STM JOURNALS

Research & Reviews: A Journal of
Life Sciences

https://journals.stmjournals.com/rrjols

ISSN: 2249–8656 (Online)
ISSN: 2348–9545 (Print)
Volume 15, Issue 2, 2025
May–August
DOI (Journal): 10.37591/RRJoLS

Research RRJoLS

Blood Cell Saver Machine

Kaisar Ahmad Bhatt[1,*], Jasmina Junaid Shah[2], Abid Hussain[3], Sheezan Shafi[4]

Abstract

Intraoperative Cell Salvage (ICS) is a crucial technique in modern surgical practice aimed at minimizing the need for allogeneic blood transfusions. By collecting, filtering, washing, and re-infusing a patient's own blood lost during surgery, ICS provides a safer and cost-effective alternative to donor transfusion, reducing the risk of transfusion-related infections and immunologic reactions. Initially conceptualized in the early 19th century, ICS technology evolved significantly with the introduction of the Cell Saver by Haemonetics in 1976. Today, it is widely adopted in both elective and emergency surgeries, including orthopaedic, cardiac, vascular, and obstetric procedures. The process involves anticoagulating collected blood, centrifuging to separate red blood cells (RBCs), and washing them with saline before reinfusion. Several system variants exist, such as fixed volume bowl, variable volume disk, and continuous rotary systems, each with specific advantages depending on surgical circumstances. While ICS offers substantial benefits, contraindications include contamination by bowel contents, infection, or specific patient conditions like sickle cell disease. Special considerations are required in oncological and obstetric cases due to the risk of reinfusing malignant cells or amniotic fluid. Advances in filtration, including leukodepletion filters, have addressed some of these risks. Patient consent and ethical considerations are integral, especially for those with religious objections to donor blood. Effective implementation of ICS also involves careful clinical judgment regarding when and how to process and reinfuse salvaged blood. Despite limitations, ICS significantly contributes to blood management strategies, conserving donor blood supplies and improving surgical outcomes.

Keywords: Intraoperative cell salvage (ICS), autologous blood transfusion, blood management in surgery, cell saver machine, allogeneic transfusion alternative

INTRODUCTION

Cell salvage is a technique used to collect, process, and reinfuse a patient's own blood lost during surgery or through wound drainage. This method is widely regarded as a safer alternative to allogeneic blood transfusion, which may carry the risk of transmitting infectious diseases. To reduce dependence on donor blood, various strategies have been developed – among them, the introduction of the Cell Saver system by Haemonetics Corporation in 1976 marked a significant advancement. This device efficiently suctions, filters, and washes the lost blood, allowing it to be reinfused back into the patient. A major benefit of this approach is the use of autologous blood, eliminating the risks associated with transfusions from external donors. Furthermore, cell salvage is particularly beneficial for individuals who decline donor blood for religious or personal reasons. The system operates by aspirating blood using a controlled vacuum, along with an anticoagulant, such as heparinized saline or citrate. The red blood cells are then separated via centrifugation, thoroughly washed with saline, and subsequently reinfused either through the cardiopulmonary bypass (CPB) circuit or intravenously [1].

***Author for Correspondence**
Kaisar Ahmad Bhatt
E-mail: bhatkaisar1@gmail.com

[1]Lecturer, Department of Operation Theatre Technology and Anesthesia Technology, Jammu University, Jammu, Jammu & Kashmir, India
[2]Assistant Professor, Department of Medical Lab & Technology, BEE ENN College of Nursing, Kainkh, Jammu and Kashmir, India
[3]Lecturer, Department of Radioimaging Technology, BEE ENN College of Nursing, Kainkh, Jammu and Kashmir, India
[4]Tutor, Department of Operation Theatre Technology and Anesthesia Technology, BEE ENN College of Nursing, Kainkh, Jammu and Kashmir, India

Received Date: February 07, 2025
Accepted Date: April 20, 2025
Published Date: April 21, 2025

Citation: Kaisar Ahmad Bhatt, Jasmina Junaid Shah, Abid Hussain, Sheezan Shafi. Blood Cell Saver Machine. Research & Reviews: A Journal of Life Sciences. 2025; 15(2): 51–59p.

