Section 9

Practicalities – Blood Processing

Aim

- To introduce the basic theory and principles of processing blood during Intraoperative Cell Salvage (ICS)

Learning Outcomes

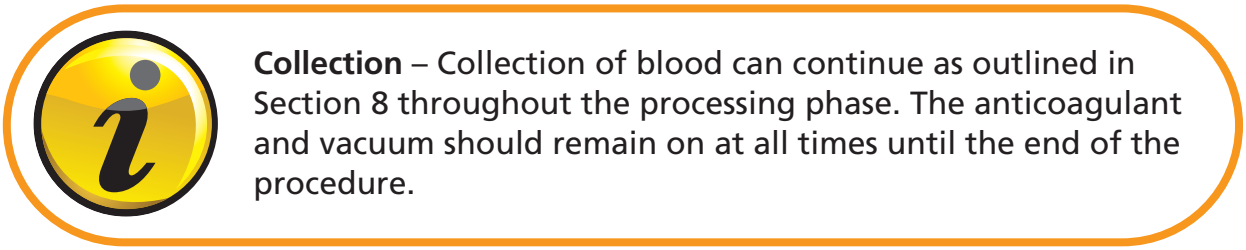
- To identify the steps taken in making the decision to process
- To list the equipment used for blood processing and describe the function of each component
- To describe the steps required in preparing for and commencing blood processing
- To describe the risks of overriding the automatic functions of the machine
- To identify the steps necessary to complete the blood processing phase

Introduction

While the practical set up of the equipment for the blood processing phase of ICS is specific to the machine in use, the basic theory and principles are the same for all machines.

During the blood processing phase of ICS, blood that has been collected in the collection reservoir is processed by the ICS machine to separate the red blood cells (RBCs) from the waste products (plasma, clotting factors, platelets, anticoagulant etc). The RBCs are concentrated to produce a high haematocrit and washed with intravenous (IV) normal saline (0.9% NaCl). At the end of the processing phase the RBCs, now suspended in IV normal saline (0.9% NaCl), are pumped to a re-infusion bag.

The types of processing systems (Fixed Volume Bowl, Continuous Rotary and Variable Volume Disk systems) were discussed in Section 6. All of the systems work on the principle of separating the dense RBCs from the less dense waste products using centrifugal forces.



Collection – Collection of blood can continue as outlined in Section 8 throughout the processing phase. The anticoagulant and vacuum should remain on at all times until the end of the procedure.

9.1 Decision to Process Blood

If a "collect only" system has been used for blood collection, the ICS operator must make an informed decision to proceed to set up for processing the salvaged blood. The processing set usually comes packaged separately from the blood collection equipment (A&A line/collection reservoir). This reduces unnecessary waste and is more cost effective if there is insufficient blood loss to warrant processing.

The decision to load the processing set can be based on a number of factors including:

- Adequate blood loss in the collection reservoir
- Anticipated adequate blood loss due to rapid bleeding during the procedure
- Patient factors e.g.
  - Low haemoglobin (Hb)
  - Anticipated post-operative benefit

Emergency Procedures – for emergency procedures when blood loss is likely to be rapid, it may be considered appropriate to set up the collection and processing equipment before the procedure begins to ensure blood can be processed and returned to the patient without delay.

Adequate Blood Loss

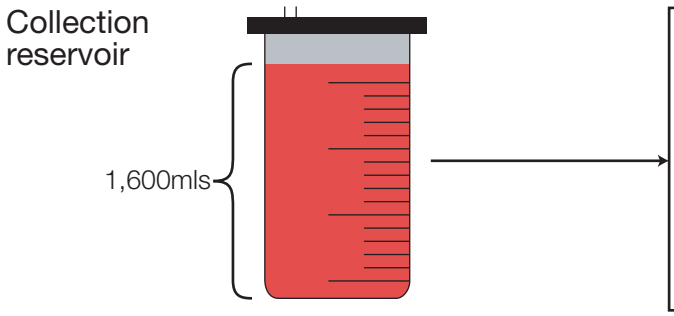
Adequate blood loss relates to two issues:

- The benefit of returning the blood to the patient e.g. will reinfusing 60mls of RBCs be of any benefit to a patient with a pre-operative Hb of 14g/dl and low intraoperative blood loss?
- The minimum volume of blood necessary for processing in volume dependent systems (fixed volume bowl systems)

While there is no absolute way to determine if sufficient blood has been collected to warrant loading the processing kit, an experienced operator can make a judgement based on an estimate of the volume of blood in the collection reservoir.

