UK CELL SALVAGE ACTION GROUP

EDUCATION WORKBOOK

Intraoperative Cell Salvage
Education Workbook

Edition 1
December 2008

Trainee Details

Name: .....

Department/Hospital: .....

.....

Acknowledgements

This education workbook has been produced by the UK Cell Salvage Action Group.

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Section 1
Using the Education Workbook

Aim

- To introduce the learner to the education workbook

Learning Outcomes

- Identify how to use the workbook
- Identify who the workbook is produced for
- Identify different learning styles

Introduction

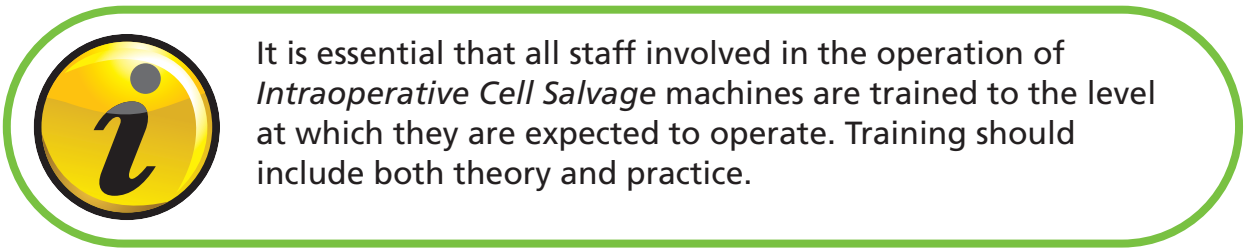
The aim of this education workbook is to provide learners with the necessary knowledge to assist them in the safe use of Intraoperative Cell Salvage (ICS) machines and disposables in the operating theatre and other areas. It should be used in conjunction with practical training covering the following skills:

- Set up of machines/disposables
- Processing red cells for reinfusion
- Reinfusion
- Disposal of cell salvage waste

This education workbook has been developed by the UK Cell Salvage Action Group. The group was established to help support the wider implementation of cell salvage as an alternative to allogeneic (donor) blood, and to facilitate a UK-wide approach to its use.

This workbook is intended for Doctors, Operating Department Practitioners, Perfusionists, Nurses, Midwives, Health Care Support Workers and all other staff responsible for the setup and/or running of ICS machines.

This workbook does not currently cover any specialised requirements for paediatric practice.



1.1 How to use the Education Workbook

This publication is designed to be used by the learner as a workbook and once completed can be kept and used for reference.

Each section follows the same format and contains the following:

- Aims
- Learning Outcomes
- Subheadings for each "topic"
  - These will include the body of the text, pictures, and boxes containing information and best practice guidance/cautions
- Documentation (if applicable)
- Key Points
- Further Reading
- Self Directed Learning section

The theory component of each section can be accessed as:

- Face to face training, either classroom style and/or delivered by "key trainers"
- An e-learning package "Learn Cell Salvage" (available at *www.transfusionguidelines.org.uk*)
- Part of a manufacturer's training programme
- A combination of these

Self directed learning allows the learner to identify practice within their own organisation and reinforces the theory component of each section.

In some of the sections the learner will find the following symbols:

Relates to information and best practice

Cautions

Self directed learning questions

1.2 Associated Competency Assessment Skills

This workbook is designed to be used in conjunction with the UK Intraoperative Cell Salvage Competency Assessments. The related competency assessments for each section are listed in Appendix 1.

The ICS competency assessment workbook can be downloaded through the UK Cell Salvage Action Group section of the Better Blood Transfusion Toolkit (*www.transfusionguidelines.org.uk*).

Self Directed Learning

Who will deliver training and how will it be delivered in your organisation?

Have you accessed the e-learning package Learn Cell Salvage at *www.transfusionguidelines.org.uk*? If yes, identify three key learning points.

Section 2
Training Pathway

Introduction

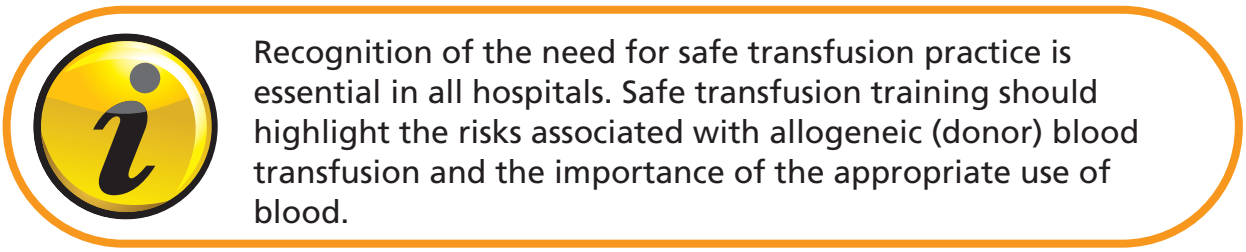
This education workbook can be used as part of a training pathway. A suggested pathway designed to offer comprehensive and flexible learning in the use of Intraoperative Cell Salvage (ICS) is outlined below, followed by an explanation of each of the stages at the end of this section.

	✔	Date achieved
Safe Transfusion Practice	☐	__ __ / __ __ / __ __ __ __
Learncellsalvage.org.uk	☐	__ __ / __ __ / __ __ __ __

ICS Education Workbook	☐	__ __ / __ __ / __ __ __ __
Practical Session	☐	__ __ / __ __ / __ __ __ __

Competency Assessment	☐	__ __ / __ __ / __ __ __ __
Maintenance of Case Logs	Ongoing	

Reflective practice should be undertaken at each stage of the training pathway.



Recognition of the need for safe transfusion practice is essential in all hospitals. Safe transfusion training should highlight the risks associated with allogeneic (donor) blood transfusion and the importance of the appropriate use of blood.

The background to safe transfusion practice is covered by level one of Learn Blood Transfusion, an online package aimed at all staff groups involved in the transfusion process. There is an online assessment at the end of each of the seven modules in level one. There are further modules that can be undertaken in level two of this package. Level two is aimed at members of staff who regularly use blood and blood components in their day-to-day practice. Learn Blood Transfusion is part of the Better Blood Transfusion (BBT) Toolkit (*www.transfusionguidelines.org.uk*).

Learn Cell Salvage is another online package on the BBT Toolkit. This course provides you with an introduction to blood conservation in general and ICS in particular. An online assessment can be taken at the end of this course.

A device-specific practical session on setting up, operating and unloading of the ICS equipment should be undertaken. Training is usually offered by manufacturers but may also be delivered by "in-house" trainers.

An ICS Competency Assessment Workbook is available to download from *www.transfusionguidelines.org.uk* and has been created based on standards developed by Skills for Health (PCS 19-22 *www.skillsforhealth.org.uk*). In-house trainers may offer competency assessment.

The ICS Competency Assessment Workbook also provides the learner with a case log for recording ICS cases that they have been involved in.

Section 3
Basic Blood Facts

Aim

- To introduce the basic concepts of haematology, blood components and blood products and how they interlink with Intraoperative Cell Salvage (ICS) and blood conservation

Learning Outcomes

- Describe the main functions of blood
- Identify the main components of blood and describe their individual functions
- Describe the basics of simple coagulation
- List the allogeneic (donor) blood components available for clinical use
- Identify the allogeneic (donor) blood products available for clinical use
- Identify the recombinant therapies available for clinical use

Introduction

Before considering ICS it is important to understand the composition and function of whole blood as well as the functions of the main components of blood and how these components can be separated.

3.1 Functions of Blood

Human blood is a collection of cells suspended in liquid and has the following definable functions:

- Transport:
  - Dissolved gases (e.g. oxygen, carbon dioxide)
  - Waste products of metabolism (e.g. water, urea)
  - Hormones, enzymes and nutrients
  - Plasma proteins (associated with defence, such as blood clotting and antibodies)
  - Blood cells (including white blood cells and red blood cells)
- Maintenance of body temperature
- Control of pH:
  - The pH of blood must remain in the range 6.8 to 7.4 otherwise cells become damaged
- Removal of toxins from the body:
  - The kidneys filter all of the blood in the body (approximately 8 pints), 36 times every 24 hours. Toxins removed from the blood by the kidneys leave the body in the urine. Toxins also leave the body in the form of sweat.
- Regulation of body fluid electrolytes:
  - Excess salt is removed from the body

3.2 Composition of Blood

Blood has both cellular and non-cellular components, each accounting for approximately half of the total volume. The cellular components, which are produced in the bone marrow, include red blood cells (RBCs), white blood cells (WBCs) and platelets. The non-cellular component of blood is plasma which is primarily water. Plasma contains proteins such as albumin, clotting factors, immunoglobulin and electrolytes. Blood constitutes about 7% of body weight, which is 70ml/kg.

Haemoglobin (Hb) is a complex protein-iron compound in the blood that carries oxygen to the cells from the lungs and carbon dioxide away from the cells to the lungs. Each red blood cell contains 200 to 300 molecules of haemoglobin. Each molecule of haemoglobin contains several molecules of haem, each of which can carry one molecule of oxygen. The normal concentration of haemoglobin is between 12.5 and 16g/dl.