HISTORY AND EVALUATION

The earliest documented use of cell salvage and autologous transfusion dates to 1818, when it was applied in cases of post-partum hemorrhage. At that time, blood-soaked materials were rinsed with saline and the resulting solution was reinfused into the patient – though this technique was linked with high mortality. Over time, the method evolved, and by 1931, blood collected from haemothorax cases was directly reinfused. In 1943, the development of a device capable of collecting and filtering suctioned blood marked a significant step forward, as it introduced the fundamental principle behind modern cell salvage systems. By the 1960s, commercially available devices started appearing, and in the 1970s, the first fully modern cell saver was introduced. However, initial versions were associated with several complications including haemolysis [2], air embolism, and coagulopathy. A meta-analysis published in 2016, which reviewed 47 clinical trials, demonstrated that cell salvage effectively reduced the need for allogeneic red blood cell transfusion during surgery by approximately 39%. Despite advancements, challenges persist in maintaining a safe and sufficient blood supply. Immunological reactions linked with donor blood and the rising costs of processing and testing to avoid transfusion-transmitted infections further complicate the situation. Additionally, the availability of blood donors is steadily declining. A recent survey revealed that 53% of hospitals in the UK have adopted intraoperative cell salvage. The overarching goal remains to ensure the safe and proficient use of this technique to improve patient care during surgical procedures [3]. Characteristics of Blood Cells depicts in Table 1.

Table 1. Comparison of key characteristics of blood cells: Red blood cells, white blood cells, and platelets.

Properties	Red Blood Cells	White Blood Cells	Platelets
Size	7 microns	7–20 microns	2–5 microns.
Survival	120 days	Hours – few days	5–9 days.
Normal Range	4.5–5.8 million	5,000–10,000	150,000–400,000.
Function	Transport of O_2	Immune response, fight infection	Clotting.

COMPOSITION OF BLOOD

Blood is composed of cellular and non-cellular elements, with each making up nearly half of its total volume. The cellular portion – formed in the bone marrow – consists of red blood cells (RBCs), white blood cells (WBCs), and platelets. The non-cellular portion, known as plasma, is primarily made up of water and contains various proteins, like albumin, clotting factors, immunoglobulins, as well as essential electrolytes. On average, blood volume constitutes approximately 7% of an individual's body weight, equating to around 70 ml per kilogram.

- *Hemoglobin (Hb)* is a protein-iron complex found in red blood cells that plays a vital role in transporting oxygen from the lungs to the body's tissues and removing carbon dioxide from the tissues back to the lungs. Its normal concentration ranges from 12.5 to 16 grams per deciliter.
- *Hematocrit (Hct)* refers to the percentage of red blood cells within the total blood volume. Typical hematocrit values are 43–49% in males and 37–43% in females. Blood separation into its constituent parts is depicted in Figure 1.

Coagulation Cascade

The clotting process, known as the coagulation cascade, can be triggered through either the intrinsic or extrinsic pathway, both ultimately leading to a series of reactions that form a blood clot. The intrinsic pathway is set off when blood encounters a non-endothelial surface, such as artificial heart valves or tissue grafts, or when it is exposed outside the body. In contrast, the extrinsic pathway begins in response to external trauma, like a cut or damaged blood vessel. Regardless of which pathway is activated, both converge at a common point where fibrinogen is transformed into fibrin, forming the structural basis of a clot. During surgical procedures, it is common for both pathways to be simultaneously activated [4].

Donor Blood Components

Table 2 provides an overview of the primary blood components commonly utilized in surgical procedures, highlighting their volumes, storage requirements, and clinical applications. Each

component – red blood cells, platelets, fresh frozen plasma, and cryoprecipitate – serves a vital function in controlling bleeding, addressing coagulation disorders, and maintaining effective hemostasis during and following major operations. Ensuring appropriate storage conditions and timely use is critical to achieving the best possible outcomes for patients.