The collection reservoir will contain blood *and* anticoagulant as well as any irrigation fluids from the sterile field. This is illustrated in Figure 14 (opposite).

Figure 14. Estimating Salvaged Blood Volume in the Collection Reservoir



Collection reservoir volume	= 1,600mls
Anticoagulant used	= 300mls
Irrigation used	= 400ml
Total volume of blood	**= 900mls**

(which is made up of approximately 40 – 50% red blood cells)

While the continuous rotary and variable volume disk systems require only a very small volume of blood for processing to begin, the fixed volume bowl systems require a minimum volume of RBCs in the bowl for processing to be completed. The volume of RBCs required in turn depends on the size of the bowl being used.

Example

Assume 100% of the bowls volume will be occupied by RBCs once it is full. Therefore, a processing kit with a 225ml bowl requires 225mls of RBCs in the bowl for processing to be completed.

If the collection reservoir contains 900mls of whole blood (made up of 40 – 50% RBCs – See Figure 14), the volume of RBCs in the collection reservoir would be approximately 360 – 450mls. Since we need 225mls of RBCs, this is sufficient for the processing to be carried out.

This calculation allows the operator to estimate if sufficient blood for processing has been collected. In reality, many factors affect the volume of RBCs available/required for processing e.g. the patient's haematocrit, the amount of haemolysis and the amount of time it takes to fill the bowl (long fill cycles result in a higher concentration of RBCs). Therefore this calculation should only be used as a guide to assist the operator in making the decision to process.

Swab Wash – don't forget to include swab wash blood when making the decision to process, however, this can be very dilute, so don't presume that it will make up the necessary volume for processing.

9.2 Equipment

The equipment listed in Table 4 (below) is required for blood processing.

Table 4. Blood Processing Equipment

Equipment	Function
ICS device	Contains pump, sensors, centrifuge mechanism and control panel.
Processing set machine specific	Contains tubing, centrifuge system (bowl, disk etc), re-infusion bag and waste bag.
IV normal saline (0.9% NaCl)	Used to wash the RBCs during processing.
Autologous transfusion label	Identifies the blood as autologous, belonging to a particular patient and enables the recording of procedure specific details.

9.3 Choice of Bowl Size

The fixed volume bowl systems are generally available in a range of sizes that differ depending on the ICS machine being used. As outlined above, bowl systems require a minimum volume of RBCs in the bowl for processing to be completed, whereas the continuous rotary and the variable volume disk systems are one size and not dependent on volume.

For fixed volume bowl systems, where there is a choice of bowl size, the appropriate size will depend on the anticipated blood loss. A small bowl requires a lower volume of RBCs for processing than a larger bowl.

Where there is a choice of bowl size for a particular machine:

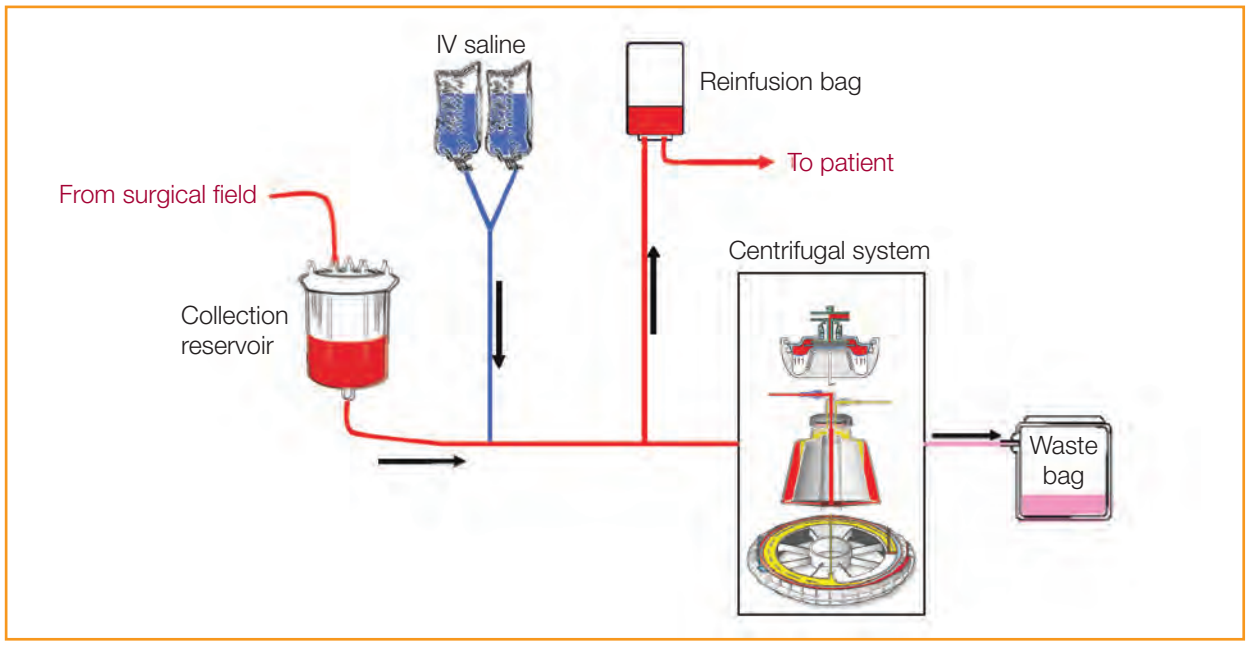
Smaller bowls – Will take longer to process a large volume of blood, as the blood is processed in small batches.

