be readily apparent, the operator should monitor for other indications of abnormal operation. A restriction which will cause hemolysis may also cause a reduction in flow rate, which in turn could result in an abnormally long time required to empty the bowl. CS5+ will detect abnormally long EMPTY and RETURN states and notify with display “LONG EMPTY CYCLE”. If the operator visually confirms that the bowl is still not emptied, a sample should be taken from the reinfusion bag prior to transfusion to the patient to determine the presence of plasma Hb.
  
- Contents of the reinfusion bag should not be transfused under pressure. The blue-coded harness line is factory-primed with 20ml sterile air, which is sent into the reinfusion bag during the first cycle
  
- Washed, packed cells are depleted of clotting factors, supplementation of FFP and platelets if required for hemostasis

### Reference

- AAGBI Safety Guidelines Transfusion and the Anaesthetists: Intraoperative Cell Salvage (2009)
- <http://www.youtube.com/watch?v=1Yd-3VGotng>
- Carless PA, Henry DA, Moxey AJ, O’Connell D, Brown T, Fergusson DA “Cell salvage for minimising perioperative allogeneic blood Transfusion” *The Cochrane Library* 2010, Issue 3
- Haemonetics® Cell Saver 5+ Operation Manual