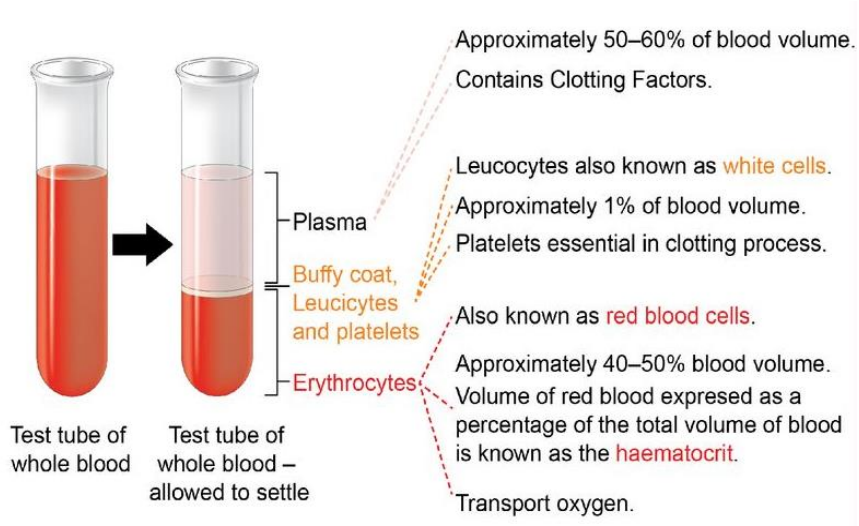

Figure 1. Blood separation into its constituent parts.

Table 2. Donor blood components.

Component	Volume	Storage	Clinical Indications in the Surgical Setting
Red cells	180–350 ml	Designated temperature-controlled fridge (2–6°C) Shelf life: 35 days	To raise the oxygen-carrying capacity of the blood when it is symptomatically reduced due to red cell loss or reduced red cell production
Platelets	Apheresis: 180–300 ml Pooled: 250–400 ml	Temperature-controlled room temperature (22°C ± 2°C) with gentle agitation to ensure oxygen availability Shelf life: 5–7 days	– Thrombocytopenia associated with large volume blood transfusions – Consumption due to disseminated intravascular coagulation (DIC), major surgery
Fresh frozen plasma	240–300 ml	Designated temperature-controlled freezer (−30°C) Shelf life: 24 months	– Clinically abnormal haemostasis following massive blood transfusion or major surgery – Multiple coagulation factor deficiencies and DIC – Immediate reversal of Warfarin effect if PCC is unavailable – Haemostatic defects due to liver disease if bleeding/invasive procedure is needed
Cryoprecipitate	Not mentioned	Designated temperature-controlled freezer (−30°C) Shelf life: 24 months	– Bleeding associated with hypofibrinogenaemia Most commonly in: – DIC – Massive transfusion

SHORT (SERIOUS HAZARDS TO TRANSFUSION)

The Serious Hazards of Transfusion (SHOT) program offers a detailed review of significant complications associated with blood transfusions. It presents cumulative data on incidents reported across various categories between 1996 and 2006 (Figure 2).

INDICATIONS AND CONTRAINDICATIONS

The use of Intraoperative Cell Salvage (ICS) is widely advised for various surgical procedures, if there are no specific limitations at the facility, such as insufficiently trained personnel. Evidence from

randomized controlled trials (RCTs) and observational studies has shown that ICS effectively reduces the reliance on donor (allogeneic) blood transfusions. The decision to implement ICS is generally influenced by several considerations, including:

- The expected volume of blood loss during the surgical procedure
- Patient-specific factors, such as:
  - An elevated risk of bleeding
  - Low hemoglobin levels before surgery
  - Personal, ethical, or religious objections to receiving donor blood

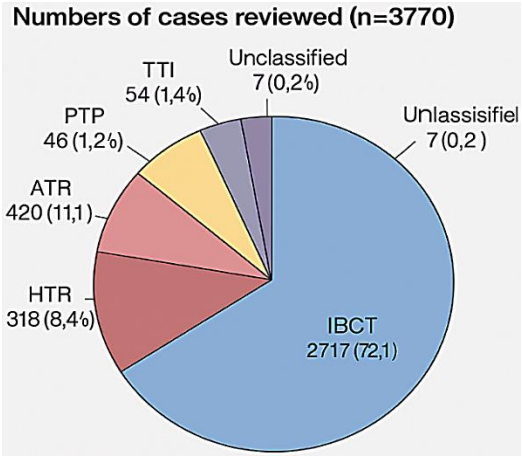

Figure 2. Bar graph of serious hazards of transfusion.