Larger bowls – Require a large volume of blood to "fill" them, if the bowl is not filled (i.e. if there is only a small volume of blood available), processing cannot be completed.

Processing rates will also differ between manufacturers/ICS systems.

9.4 Preparation of Equipment for Blood Processing

Figure 15. Movement of Fluid Through the Cell Salvage Machine



The processing set includes the tubing that will carry the fluids through the machine. This tubing consists of:

- Collection reservoir line
- Wash solution line – Y-connector allowing two bags of IV normal saline (0.9% NaCl) to be connected
- Reinfusion bag line

The three lines join to a single line that carries fluid from the collection reservoir, and the wash solution (IV normal saline (0.9% NaCl)) into the centrifugal system, and the final processed RBCs away from it and into the reinfusion bag. The flow of fluids through these lines is controlled by a pump and a series of valves that open and close particular lines depending on the stage of the process.

In addition to these lines, there is a separate line that carries waste products from the centrifugal system into the waste bag.

Figure 15 (above) outlines the flow of fluids through the cell salvage machine.

The set up of the blood processing set for ICS is specific to the machine in use. However the basic principles and theory are the same. The key steps in the preparation of the blood processing equipment are outlined opposite. The order in which these are carried out should be completed according to the manufacturer's training/guidance.

Clean/aseptic technique should be used as appropriate and protective clothing should be worn in accordance with local policy.

Centrifugal System	• The centrifugal system should be loaded into the machine carefully according to the manufacturer's guidelines. Damage to the centrifugal device could result in spillage.
Tubing Network	• Ensure there are no kinks or twists in the tubing. • Ensure the tubing is correctly placed through the pump, valves and machine sensors. • Securely close any tubing retainers.
Waste Bag	• Connect the waste bag to the waste line, (for some machines this is already done by the manufacturer) and hang on the machine according to the manufacturer's guidelines. • Ensure the waste line is **not** clamped. • Check the outlet port on the bag is closed.
Reinfusion Bag	• Hang the reinfusion bag on the machine dripstand. • Connect the reinfusion line (for some machines this is already done by the manufacturer). • Close the clamps on the reinfusion bag outlet/giving ports. • Ensure the reinfusion bag line is **not** clamped. • Transfer the autologous transfusion label (Appendix 3) from the collection reservoir (see Section 8) and securely attach to the reinfusion bag, or complete a new label and securely attach to the reinfusion bag.

Labelling – Section 8 outlines the importance of how and when the autologous label is completed. It is recommended that if a "collect only" system has been set up, the label is attached to the collection reservoir, and subsequently transferred to the reinfusion bag when the processing set is loaded.

If the entire system is set up from the start of the procedure, the autologous label should be completed at the patient's side at the start of blood collection, and attached immediately to the reinfusion bag. To avoid errors in patient identification, the patient's details should be taken from the identification band on the patient's wrist.