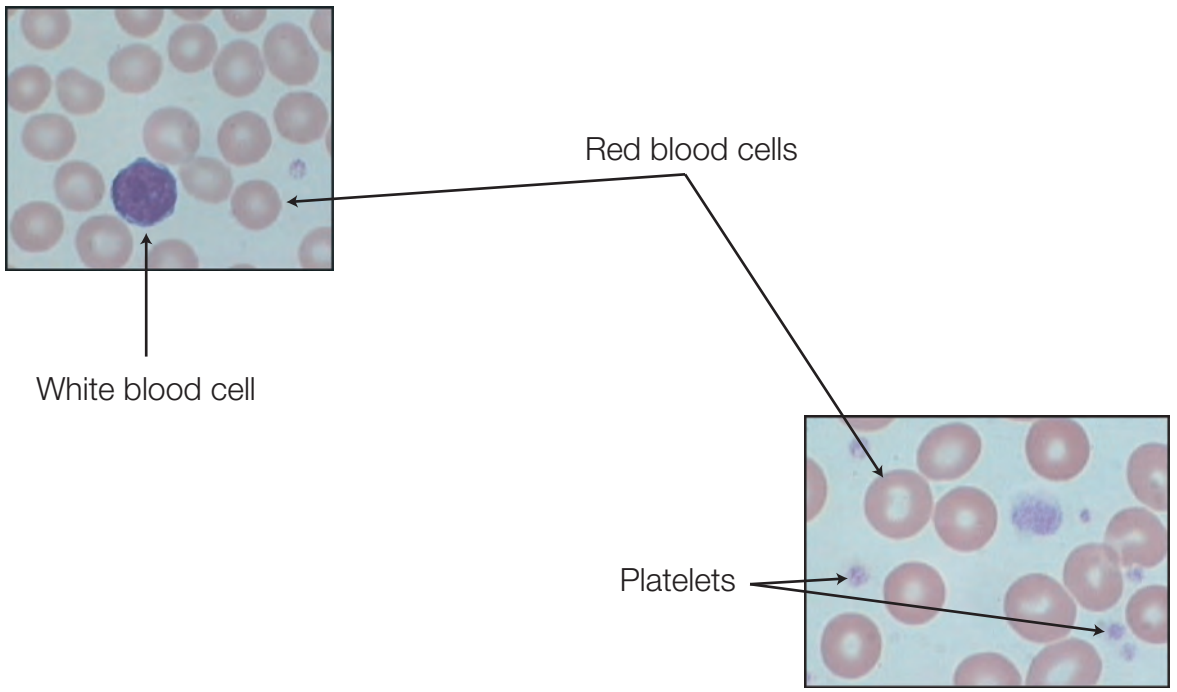
Haematocrit (Hct) is a measure of the number of red cells found in the blood, stated as a percentage of the total blood volume. The normal range is between 43 and 49% in men and between 37 and 43% in women.

Table 1. Properties of the Main Components of Blood

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 ranges*	4.5 – 5.8 million	5,000 – 10,000	150,000 – 400,000
Function	Transport of O_2	Immune response, fight infection	Clotting

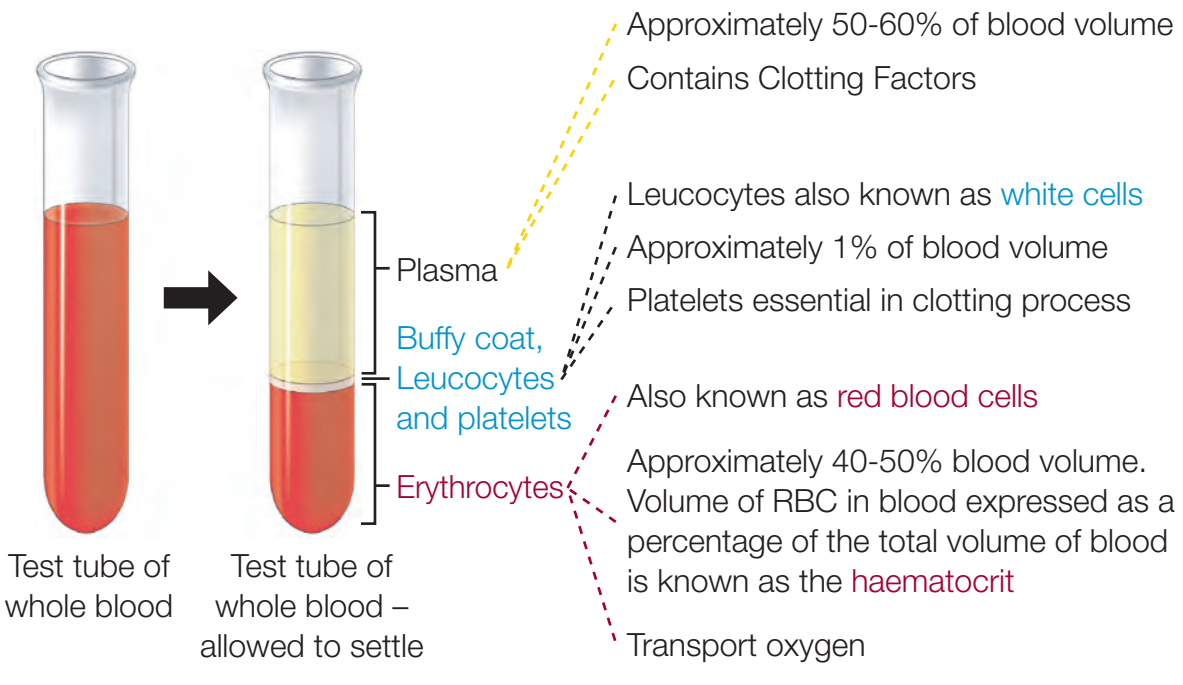
*Normal ranges will vary according to age and gender and also depending on the technology used to measure the cells.

Figure 1. Red Blood Cells, White Blood Cells and Platelets



Because the components of blood have different densities, if they are allowed to settle in a test tube or spun in a centrifuge, they will separate according to their densities (Figure 2).

Figure 2. Blood Separated into its Constituent Parts



3.3 Coagulation

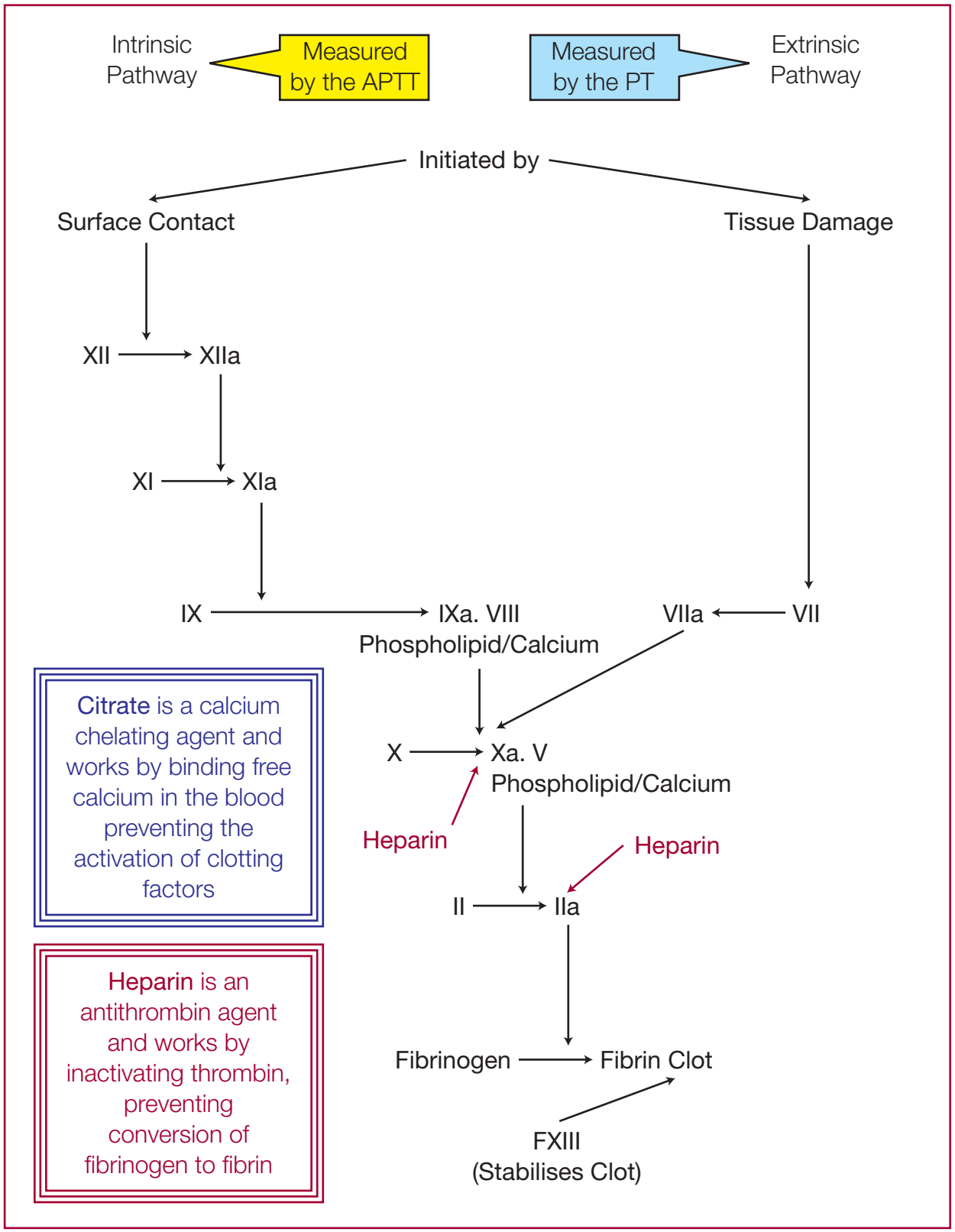
The clotting cascade is initiated by either the intrinsic or extrinsic pathway both leading to a series of coagulation events. The intrinsic pathway is initiated when blood comes into contact with a foreign (non-endothelial) surface such as tissue grafts or artificial heart valves, or when blood is removed from the body. The extrinsic pathway is normally activated by an external tissue injury such as a cut or ruptured vessel. Regardless of the origin, an amplification of the coagulation process leads to a common pathway where fibrinogen is converted to fibrin. During surgical procedures both the intrinsic and extrinsic pathway are stimulated.