1. *IBCT: Incorrect Blood Component Transfused.*
2. *ATR: Acute Transfusion Reaction.*
3. *HTR: Haemolytic Transfusion Reaction.*
4. *PTP: Post Transfusion Purpura.*
5. *TA-GvHD: Transfusion Associated Graft versus Host Disease.*
6. *TRALI: Transfusion Related Acute Lung Injury.*
7. *TTI: Transfusion Transmitted Infection.*

These criteria are explored in greater detail in the following section.

INDICATIONS AND PATIENT SELECTION

ICS can be employed during both elective and emergency surgeries, provided the surgical site is free from contamination by fecal material or infectious agents and no other contraindications are present. The decision to utilize ICS is typically made by the attending surgeon and anesthetist, based on the patient's clinical needs. It is suitable for both adult and pediatric patients undergoing procedures where the expected blood loss exceeds 20% of their estimated total blood volume. The following are illustrative examples, though not an exhaustive list.

- Total knee Replacement. (if no Tourniqute is used).
- Revision total Hip replacement.
- Spinal surgery.
- Abdominal aortic aneurysm surgery.
- Traumatic liver of spleen injury not associated with perforated bowel.
- Thoracic aneurysm surgery.
- Cardiac surgery.
- Benign urological surgery.

ICS is especially beneficial for patients with uncommon blood types or multiple antibodies, making it challenging to source compatible donor blood. It is also appropriate for individuals who, due to religious, ethical, or personal beliefs, decline allogeneic transfusions but have consented to receive their own salvaged blood through ICS. In such cases, thorough documentation of the patient's decision is essential [5, 6].

CONTRAINDICATIONS WARNINGS AND RISKS

The risk/benefit ratio of ICS should be assessed for each individual patient by the surgeon and anaesthetist responsible for the patient's care.

CONTRAINDICATION

ICS should not be used in the following situations:

1. The presence of bowel contents in the operative area is a contraindication for using ICS.
2. ICS should be avoided in patients with heparin-induced thrombocytopenia if heparin is the only anticoagulant option; a citrate-based anticoagulant may be considered as an alternative.
3. Using ICS in infected surgical sites may introduce bacteria into the salvaged blood; therefore, such areas should not be aspirated, and appropriate antibiotics should be administered when necessary.
4. Fluids from the stomach or pancreas should not enter the ICS system, as their enzymes can cause hemolysis and are not effectively removed by the standard washing process.
5. Pleural effusions must be drained before initiating ICS, although blood that collects afterward in the pleural cavity can be salvaged.
6. Caution is advised when considering ICS for patients with sickle cell disease or other abnormal red blood cell conditions; such decisions should be based on individual clinical assessments.

CAUTIONS

Using Hartmann's Solution as a wash or irrigation fluid can interfere with the effectiveness of citrate-based anticoagulants, such as ACD. Additionally, air may remain in the primary reinfusion bag if it stays connected to the cell salvage system or if it has been detached without removing the air. It is essential to eliminate any air from the reinfusion bag before administering the blood to the patient. Manufacturers caution against the use of pressure cuffs, as they pose a risk of air embolism and may trigger back pressure alarms if the reinfusion line is left open.

MANUAL MODE

Running ICS machines in manual mode is generally discouraged, as it can compromise the quality of the processed blood by leading to inadequate washing and potential reinfusion of harmful substances, such as residual heparin. The automatic mode is preferred to ensure consistent and safe processing. Manual operation should be reserved for urgent situations where rapid reinfusion of red blood cells is necessary, and the clinical benefits outweigh the associated risks.

FIXED VOLUME BOWL

The fixed volume bowl system operates by spinning at speeds of up to 6,000 revolutions per minute (rpm) and processes salvaged blood in set volume increments. As anticoagulated blood enters the rotating bowl, centrifugal force separates its components. Red blood cells (RBCs) are retained within the bowl, while the lighter components, including plasma and anticoagulants, are expelled through an outlet and collected in a waste container. Once the system identifies that enough RBCs has accumulated, it initiates a wash cycle using intravenous normal saline (0.9% NaCl). This saline solution passes through the red cell layer, flushing out the remaining non-RBC elements, which are also discarded into the waste bag along with excess saline.

Fixed volume bowls come in various sizes based on the manufacturer and are selected according to the expected blood loss during surgery. To ensure a uniform and high-quality final product, the machine requires the bowl to reach a specific volume of RBCs before automatically transitioning to the washing phase (Figure 3).