IV Saline Wash Solution	• Hang one or two bags of IV normal saline (0.9% NaCl) onto the machine dripstand. • Clamp both of the wash solution lines. • Connect (spike) the wash solution line(s) to the IV normal saline (0.9% NaCl) bag(s) and open the clamp on one line.
Collection Reservoir Line	• Connect the collection reservoir line to the collection reservoir. • If there is a clamp on the collection reservoir/collection reservoir line, ensure this is open.
Machine	• Securely close all covers on the machine, ensuring none of the tubing is trapped. • Follow the manufacturer's guidance with regard to checking machine parameter (if applicable). • Follow the manufacturer's guidance with regard to initiating blood processing.

Patients with religious requirements – the set up of ICS equipment for patients with religious requirement may differ. The requirements should be discussed with the patient prior to use, and all relevant staff should be made aware of these requirements. Further information can be found in Appendix 2.

Automatic mode – Most machines are fully automatic. The responsibility of the operator is to start the processing cycle and then allow the machine to complete the cycle automatically. **It is highly recommended that ICS machines are run in automatic mode**. Running the machine in manual mode could result in residual contaminants in the RBCs, which could be potentially harmful to the patient.

Wash volumes – The minimum wash volume outlined by the manufacturers should be used. This will be set in the machine parameters and should not be changed. Reducing the wash volume may lead to residual contaminants in the RBCs, which could be potentially harmful to the patient.

In some circumstances it may be acceptable to **increase** the wash volume e.g. in orthopaedics or neurological procedures, where there are contaminants such as fat within the surgical field that could be potentially harmful. However, many machines have a high quality wash programme for this purpose, in which case the manufacturer's guidance should be followed for selecting this programme.

9.5 Blood Processing

During the blood processing phase, it may be necessary for the operator to make minor adjustments to the system (but not the processing functions of the machine):

- Replacing the wash solution – it is likely that the IV normal saline (0.9% NaCl) will need to be replaced regularly. The operator can anticipate this and change the bag, (while the machine is in standby) or wait for the machine alarm during processing (following the onscreen instructions to restart the process).
- Changing the reinfusion bag – most manufacturers can supply replacement reinfusion bags. The operator can replace the bag as necessary **between processing cycles**. The disconnected bag should be kept with the patient until it is reinfused, and the new bag should be labelled with an autologous label, which has been completed as outlined in Section 8.
- Emptying the waste bag – the waste bag can be emptied through a port on the bottom of the bag into a bucket. This can be disposed of as per local policy. The waste bag should **never** be **fully** emptied during the procedure, as the loss of air from the bag will prevent fluid movement through the machine.

Ensure protective clothing is worn in accordance with local policy.

9.6 Incomplete Bowls

Machines that use the fixed volume bowl system require the bowl to be full of RBCs before the machine will wash them and send them to the reinfusion bag.

Incomplete bowls – Overriding the automatic function of the machine, and manually washing a partially filled bowl could result in residual contaminants in the RBCs, which could be potentially harmful to the patient. Although the bowl may look full to the eye, this can be misleading. The machine uses sensors to guide this process, these are far more accurate than the human eye.

There are several things the operator can do in the event of an incomplete bowl:

- Wait for more blood loss – the machine will return to standby mode after a few minutes. The operator can then wait for more fluid in the collection reservoir, before starting processing in automatic mode again.
- **Concentrate Function** – This function should only be used at the end of the procedure when no more intraoperative blood loss is expected, and the swab wash has also been processed. The concentrate function uses RBCs that have already been processed and sent to the reinfusion bag to fill the bowl and complete the process as normal. **This function can only be used if there are RBCs in the reinfusion bag.**

If neither of the above options are possible, the operator should discuss how to proceed with the lead clinician taking responsibility for ICS in the procedure (normally the lead anaesthetist, however, in some cases it may be the lead surgeon), outlining the potential risks of processing an incomplete bowl.

9.7 Completing the Process

At the end of the procedure, when all of the blood has been processed, there are several things the operator may need to do. These functions may vary between machines, the manufacturer's guidance for these functions should be followed.

- Emptying the reinfusion line – the line contains dead space which can hold a significant volume of processed RBCs. These can be transferred to the reinfusion bag for reinfusion to the patient.
- Removing air from the reinfusion bag – a large portion of the air in the reinfusion bag can be removed, however, it is likely that the bag will still contain some air, therefore the blood should **not** be reinfused under pressure (see Section 10).
- Disconnecting the reinfusion bag – the clamp on the reinfusion bag (from the reinfusion line) should be securely closed before the bag is disconnected (there may also be a clamp on the reinfusion line). Most manufacturers provide caps to attach to the disconnected ends of the line to prevent slight spillage, but in most cases these will not prevent spillage if the clamps are left open.