Coagulation tests

- The APTT is a test of the intrinsic pathway of coagulation. (Activated Partial Thromboplastin Time (APTT, KCCT, PTTK, KPTT, PTT)). All the above abbreviations refer to the same test and terminology varies between laboratories.
- The PT tests the extrinsic pathway of coagulation (One Stage Prothrombin Time (OSPT, PT))

Figure 3. The Coagulation Cascade

(Adapted from the American Association for Clinical Chemistry[1])



3.4 Allogeneic (Donor) Blood Components

All blood components in the UK are collected from blood donors who are unpaid volunteers. They are very carefully selected and tested to make sure that the blood they donate is as safe as possible. Compared to other everyday risks, the likelihood of getting an infection from a blood transfusion is very low. All units supplied in the UK are leucodepleted (white blood cells removed) and have been since 1999. White blood cells are removed as a precaution against variant Creutzfeldt-Jakob Disease (vCJD). Table 2 lists the blood components available for clinical use.

Table 2. Allogeneic (Donor) Blood Components

Component	Volume	Storage	Clinical indications in the surgical setting
Red cells	180-350ml	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 180-300ml Pooled 250-400ml	Temperature controlled 'room temperature' (22°C +/– 2°C) – gentle agitation to ensure availability of oxygen. Shelf Life: 5-7 days.	The prevention and treatment of bleeding due to: • Thrombocytopenia associated with large volume blood transfusions • Consumption due to disseminated intravascular coagulation (DIC), major surgery
Fresh frozen plasma	240-300ml	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 disseminated intravascular coagulation (DIC) • Immediate reversal of Warfarin effect if prothrombin complex concentrate (PCC) is unavailable • Haemostatic defects associated with liver disease **if** bleeding/invasive procedure
Cryo-precipitate		Designated temperature controlled freezer –30°C. Shelf life: 24 months.	Bleeding associated with hypofibrinogenaemia This most commonly occurs in: • DIC • massive transfusion

3.5 Risks of Allogeneic (Donor) Transfusion

The risk of getting hepatitis from a blood transfusion in the UK is currently about 1 in 850,000 for Hepatitis B, and 1 in 51,000,000 for Hepatitis C. The chance of getting Human Immunodeficiency Virus (HIV) is 1 in 5,000,000 and Human T-Lymphotropic Virus (HTLV) infection is 1 in 11,000,000. Although the risk of getting vCJD from a blood transfusion is probably low with a single blood transfusion, the risk of any infection will increase with additional blood transfusions. Within the UK there have been just a handful of cases where patients are known to have become infected with vCJD from a blood transfusion. The largest risk is from getting the "wrong blood" as evidenced by the Serious Hazards of Transfusion (SHOT) annual reports[2].

Blood and blood components must always be stored under controlled storage conditions in designated fridges, freezers etc.

3.6 Allogeneic (Donor) Blood Products

Human Albumin 4.5%

4.5% human albumin is iso-oncotic with human plasma. It is usually supplied in a 400ml bottle which is stored at room temperature. The dosage should reflect circulating blood volume, rather than measures of albumin levels, and will vary according to patient size and the severity of the illness or fluid/protein losses. It is usually administered through a standard infusion set at rates of 5-15ml per minute, although this varies according to clinical need.

There is no firm evidence that the use of albumin is advantageous over the use of saline for fluid resuscitation in patients with trauma, burns or following surgery[3].

Simply raising a patient's albumin level does not improve outcome and other fluids may be effective for raising blood pressure: e.g. crystalloids or synthetic colloids.

Human Albumin 20%

20% albumin has an oncotic pressure approximately 3-4 times higher than that of normal human plasma and infusion will therefore expand plasma volume by drawing in extravascular fluid. It is supplied in 100ml bottles and again is infused through a standard infusion set at rates of 1-2ml per minute.

20% albumin solutions are used in the management of:

- Hypoproteinaemic oedema associated with nephrotic syndrome (diuretic resistant oedema)
- Ascites in liver disease

Immunoglobulin Products

Immunoglobulins are the antibodies produced by B-lymphocytes in response to infection. Immunoglobulins are important for the correct functioning of the immune system, fighting bacterial infections, neutralising viruses and activating the complement systems.

Other Plasma Derivatives

Many other plasma derivatives are available for patient use, such as Factor VIII and IX concentrates and prothrombin complex concentrates. On the whole, their use is very specialised and outside the remit of this workbook. Their use is very specialised and should be guided by consultant haematologists.

3.7 Recombinant Therapies

Recombinant Clotting Factors

Recombinant clotting Factors VIII and IX are used as a treatment for people with Haemophilia A and B, respectively.

Recombinant Factor VIIa (NovoSeven®)

This was originally developed for use in haemophilia patients with inhibitors and is licensed for this indication. Other indications for use are still being established. Recombinant Factor VIIa works by activating coagulation and platelet adhesion, but only if tissue factor is exposed. It requires the presence of platelets and other coagulation factors. Case reports show it can be effective in stopping traumatic, surgical or obstetric haemorrhage, allowing a major bleeding source to be dealt with surgically. However, the product is not licensed for this indication. There may be risks of thrombotic complications and as the drug is currently extremely expensive, UK hospitals have special procedures for making it available. It must only be used according to local guidelines.

Key Points

- Red cells are the heaviest component of blood and it is this property that allows the separation of washed red cells from the waste products in ICS.
- Heparin and citrate both inhibit coagulation and this allows for blood to be collected without clotting.
- Allogeneic blood and blood components are extremely safe and the greatest risk is in giving the wrong blood.

References

1. The American Association of Clinical Chemistry (2003) The Coagulation Cascade *http://www.labtestsonline.org.au/images/coag_cascade.pdf* [Accessed on 15 July 2008]
2. Serious Hazards of Transfusion (1996 – 2007) Annual Reports *www.shotuk.org*
3. The SAFE Study Investigators (2004) A Comparison of Albumin and Saline for Fluid Resuscitation in the Intensive Care Unit. *N Engl J Med,* 350; 2247-56

Further Reading

- Essential Haematology by A. V. Hoffbrand *(ISBN-13:978-4051-3649-5)*
- ABC of Transfusion (ABC Series) by Marcela Contreras *(ISBN 0-7279-1209-7)*
- Handbook of Transfusion Medicine *ed DBL McClelland (ISBN-10 0 11 322677 2)*

Self Directed Learning

What are the normal ranges for Hb, Hct, Wbcs, and platelets in your hospital?

What are the normal ranges for Prothrombin Time (PT), Activated Partial Thromboplastin Time (APTT) and Fibrinogen in your hospital?

What allogeneic components are readily available from your blood transfusion laboratory?

What blood products are immediately available in your hospital?

Section 4
Blood Conservation

Aim

- To introduce the learner to the basic concepts of blood conservation

Learning Outcomes

- Identify the principles of blood conservation
- Identify the areas where blood conservation can be undertaken in surgical patients
- Describe the main method of blood conservation

Introduction

Allogeneic (donor) blood is a valuable but limited resource and although potentially life-saving, is not without risks e.g. wrong blood incidents, transmission of infection and immunosuppression.

Precautionary measures, introduced due to concerns over the potential risk of variant Creutzfeldt-Jakob Disease (vCJD) transmission through blood transfusion, together with additional testing for a wider range of blood-borne viruses have further improved the safety of donated blood. However, the result has been a significant increase in cost.

In addition, individuals who have received or think they may have received a transfusion after 1st January 1980 are no longer eligible to donate blood. This and other restrictions have reduced the already diminishing blood donor population. The introduction of a possible test for vCJD could impact on the willingness of donors to donate. It is possible that blood shortages may in future result in the restriction of transfusion to treatment of active major bleeding, emergency surgery and life-threatening anaemia.

4.1 Health Service Circular (HSC)

In March 2007, the Chief Medical Officers of England, Northern Ireland, Scotland and Wales participated in a third "Better Blood Transfusion" seminar. In England the publication of Health Service Circular (HSC) 2007/001 – "Safe and Appropriate Use of Blood"[1] followed.