VARIABLE VOLUME DISK SYSTEM

The variable volume disk system, also known as the dynamic disk system, functions similarly to the fixed volume bowl by separating red blood cells (RBCs) through centrifugation and washing them with intravenous normal saline (0.9% NaCl). However, instead of requiring a fixed number of RBCs for

processing, it features a flexible silicone diaphragm that adjusts its shape and capacity to handle varying volumes. This allows the system to produce final blood products of differing volumes while maintaining a consistent hematocrit (Hct). The device processes approximately 100 ml of fluid from the reservoir per cycle. If the RBC volume entering the disk is less than 15 ml, the machine accumulates multiple batches before initiating the wash cycle. This flexibility makes the variable volume disk especially suitable for surgeries with lower or continuous slow blood loss, offering efficiency in longer or minimally bleeding procedures [7].

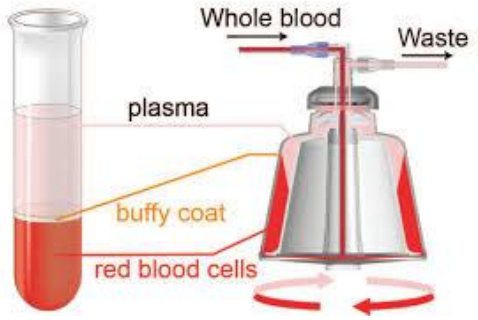

Figure 3. Fixed volume bowl.

CONTINUOUS ROTARY SYSTEM

The continuous rotary system operates by steadily separating the supernatant while simultaneously concentrating and washing red blood cells. It is capable of functioning with minimal blood volume, making it efficient even in cases of limited blood loss. However, the presence of a small amount of blood does not automatically justify initiating the processing cycle. The decision to proceed should be based on the specific clinical condition and needs of each individual patient (Figure 4).

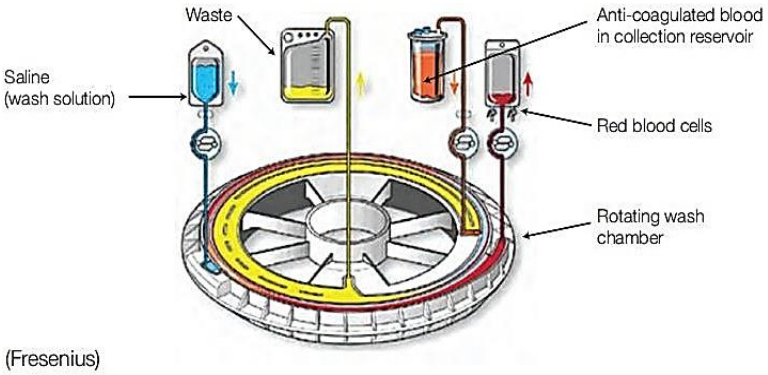

Figure 4. Continuous rotary system.

STAGES OF THE PROCESS

Both fixed and variable volume systems generally follow a similar operational sequence, whereas in the continuous rotary system, the processes of separation, washing, and reinfusion occur simultaneously (Figure 5) & equipment used in the process is depicted in Table 3.

1. *Collection:* Blood from the surgical field is suctioned and mixed with an anticoagulant using an aspiration and anticoagulation (A&A) line, directing it into a collection reservoir. This reservoir includes a filter that captures clots and large particles.
2. *Separation:* The collected blood is then transferred into a centrifuge, where red blood cells are retained within the spinning chamber. Meanwhile, the less dense components are expelled through a waste outlet. As more blood is processed, the hematocrit (Hct) within the system gradually increases.
3. *Washing:* Some devices are equipped with optical sensors that detect a specific Hct level during automatic operation. Once this threshold is reached, the system initiates the washing phase.

Intravenous normal saline (0.9% NaCl) is introduced into the centrifuge, flowing through the concentrated RBC layer and flushing out residual substances, such as anticoagulants, cell fragments, free hemoglobin, and plasma into the waste line. Reinfusion: The product of washed, packed, RBCs, suspended in IV normal saline (0.9% NaCl) is pumped into a bag ready for reinfusion [8].