9.8 Troubleshooting

As with any technical procedure, there is a potential for problems to arise during the process e.g.

- Incomplete bowls – see 9.6.
- Machine alarms – if the machine detects a problem, it will stop processing and display information relating to the problem on the control screen. The operator should follow the on screen instructions to resolve the problem.

Monitoring the system – the operator is responsible for the machine during the procedure. Although the machines are automatic and therefore, in most cases, do not need a dedicated operator, the operator should be working within the vicinity of the machine to allow them to monitor the system and respond to alarms. The operator should ensure that necessary procedures are carried out, e.g. emptying the waste bag. The operator should also monitor the collection equipment throughout the procedure (see Section 8).

9.9 Blood Loss Calculations

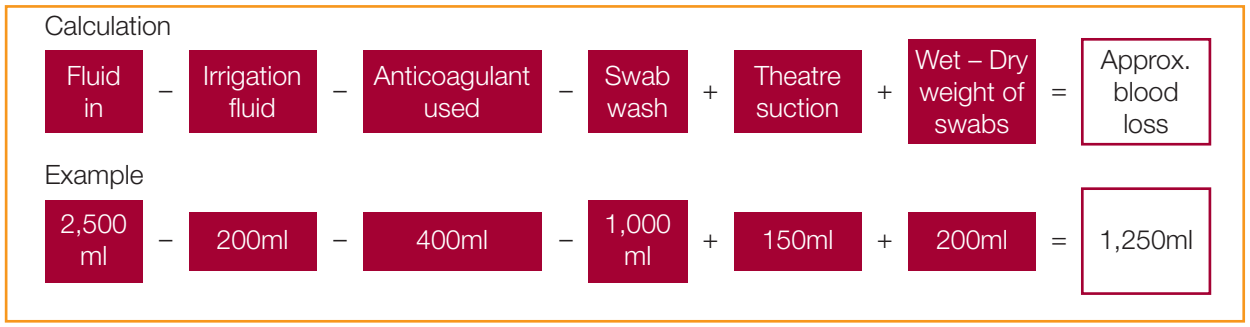
At the end of the procedure, when all of the blood from the collection reservoir has been processed, an estimate of the volume of blood the patient has lost during the procedure can be made using a simple calculation.

The information you will need is:

- **Fluid in volume** (machine read out) – Total volume of fluid processed by the machine, includes: blood aspirated from the surgical field, anticoagulant and irrigation from the surgical field.
- **Irrigation fluid** – Volume of sterile irrigation fluid used within the surgical field and aspirated into the ICS collection reservoir, (this is **not** the volume of IV normal saline (0.9% NaCl) wash solution used by the machine – this volume is **not** required for the blood loss calculation).
- **Anticoagulant used** – An estimate of the volume of anticoagulant that has been used.
- **Swab wash** – Volume of IV normal saline (0.9% NaCl) or equivalent used to wash swabs.
- **Theatre suction** – Volume of blood in theatre suction.
- **Wet-dry weight of swabs** – Compensates for blood *and* saline swab wash retained on swabs and allows them to be weighed outside of the sterile field after washing.

Once you have all of this information, an estimate of blood loss can be calculated as demonstrated in Figure 16 (opposite).

Figure 16. Estimated Blood Loss Calculation



9.10 Documentation

The documentation required during blood processing is the same as outlined in Section 8:

- Autologous transfusion label (Appendix 3)
- ICS data form (Appendix 4)

Key Points

- The operator must be able to make an informed decision regarding proceeding to process the blood.
- The blood processing set includes a centrifugal system, reinfusion bag, waste bag and tubing, which are all loaded into the ICS machine.
- The operator should follow the manufacturer's guidance with regard to loading the processing equipment and running the processing phase of the procedure.
- The operator must maintain awareness throughout the procedure in order to prevent errors occurring.

Further Reading

UK Cell Salvage Action Group Publications

The following publications are available to download at:
www.transfusionguidelines.org.uk

- Policy for the provision of Intraoperative Cell Salvage.
- Technical Factsheets 6 – Use of ICS in Jehovah's Witness Patients
  9 – Contraindications

Other

- American Association of Blood Banks – Standards for Perioperative Autologous Blood Collection and Administration 3rd Edition
- Manufacturer's ICS Machine Specific Guidance