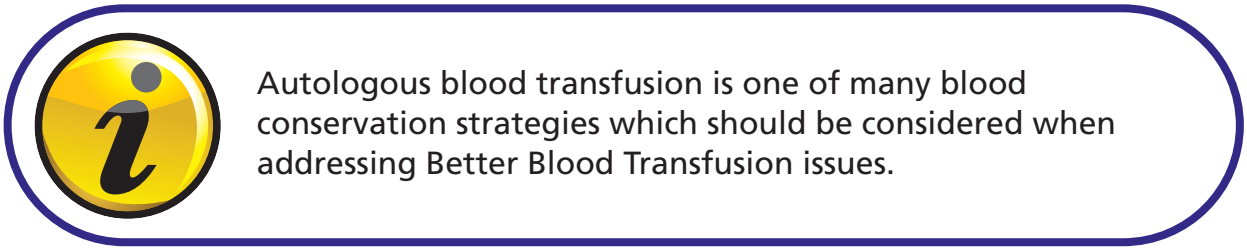
It outlines a new programme of action for NHS Trusts:

- Each NHS Trust should develop a Blood Conservation Plan
- Build on the success of previous *Better Blood Transfusion* initiatives to further improve the safety and effectiveness of transfusion
- Ensure that *Better Blood Transfusion* is an integral part of NHS care
- As part of clinical governance responsibilities, make blood transfusion safer
- Avoid the unnecessary use of blood and blood components (fresh frozen plasma and platelets) in medical and surgical practice
- Avoid unnecessary blood transfusion in obstetric practice and minimise the risk of haemolytic disease of the newborn (HDN)
- Increase patient and public involvement in blood transfusion

A toolkit to assist Trusts in the implementation of *Better Blood Transfusion* is available at *www.transfusionguidelines.org.uk*. It provides access to national guidance, examples of good practice and patient leaflets.

4.2 Reasons for Blood Conservation

Concerns over possible future blood shortages have resulted in increased efforts to manage the blood supply more effectively. This includes efforts to increase the supply and to reduce the demand for blood. Reducing the demand (blood conservation) takes many forms and can occur in both medical and/or surgical patients. This section focuses on surgical patients.

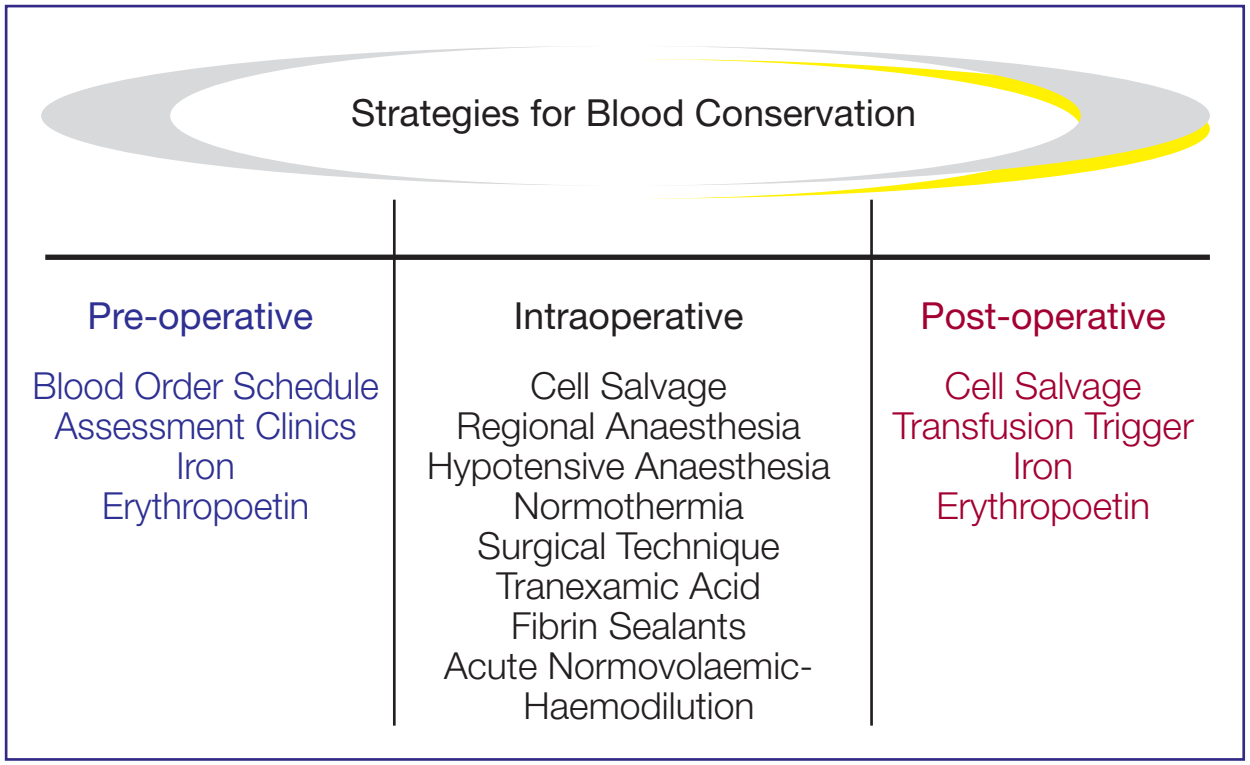


Emergency Plans for Blood Shortages

Blood services and the hospitals across the UK have made plans to manage the supply of blood in the event of a prolonged shortage. The UK blood services and hospitals have a responsibility to develop an integrated Emergency Blood Management Plan to ensure shortages are handled in a fair way and, once implemented, will invoke a controlled response to a shortage situation. For this reason, efforts at better and more appropriate management of the blood supply are being advocated.

4.3 Strategies for Blood Conservation

Figure 4. Strategies for Blood Conservation



- Pre-operative Planning:
  - Manage haemoglobin (Hb) (Manage and correct pre-operative anaemia)
  - Manage haemostasis (detect and manage coagulation disorders, stop anti-coagulants and anti-platelet drugs if safe to do so)
  - Cell salvage (arrange for blood salvage to be available if it is appropriate for the planned surgery)
- During Surgery:
  - Surgical techniques
  - Anaesthetic techniques
  - Normothermia
  - Intraoperative cell salvage (ICS)
  - Check Hb and coagulation using near patient testing
- Post Surgery:
  - Minimise blood loss
  - Transfusion threshold
  - Postoperative cell salvage (PCS)
  - Check Hb

4.4 Pre-operative Optimisation of Haemoglobin

Patients scheduled for elective surgery should have anaemia investigated before presenting for surgery.

Low iron stores define iron deficiency. Iron deficiency anaemia is the presence of low haemoglobin concentration in addition to low iron stores. Iron deficiency anaemia is detectable from routine pre-operative screening and, after investigation, may be corrected using oral or parenteral iron.

Oral Iron

Oral iron is available in a variety of preparations and is the recommended treatment for mild to moderate iron deficiency anaemia. The recommended dose is 80-100mg elemental iron per day but compliance is often poor because of gastrointestinal side effects. Oral iron therapy may fail in the presence of chronic diseases, e.g. Crohn's, ulcerative colitis, coeliac disease, renal failure, parasitic disease, and drugs that inhibit erythropoiesis (red blood cell production).

Parenteral Iron

This is the most important alternative to oral iron and may be required if there is insufficient or no response to oral iron, intolerance of oral iron, severe anaemia or a need for a rapid response. Parenteral iron should only be administered if the patient's iron status is known, to prevent iron overload.

There are three different types of parenteral iron and they may not all be available in every organisation.

Iron dextran has the advantage that it can be administered in a total dose infusion, but it is associated with allergic reactions.

Iron sucrose may be rated as very safe, with anaphylaxis occurring rarely. However, repeat injections are required to achieve the target haemoglobin making this labour intensive and inconvenient for patients.

Iron carboxymaltose is a new parenteral iron compound, which is delivered in a total dose infusion over about 15 minutes. It has a similar safety profile to iron sucrose and has been available in the UK since 2008.

Erythropoietin (EPO)

In normal healthy adults red cells are formed in the bone marrow under the influence of haemopoetic agents (agents that control the formation of the cellular components of blood). Erythropoietin is formed predominantly in the kidneys and is the key regulator of erythropoiesis (red blood cell production). Low Hb concentration is a potent stimulus of erythropoiesis in normal healthy adults. As a result, the new red cells will incorporate iron and form haemoglobin. In the presence of renal disease, critical illness and malignancy, recombinant erythropoietin may be required in addition to intravenous iron, to raise the Hb level.

4.5 Autologous Transfusion Techniques

The following techniques involve the collection and reinfusion of the patient's own blood or blood components.

Preoperative Autologous Donation (PAD)

PAD is a form of autologous transfusion where blood is collected from the patient, stored and reinfused at surgery, if appropriate.

This technique is not currently recommended

Preoperative Autologous Donation prior to planned surgery has been used extensively in the USA. In practice the patient goes to theatre with a lower than normal Hb and there is no evidence that these patients receive any less allogeneic (donor) blood, so this technique is no longer recommended as routine. In rare cases of unusual antibody formation or in a situation of blood shortage, it may be considered but it can only be carried out in premises licensed by the Medicines and Healthcare products Regulatory Agency (MHRA) as a blood establishment. Additional information can be obtained from the British Committee for Standards in Haematology (BCSH) approved document "Guidelines for Policies on Alternatives to Allogeneic Blood Transfusion 1. Predeposit Autologous Blood Donation and Transfusion"[2].

Acute Normovolaemic Haemodilution (ANH)/Isovolaemic Haemodilution

This technique is not currently recommended

This is a procedure where the patient donates their own blood in the anaesthetic room with full monitoring in place. At the same time, a plasma expanding fluid is infused to maintain the circulating volume. The patient's whole blood is collected, labelled and kept by the patient's side, then reinfused when surgical bleeding has ceased.

Adverse events include myocardial ischaemia, pulmonary oedema and mis-identification of blood. A recent meta-analysis[3] suggests only modest benefits and therefore this technique has limited benefit.

Post-operative Cell Salvage (PCS)

Generally used in orthopaedic surgery, blood that is lost from the wound post-operatively is collected into special autologous wound drains where it is filtered before being reinfused to the patient. There are also machines available that extend the intraoperative cell salvage process into the post-operative period providing washed red blood cells for reinfusion.