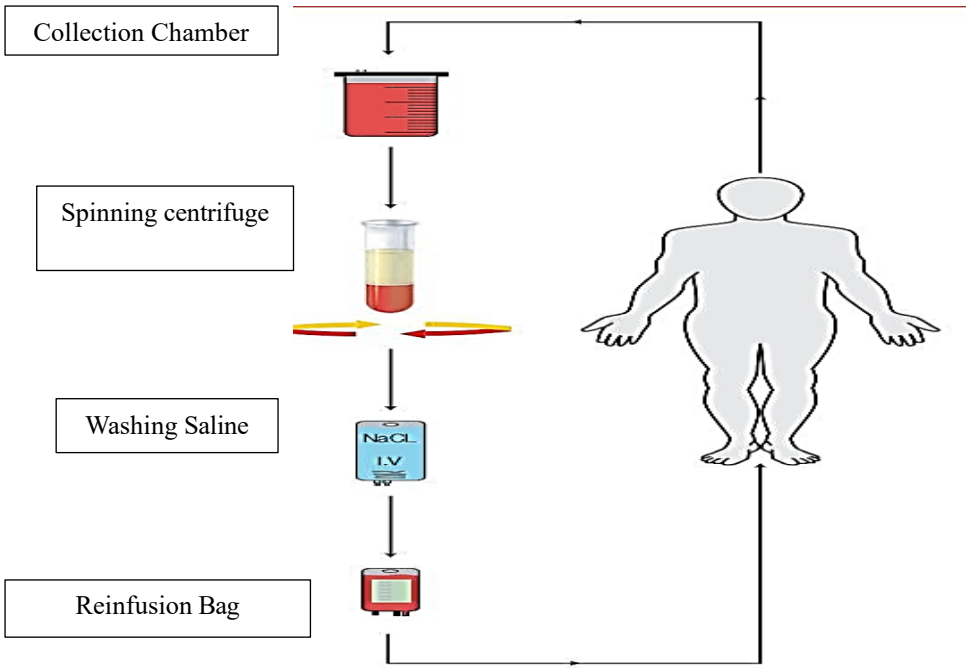

Figure 5. Schematic diagram of the blood salvage process, including blood collection, centrifugation, saline washing, and reinfusion back into the patient.

Table 3. Equipment used.

Equipment	Function
Anticoagulant (heparin saline 30,000 iu/l or Citrate (ACD-A))	To prevent clotting of salvaged blood.
Aspiration & anticoagulation line (A&A line) (machine specific/sterile)	Dual lumen suction line that delivers anticoagulant to the point of blood collection within the surgical field, and aspirates blood and anticoagulant into the ICS system. Prevents anticoagulant entering surgical field.
Collection reservoir (machine specific)	Holds collected blood prior to processing. Contains a filter to remove large particulate debris (clots, bone fragments, etc.).
ICS machine or drip stand with collection reservoir bracket	Holds the collection reservoir in position throughout the procedure.
Vacuum source	Connects to the collection reservoir allowing aspiration of blood from the surgical field. Some machines have an integrated vacuum; others require connection to a separate suction unit or theatre wall suction.
Suction tip (wide bore/single lumen) (sterile)	Attaches to A&A line to allow aspiration of blood within the surgical field.
Suction tubing (standard theatre supplies)	Used to connect the vacuum source to the collection reservoir.
Autologous transfusion label	Identifies the blood as autologous, belonging to a particular patient, and enables recording of procedure-specific details.

RE INFUSION

Once the blood collected using ICS has been processed, the next step is re-infusion of the final product to the patient. Many of the principles of re-infusing ICS blood are similar, if not the same, as the principles of transfusing allogeneic (donor) blood.

ICS END PRODUCT

On completion of processing, the ICS machine sends the final product to the re-infusion bag. The final product consists of:

- Red blood cells (RBC's).
- Intravenous (IV) normal saline (0.9% NaCl).

In addition to these, the final product may contain very small amounts of the following:

- Platelets.
- Clotting factors.
- Anticoagulant.
- Micro-aggregates.
- Other cells/proteins aspirated into the system from the surgical field.
- Contaminants – if these have been aspirated into the system from the surgical field, e.g., betadine [9].

Blood filtration strategies (Table 4), effectively remove particulate matter, microaggregates, lipids, and leucocytes.

Table 4. Types of blood filters, their medium, and the materials they remove.

Type of Filter	Medium	Removes
Standard blood administration set	200 μm screen	Blood component and non-blood component particulate matter.
Microaggregate blood filter	40 μm screen	Blood component microaggregates and non-blood component particulate matter.
Lipid depleting microaggregate filter	40 μm screen	Microaggregates, lipids, C3a, some leucocytes.
Leucodepletion filter	Affinity filter	Leucocytes, lipids, microaggregates.

CONSENT FOR REINFUSION OF ICS BLOOD

Like the protocol for allogeneic blood transfusions, the plan to use Intraoperative Cell Salvage (ICS) for collecting and reinfusing a patient's own blood should be clearly explained and included in the surgical consent process. For individuals who decline donor blood due to religious or personal beliefs, it is essential to obtain formal written consent specifically for the use of ICS. Any religious considerations that may affect the setup or operation of the ICS system must be carefully recorded in the patient's medical file and respected throughout the procedure. If the patient has an Advance Medical Directive, their preferences regarding autologous transfusion should be clearly noted in that document.

UNLOADING AND DISCARDING

Once a surgical procedure concludes or it becomes clear that no additional blood will be collected, it is essential to confirm with both the surgeon and anesthetist that the use of ICS is no longer necessary before beginning the shutdown process. After receiving confirmation:

- Make sure any collected blood intended for washing and reinfusion is fully processed.
- Verify that all salvaged red blood cells (RBCs) have either been administered to the patient or that the reinfusion bag has been properly disconnected from the processing unit.

The steps for unloading disposable components vary depending on the specific ICS machine model and whether it was used for collection only or full processing. Therefore, it is crucial to follow the manufacturer's instructions for safe and proper disposal. Despite differences in equipment design, the potential risks during this phase remain consistent [10].

CONCLUSIONS

Intraoperative Cell Salvage is a reliable and safe technique that plays a pivotal role in reducing reliance on allogeneic blood transfusions. With proper patient selection, adherence to guidelines, and

advanced filtration methods, ICS can be effectively integrated into various surgical settings. It supports both ethical and clinical priorities, enhancing patient care while minimizing transfusion-related risks.

REFERENCES

1. Fourtounas M. Cell saver physics–a review. South Afr J Anaesth Analg. 2020 Nov 13;26(6):S49–54.
2. Burman JF, Westlake AS, Davidson SJ, Rutherford LC, Rayner AS, Wright AM, et al. Study of five cell salvage machines in coronary artery surgery. Transfus Med. 2002 Jun;12(3):173–9.
3. Vermeijden WJ, Hagenaars A, van Oeveren W, de Vries AJ. Do repeated runs of a cell saver device increase the pro-inflammatory properties of washed blood? Eur J Cardiothorac Surg. 2008 Aug 1;34(2):350–3.
4. Oon CJ, Hobbs JR. Clinical applications of the continuous flow blood separator machine. Clin Exp Immunol. 1975 Apr;20(1):1.
5. Qudeimat A, Zandaki DA, Bi Y, Li Y, Davis K, Alloush L, et al. Comparison of Haemonetics Cell Saver 5+ and manual density separation for optimum depletion of red blood cells and preservation of CD34+ cells in major ABO-incompatible bone marrow grafts. Cytotherapy. 2023 Nov 1;25(11):1145–8.
6. Eichert I, Isgro F, Kiessling AH, Saggau W. Cell saver, ultrafiltration and direct transfusion: comparative study of three blood processing techniques. Thorac Cardiovasc Surg. 2001 Jun;49(3):149–52.
7. Vermeijden WJ, Hagenaars A, van Oeveren W, de Vries AJ. Do repeated runs of a cell saver device increase the pro-inflammatory properties of washed blood? Eur J Cardiothorac Surg. 2008 Aug 1;34(2):350–3.
8. Muñoz M, Slappendel R, Thomas D. Laboratory characteristics and clinical utility of post-operative cell salvage: washed or unwashed blood transfusion? Blood Transfus. 2011 Jul;9(3):248.
9. Bennett-Guerrero E, Kirby BS, Zhu H, Herman AE, Bandarenko N, McMahon TJ. Randomized study of washing 40-to 42-day-stored red blood cells. Transfusion. 2014 Oct;54(10):2544–52.
10. Gruber M, Breu A, Frauendorf M, Seyfried T, Hansen E. Washing of banked blood by three different blood salvage devices. Transfusion. 2013 May;53(5):1001–9.