4.6 Appropriate Use of Blood

Restrictive Transfusion Strategy

A lower Hb level is accepted before an allogeneic (donor) red cell transfusion is considered. The acceptable Hb level varies between patient groups and often between individual patients. Generally however, in young fit patients, a transfusion will not be considered until the Hb is less than 8g/dl or lower. It is not necessary to transfuse to a target Hb of 10g/dl in healthy patients. A restrictive transfusion strategy is not appropriate for patients with ischaemic heart disease or in the presence of ongoing rapid haemorrhage.

Point of Care Testing (PoCT)

Blood samples are drawn from the patient and tested for Hb concentration and coagulation abnormalities. The tests are performed close to the patient, often in the operating theatre. During large blood loss and transfusion the patient's haemoglobin and coagulation status can change considerably. PoCT rapidly provides the clinician with information that permits targeted, appropriate treatment of low Hb and rapid correction of a coagulopathy.

4.7 Haemostatic Products

Tranexamic Acid

This is a synthetic amino acid that inhibits fibrinolysis (breakdown of the clot) by preventing the binding of plasmin to fibrin. It is used as adjuvant therapy in primary menorrhagia, gastrointestinal bleeding and in patients with bleeding disorders. It is sometimes used post-operatively in orthopaedic surgery to decrease bleeding. It should be used with caution in patients who have a high risk of thrombotic disease or myocardial infarction.

Key Points

- Blood conservation requires a team approach if it is to be successful.
- Safe and appropriate use of allogeneic (donor) blood should be a priority for all staff.
- Developing a blood conservation policy for each organisation is essential.

References

1. Health Service Circular 2007/001 – Safe and Appropriate Use of Blood *www.transfusionguidelines.org.uk/bbt*
2. British Committee for Standards in Haematology (BCSH) (2006) Guidelines for policies on Alternatives to Allogeneic Blood Transfusion 1. Predeposit Autologous Blood Donation and Transfusion. *www.bcshguidelines.com*
3. Segal, J. B., Blasco-Colmenares, E., Norris, E.J., Guallar, E. (2004) Preoperative acute normovolaemic haemodilution: A meta-analysis. *Transfusion*, 44(5) 632-644

Further Reading

- Llewellyn CA *et al* (2004) Possible transmission of vCJD by blood transfusion. *Lancet*; 363: 417-421
- A Manual for Blood Conservation *ed Thomas, Thompson and Ridler (ISBN-10: 1903378249)*

Self Directed Learning

What pre-operative assessment clinics are run in your Organisation?

What methods of blood conservation are you aware of in your theatre/department?

Has your Organisation got an "Emergency Blood Plan"?
If yes, what are the implications for cell salvage within the hospital?

Section 5
Haemovigilance

Aim

- To introduce the learner to the basic concepts of haemovigilance

Learning Outcomes

- Demonstrate an understanding of the principles of haemovigilance
- Identify the risks associated with administration of allogeneic (donor) blood

Introduction

Haemovigilance comprises organised surveillance procedures relating to serious adverse or unexpected events or reactions in blood donors and recipients.

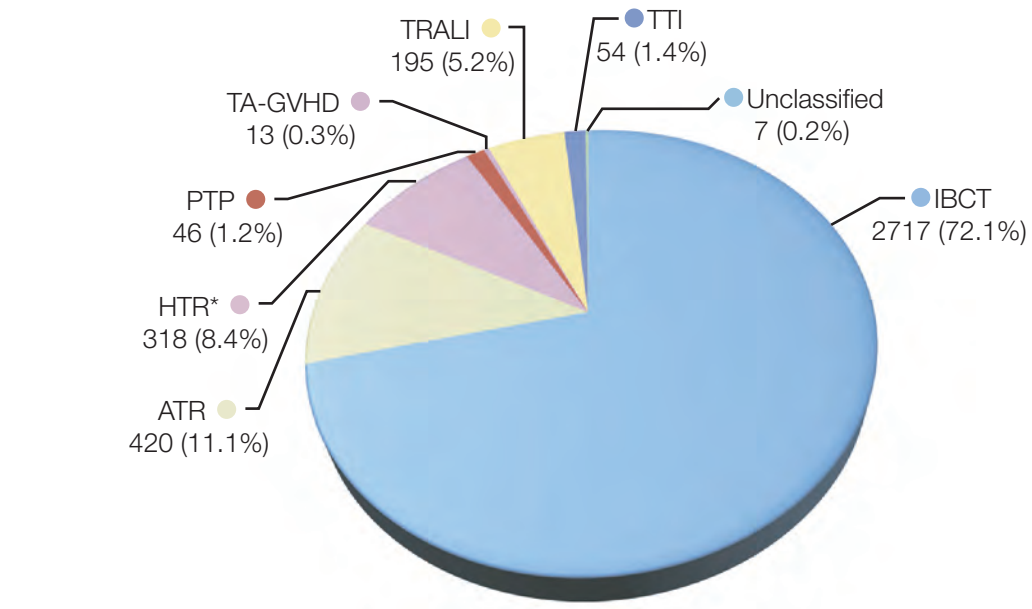
5.1 Serious Hazards of Transfusion (SHOT)

The Serious Hazards of Transfusion scheme (SHOT) provides an analysis of serious transfusion complications in the UK. It was launched in 1996 following growing concern amongst the UK transfusion specialists, haematologists and other clinicians that there was little information available on the safety of the transfusion process (SHOT Report 1996-1997)[1]. SHOT is a confidential, voluntary, anonymised, UK-wide scheme that aims to collect data on adverse events of transfusion of blood and blood components (red cells, platelets, fresh frozen plasma and cryoprecipitate).

Over a ten year period, from 1996 to the end of 2006, 2,626 incidents and more than 3,500 'near miss' events have been analysed.

The cumulative incidents, reported to SHOT, within each category from 1996 to 2006 are shown in Figure 5.

Figure 5. Cumulative SHOT Data from 1996 – 2006



IBCT	–	Incorrect Blood Component Transfused
ATR	–	Acute Transfusion Reaction
HTR	–	Haemolytic Transfusion Reaction
PTP	–	Post Transfusion Purpura
TA-GvHD	–	Transfusion Associated Graft versus Host Disease
TRALI	–	Transfusion Related Acute Lung Injury
TTI	–	Transfusion Transmitted Infection

SHOT findings are used to:

- Inform policy within transfusion services
- Improve standards of hospital transfusion practice
- Aid the production of clinical guidelines for the use of blood
- Educate users on the hazards of transfusion and their prevention

5.2 Serious Adverse Blood Reactions and Events (SABRE)

The European Union (EU) Blood Safety Directive[2] introduced a legal requirement for the reporting of *serious adverse reactions* and *serious adverse events* occurring within EU Member States to the relevant *Competent Authority.* The Department of Health has designated the Medicine and Healthcare products Regulatory Agency (MHRA) as the UK Competent Authority. To facilitate reporting, in 2005 the MHRA developed an online reporting system: *SABRE* (Serious Adverse Blood Reactions and Events).

Serious Adverse Events

Definition *"any untoward occurrence associated with the collection, testing, processing, storage and distribution of blood or blood components that might lead to death or life-threatening, disabling or incapacitating conditions for patients or which results in, or prolongs, hospitalisation or morbidity."*

Serious Adverse Reactions

Definition *"an unintended response in a donor or in a patient that is associated with the collection or transfusion of blood or blood components that is fatal, life-threatening, disabling or incapacitating, or which results in or prolongs hospitalisation or morbidity."*

Key points

- All staff involved in the transfusion process are responsible for haemovigilance and the reporting of adverse events and reactions.

References

1. SHOT Annual reports/Annual summaries available at *www.shotuk.org/home.htm*
2. Directive 2002/98/EC of the European Parliament and of the Council of 27 January 2003 (2003) Setting Standards of Quality and Safety for the Collection, Testing, Processing, Storage and Distribution of Human Blood and Blood Components and Amending Directive 2001/83/EC. *Official Journal of the European Union,* V46: L33/30-40 *http://eur-lex.europa.eu/JOIndex.do*

Self Directed Learning

Can you identify any events which may occur in your area of practice which would be reportable to SHOT/SABRE?

What is the most frequently reported risk from having a blood transfusion?

a) Transfusion transmitted infection?

b) Administration of blood intended for another patient?

Section 6
Principles of Intraoperative Cell Salvage

Aim

- To enable the learner to develop an understanding of the various stages of Intraoperative Cell Salvage (ICS)

Learning Outcomes

- Identify the four main stages of ICS
- Identify the different ICS systems that exist
- Describe the end product of ICS

Introduction

As highlighted in Figure 2 (Section 3), if whole blood is allowed to settle, it will separate into its constituent components. Red blood cells (RBC) are the most dense component of blood and consequently will settle at the bottom.

A centrifuge can significantly increase this rate of separation. It is through this process of centrifugation that many cell salvage machines separate red blood cells from the mixture of whole blood and anticoagulant that is salvaged from the surgical field.

ICS begins with the collection of shed blood from the surgical field. The blood is anticoagulated as it is aspirated with low suction into a collection reservoir where it passes through a filter. Separation of RBCs from whole anticoagulated blood occurs through centrifugation. The RBCs are washed using IV normal saline (0.9% NaCl) solution and then pumped into a bag for reinfusion to the patient. There are a variety of ICS systems available. All of the systems produce a comparable end product, i.e. the patient's own RBCs suspended in IV normal saline (0.9% NaCl).

This section looks at the various stages of processing and the different systems that exist.

6.1 Fixed Volume Bowl System

Figure 6. Examples of Fixed Volume Bowls*

(Haemonetics)

(Sorin)

(Medtronic)

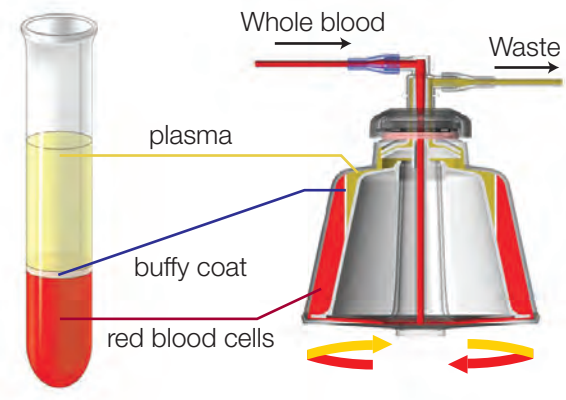
*Bowls for different machines/processing volumes also exist.

The fixed volume bowl rotates at speeds of up to 6,000rpm, and processes the salvaged blood in fixed volume batches. As anticoagulated whole blood is pumped into the spinning bowl, the centrifugal force separates the blood into its components as the bowl fills. As more blood is pumped into the bowl the RBCs are retained in the bowl while the supernatant, which is made up of the remaining components plus the anticoagulant, is expressed through the outlet port and into the waste bag.

When the machine detects an adequate amount of RBCs within the bowl, a wash solution of IV normal saline (0.9% NaCl) is pumped into the bowl passing through the red cell layer and displacing most of the remaining non red cell component into the waste bag. Excess IV normal saline (0.9% NaCl) is also expressed through the outlet port and into the waste bag.

The fixed volume bowl may be available in a range of sizes (depending on the manufacturer) to suit the anticipated blood loss. In order to provide a consistent and high quality end product, fixed volume bowls require a predetermined volume of RBCs to be reached within the bowl before the machine will trip automatically into the wash stage.

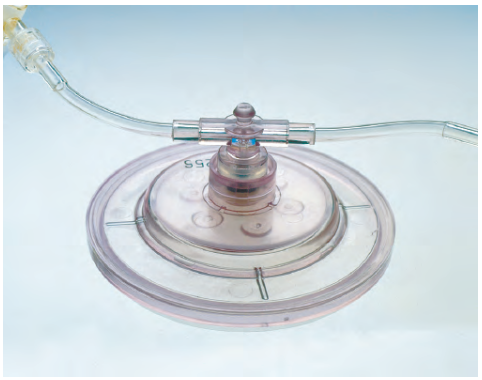
Figure 7. Separation of Red Blood Cells in a Fixed Volume Bowl

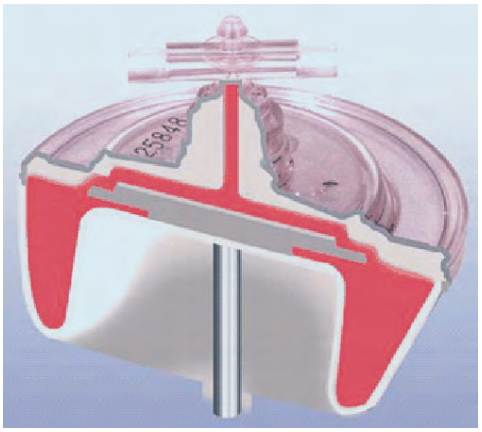


Choosing to operate an ICS machine in manual mode will remove the safety benefits and will affect the consistent, high quality end product offered by the automatic mode.

6.2 Variable Volume Disk System

Figure 8. Variable Volume Disk System



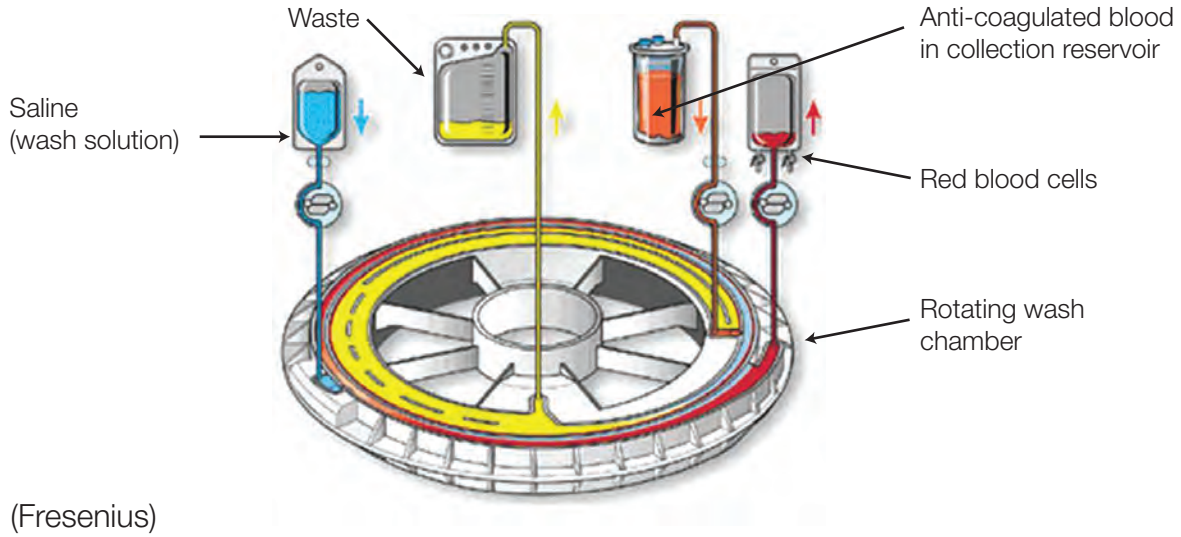


(Haemonetics)

The variable volume disk (dynamic disk) system is similar in principle to the fixed volume bowl in the separation of RBCs through centrifugation and washing with IV normal saline (0.9% NaCl). However, this system has an elastic silicone diaphragm which permits a variable volume of RBCs to be processed, i.e. it does not require a set volume of RBCs for processing to take place. The elastic silicone diaphragm changes shape and size during processing so that the machine delivers an end product of variable volume with a fixed haematocrit (Hct). The variable volume disk system will process 100ml of reservoir contents at a time. If the volume of RBCs being drawn into the disk from the reservoir is under 15mls, the system will concentrate several batches of blood before washing. This system is therefore more advantageous for procedures where lower volume blood losses occur or during long procedures where the blood loss is constant and slow.

6.3 Continuous Rotary System

Figure 9. Continuous Rotary System



The continuous rotary system works by continuously removing the supernatant and concentrating and washing the RBCs. It requires only a very small volume of blood loss to process, however, this does not automatically mean processing should progress. The decision to process should always be made on an individual patient basis.

6.4 Stages of the Process

Opposite (Figure 10) is a description of each of the four main processing stages of the ICS process. The fixed and variable volume systems follow a pattern similar to that described below. In the continuous rotary system, washing, separation and reinfusion take place concurrently.

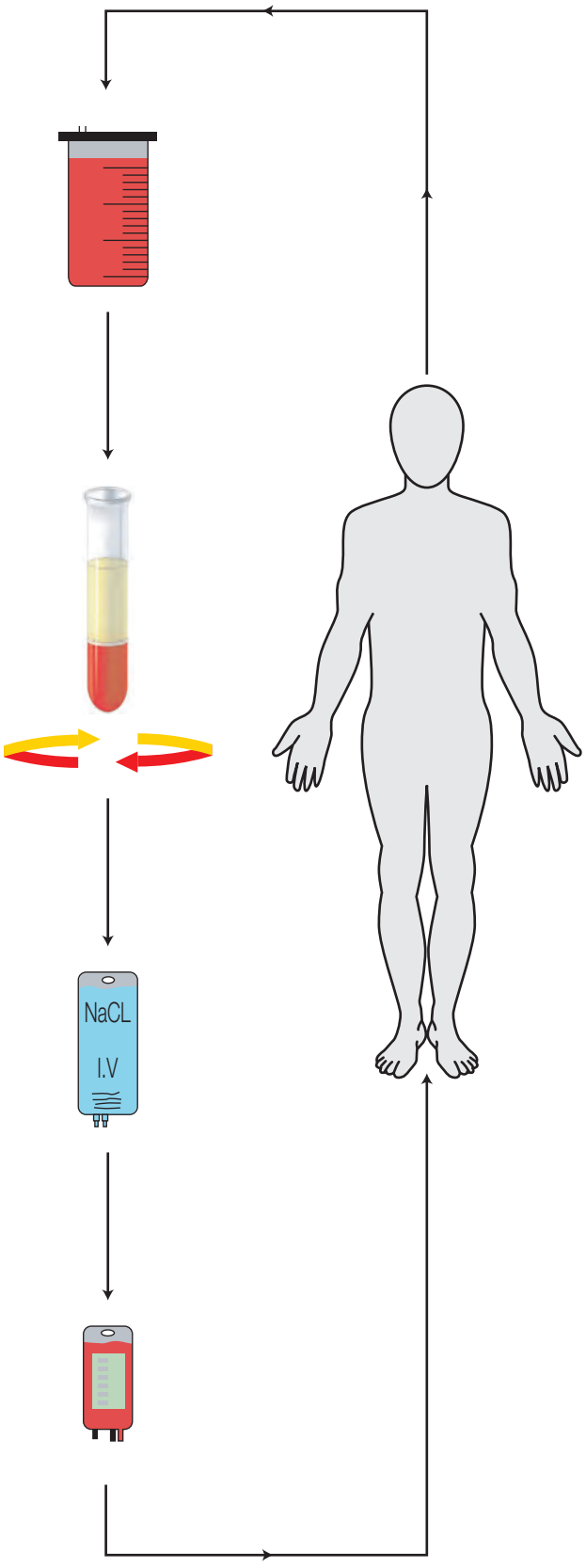
Figure 10. Stages of the Process

Collection
Blood is aspirated and mixed with anticoagulant through an aspiration and anticoagulation (A&A) line, into a collection reservoir. The collection reservoir contains a filter that removes clots and other gross particulate matter.

Separation
The reservoir contents are pumped/drawn into a spinning centrifuge system. The RBC component is retained within the bowl while the lighter components are forced out into a waste line. As the reservoir contents continue to enter the system and separate, the Hct within the system increases.

Washing
In some systems, optical sensors are positioned to detect a precise Hct during automatic mode. When this Hct is reached, the machine trips into the wash stage. IV normal saline (0.9% NaCl) is pumped into the spinning centrifuge system, passing through the heavier RBC component and out into the waste line displacing the remaining waste products (anticoagulant, cell debris, free haemoglobin, plasma etc.).

Reinfusion
The end product of washed, packed, RBCs, suspended in IV normal saline (0.9% NaCl) is pumped into a bag ready for reinfusion.



Most systems have a minimum wash volume recommended by the manufacturer. It is not advisable to decrease the wash volume below this level.

It is advisable to increase the wash volume for procedures where there is a high risk of contamination of salvaged blood, e.g. obstetrics and orthopaedics. See Section 9 for further details.

ICS can reduce and sometimes eliminate the need to transfuse allogeneic (donor) RBCs. In cases where large blood loss occurs, patients receiving ICS may still become depleted of clotting factors and platelets. In such cases transfusion of allogeneic (donor) components such as fresh frozen plasma (FFP), platelets or cryoprecipitate may be required.

Key Points

- ICS has four key processing stages:
  - Collection
  - Separation
  - Washing
  - Reinfusion
- ICS produces an end product of packed RBCs suspended in IV normal saline (0.9% NaCl) solution.
- Where large blood loss occurs, transfusion of allogeneic (donor) blood products may be required.

Further Reading

- UK Cell Salvage Action Group – Policy for the provision of Intraoperative Cell Salvage (available to download at *www.transfusionguidelines.org.uk*)
- American Association of Blood Banks – Standards for Perioperative Autologous Blood Collection and Administration 3rd Edition (ISBN-978-1-56395-248-7)
- Manufacturers' ICS Machine Specific Guidance

Self Directed Learning

What system(s) of ICS are in use in your hospital?

How many ICS machines do you have in your hospital?

Section 7
Indications and Contraindications

Aim

- To highlight the surgical areas where Intraoperative Cell Salvage (ICS) is indicated or **may** be contraindicated

Learning Outcomes

- To identify the indications for ICS
- To identify the relative contraindications for ICS
- To outline when the risks/benefits of using/not using ICS change

Introduction

The routine use of ICS is recommended in many surgical procedures providing there are no local factors which may make its use inappropriate e.g. lack of competent staff. There is evidence from randomised controlled trials (RCT) and observational reports of decreases in allogeneic (donor) blood transfusion when ICS has been used.

The decision to collect blood is often based on a number of factors including:

- The anticipated blood loss for a particular surgical procedure
- Patient factors including:
  - Risk factors for bleeding
  - A low preoperative haemoglobin
  - Religious or other objections to receiving allogeneic (donor) blood

These factors are discussed in more detail in this section.

Each organisation should have a policy in place for ICS which includes the indications and contraindications for use.

A generic policy is available on the Department of Health Better Blood Transfusion Toolkit at *www.transfusionguidelines.org.uk*

7.1 Indications and Patient Selection

- ICS systems may be used in elective and/or emergency surgical procedures where the surgical field is not contaminated by faecal or infective matter and where no other contraindications exist (see 7.2).
- Patient selection for ICS is at the discretion of the surgeon and anaesthetist caring for the patient.

- Providing that none of the contraindications listed in Section 7.2 exist, patients to be considered for ICS include:
  - Adult and paediatric patients undergoing elective or emergency surgical procedures, where the anticipated blood loss is greater than 20% of the patient's estimated blood volume. Areas where there seems little debate that ICS can be employed are listed below (this is not an exhaustive list).
    - Total knee replacement (if no tourniquet is used)
    - Revision total hip replacement
    - Total hip replacement
    - Spinal surgery
    - Abdominal aortic aneurysm surgery
    - Traumatic liver or spleen injury not associated with perforated bowel
    - Thoracic aneurysm surgery
    - Cardiac surgery
    - Benign urological surgery
  - Adult and paediatric patients undergoing elective or emergency surgical procedures who have risk factors for bleeding or low preoperative haemoglobin levels.
  - Patients who have rare blood groups or multiple antibodies for whom it may be difficult to obtain allogeneic (donor) blood.
  - Patients who, for moral, religious or other reasons, are unwilling to receive allogeneic (donor) blood and **have given their consent** to receiving autologous blood collected using ICS (all such decisions should be documented). Reference should be made to the patient's Advance Medical Directive where one exists.
- If ICS is to be used for patients who have rare blood groups/multiple antibodies or who have moral, religious or other objections to receiving allogeneic (donor) blood, and the surgical procedure is associated with any of the contraindications as listed below, the potential risks and hazards should be discussed with the patient and their agreement to undergo ICS documented.

7.2 Contraindications, Warnings and Cautions

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

Contraindications

ICS should not be used in the following situations:

- Bowel contents in the surgical field (this is discussed in more detail later – see 7.3)
- Heparin induced thrombocytopenia if heparin is the only available anticoagulant for ICS (a citrate anticoagulant solution may be used instead)

Warnings

- ICS should be temporarily discontinued when substances not licensed for intravenous (IV) use are used within the surgical field and could potentially be aspirated into the collection reservoir. The standard theatre suction should be used to aspirate the surgical field and the wound should be irrigated with copious IV normal saline (0.9% NaCl) before resuming ICS.

  Examples of non-IV materials that should not be aspirated into the ICS system include:

  – Antibiotics not licensed for IV use

  – Iodine

  – Topical clotting agents

  – Orthopaedic cement

  A list of potential contaminants and their associated problems can be found in the UK Cell Salvage Action Group document "Technical Factsheet 9 – Contraindications to ICS"[1].

- The use of ICS in the presence of **infection** may result in bacterial contamination of the salvaged blood. The aspiration of blood from an infected site should be avoided and antibiotics should be given as appropriate.
- **Gastric/pancreatic secretions** should not be aspirated into the system as they may cause enzymatic haemolysis and are not reliably removed by the washing procedure.
- **Pleural effusions** should not be aspirated and should be drained prior to cell salvage. However, blood which subsequently accumulates in the pleural space may be aspirated.
- There are concerns relating to the use of ICS in patients with **sickle cell disease**. The use of ICS in patients with abnormal red cell disorders should be made on a clinical, individual patient basis.

Cautions

- The use of Hartmann's Solution will inhibit the action of citrate based anticoagulants (e.g. ACD) if used as an irrigant or wash solution.
- Air will be present in the primary reinfusion bag when it is still connected to the cell saver or when it has been disconnected but air has not been evacuated. Where possible, all air should be evacuated from the primary reinfusion bag prior to reinfusion. Manufacturers advise NOT to use a pressure cuff as there is a risk of air embolus and some devices may also detect a back pressure if the reinfusion line is open.
- Manual mode – It is recommended that ICS devices are not run in manual mode as this may lead to reduced quality, insufficient washing of the final red blood cell product and the possible reinfusion of potentially harmful contaminants e.g. heparin. Machines should be run in automatic mode and manual mode should only be used when the benefits of doing so outweigh the risks, e.g. emergency situations where the need to reinfuse the red cells quickly outweighs the risks associated with running the machine in manual mode.

7.3 Areas for Further Consideration

The remainder of this section examines the use of ICS in procedures where there is the potential for contamination from within the surgical field.

The decision to use blood that is potentially contaminated with bacteria, amniotic fluid or malignant cells should be made by the clinicians caring for the patient, taking into account the latest evidence and considering the risk and benefits for the individual patient.

Bowel Contamination

As outlined earlier, the use of ICS in the presence of bowel contents is contraindicated unless there is catastrophic haemorrhage.

If deemed clinically necessary the following practical tips may help:

- Initial evacuation of the soiled abdominal contents
- Additional washing (increasing the volume of IV normal saline (0.9% NaCl) the machine uses to wash the salvaged blood)
- Ensure use of broad spectrum antibiotics

It is unlikely that bowel contamination in such traumatised individuals will lead to problems in decision making about the use of ICS, but hopefully the points raised can enable all concerned to make informed management choices.

Malignancy

The use of ICS in patients undergoing surgery for malignant disease is not recommended by the manufacturers of ICS devices. This is due to concern about the possibility of malignant cells being reinfused and giving rise to metastases. However, there are now a number of published reports outlining the use of ICS in cancer surgery without obviously leading to early metastasis, some hospitals now use ICS routinely during surgery for malignant disease. Aspiration of blood from around the tumour site should be avoided to minimise contamination of salvaged blood with malignant cells. The salvaged blood should be reinfused through a leucodepletion filter to minimise the reinfusion of any malignant cells which may have been aspirated into the collection reservoir.

Theoretical context

If there is concern that circulating malignant cells may lead to systemic spread then it is inadvisable to reinfuse any malignant cells. If the cancer cells are present in the final ICS blood for reinfusion, they must have been contaminating the collected blood prior to processing. These cells can only be present in the blood if:

- The tumour margins had been compromised at the time of resection making the whole operation palliative (as the likelihood of local recurrence would be high).
- The cancer cells were already blood borne at the time of surgery as resection of blood vessels distant from the tumour margins led to spillage of cancer cells directly from the circulating systemic blood.
- Cancer cells had already spread to the lymphatic system.

Practical Issues

- The use of a Leukoguard® RS filter (Pall Medical), a leucodepletion filter, is likely to lead to a 99.99% reduction in the number of nucleated (including malignant) cells present in the ICS blood for reinfusion.
- In large cancer centres it may be possible to safely organise irradiation of the collected blood. This would destroy all viable cancer cells within the ICS blood for reinfusion (see the 'Caution Box' on the next page). It has been recommended that a dose of 50Gy be used.[2]

Under European legislation[3], the irradiation of red cells requires hospitals to register as a Blood Establishment and the irradiated ICS blood product would be subject to the requirements of the Medicines and Healthcare products Regulatory Agency (MHRA).

In addition, if the red cells are removed from the patients side (i.e. to another area of the hospital) to be irradiated, the risk of administration errors (the most frequently reported allogeneic (donor) blood incident) increases.

Obstetrics

The main concern surrounding the use of ICS during obstetric haemorrhage is the risk of reinfusing fetal contaminants with the theoretical risk of causing amniotic fluid embolus.

ICS is being increasingly used in the UK in obstetrics for women at risk from massive obstetric haemorrhage during caesarean section. In the year 2005-06, 38% of UK maternity units used ICS, and 28% included the use of ICS in their Massive Obstetric Haemorrhage (MOH) protocol. Early theoretical concerns over amniotic fluid embolism have not been borne out in clinical practice, and 80% of maternity units identified lack of training, rather than safety concerns as the barrier to more frequent use of ICS.

The use of ICS in obstetrics has been endorsed by:

- Confidential Enquiry into Maternal and Child Health (CEMACH)
- Joint Association of Anaesthetists of Great Britain and Ireland/Obstetric Anaesthetists Association (AAGBI/OAA) Guidelines
- National Institute for Health and Clinical Excellence (NICE)

It is strongly recommended that any health care professional involved with obstetric ICS is familiar with all these guidelines.

Patient Selection and Preparation

Wherever possible, the advantages and risks of ICS and allogeneic (donor) blood transfusion should be discussed with the woman prior to undergoing an obstetric surgical procedure. The NICE guidance "Intraoperative blood cell salvage in obstetrics" 'recommends that "*whenever possible*, the woman understands what is involved and the theoretical risks, and agrees (consents) to have the procedure'. When obtaining formal consent for a caesarean section, the obstetrician or anaesthetist should discuss the advantages and risks of ICS with the woman, and document clearly her agreement to undergo the procedure. Such detailed consent may not be practicable in an emergency, as for allogeneic (donor) transfusion.

Indications for ICS in Obstetrics

Case selection for ICS is at the discretion of the obstetrician and anaesthetist caring for the woman. The type of obstetric cases that should be considered for selection include:

- Emergency situations:
  - Ruptured ectopic pregnancy
  - Intra-partum haemorrhage requiring surgical intervention
  - Post-partum haemorrhage requiring surgical intervention
- Elective situations:
  - Patients with an anticipated blood loss of >1,000mls e.g. placenta praevia with placenta accrete/increta or percreta, large uterine fibroids, and other predictable causes of MOH.
- Other situations:
  - Women who, for religious or other reasons refuse allogeneic blood *and have consented* to the use of ICS in elective or emergency bleeding situations or in the presence of significant anaemia.

Practical Measures in Obstetric ICS

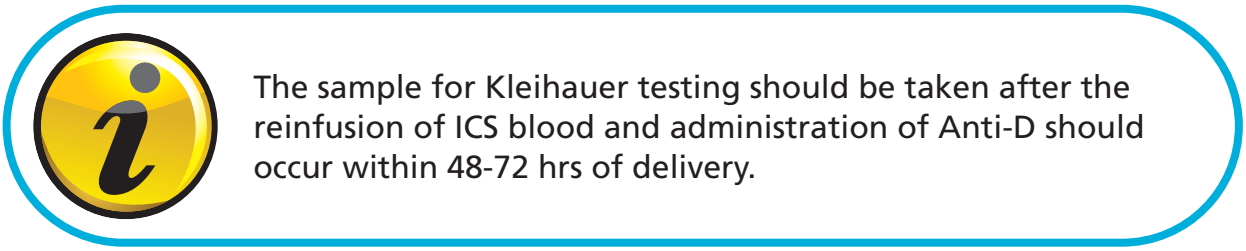
- Amniotic fluid and use of leucodepletion filter – Amniotic fluid should ideally not be aspirated into the ICS collection reservoir. A separate suction can be used to aspirate amniotic fluid prior to starting cell salvage. This recommendation will reduce the initial contamination, but it should be noted that the *in vitro* evidence suggests that the ICS process can effectively remove plasma phase elements of amniotic fluid (i.e. those less dense than red blood cells) whatever the initial load. Therefore, in life-threatening haemorrhage, a clinical decision to use ICS from the beginning of the procedure could be carefully considered.

  After processing, a leucoreduction filter (LeukoGuard® RS filter (Pall Medical)) should be used to reinfuse ICS blood. This is the only filter proved to effectively eliminate residual particulate elements of amniotic fluid (i.e. those not removed by the washing process alone). In life-threatening haemorrhage a clinical decision to reinfuse ICS blood without this filter can be considered.

- Rh Immunisation and Kleihauer testing – In any pregnancy involving an Rh negative mother and an Rh positive foetus there is a risk of Rh immunisation if the maternal circulation is exposed to fetal red cells. If untreated, antibodies against the fetal red cells may form and these can cause haemolytic disease of the newborn in subsequent pregnancies. Consequently all Rh negative mothers of Rh positive babies will have a Kleihauer performed in the immediate post partum period.

  Kleihauer testing is required to establish the amount of fetal red cell exposure and ensures that the mother receives an appropriate dose of Anti-D immunoglobulin (usually 125iu/ml of fetal blood). Depending on the results of the Kleihauer, a minimum of 500iu Anti-D will be offered in the post partum period to Rh negative mothers with Rh positive babies.

The same protocol should be followed for Rh negative mothers who have undergone reinfusion of ICS blood. The presence of fetal red cells in the ICS blood is likely because the ICS device cannot distinguish fetal from maternal red cells. The dose of Anti-D will be determined by the result of the Kleihauer test.



The sample for Kleihauer testing should be taken after the reinfusion of ICS blood and administration of Anti-D should occur within 48-72 hrs of delivery.

Key Points

- ICS is of proven benefit in certain elective and emergency surgical procedures where the predicted blood loss is in excess of 20% of the patient's estimated blood volume.
- ICS should only be used in malignancy when the benefits outweigh the risks.
- ICS should be available for obstetric cases where there is the potential for massive haemorrhage.

References

1. UK Cell Salvage Action Group (2008) Technical Factsheet 9 "Contraindications to ICS". *Better Blood Transfusion Toolkit* *www.transfusionguidelines.org.uk*
2. Hansen E., Bechmann V. and Altmeppen J. (2002) Intraoperative blood salvage in oncologic surgery. Answers to current questions. *Infus Therap Transfus Med; 29: 138-41*
3. Directive 2002/98/EC of the European Parliament and of the Council of 27 January 2003 (2003) Setting Standards of Quality and Safety for the Collection, Testing, Processing, Storage and Distribution of Human Blood and Blood Components and Amending Directive 2001/83/EC. *Official Journal of the European Union,* V46: L33/30-40 *http://eur-lex.europa.eu/JOIndex.do*

Further reading

UK Cell 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: 8 – Intraoperative Cell Salvage in Obstetrics
  9 – Contraindications to ICS

Randomised Controlled Trials/Observational Reports

- Bridgens J.P., Evans C.R., Dobson P.M. and Hamer A.J. (2007) Intraoperative red blood-cell salvage in revision hip surgery. A case-matched study. *J Bone Joint Surg;* 89(2):270-5
- Goel P., Pannu H., Mohan D. and Arora R. (2007) Efficacy of cell saver in reducing homologous blood transfusions during OPCAB surgery: a prospective randomized trial *Transfus Med;* 17(4):285-9
- Healy C.F., Doyle M., Egan B., Hendrick B., O'Malley M.K. and O'Donohoe M.K. (2007) Transfusion requirements and outcomes in patients undergoing abdominal aortic surgery using intra-operative cell salvage. *Ir J Med Sci;* 176(1):33-6

Malignancy

- National Institute For Health & Clinical Excellence (NICE) (2008) Intraoperative red blood cell salvage during radical prostatectomy or radical cystectomy – Guidance *http://www.nice.org.uk/nicemedia/pdf/IPG258Guidance.pdf*

Obstetrics

- Catling S.J., Williams S. and Fielding A.M. (1999) Cell salvage in obstetrics: an evaluation of the ability of cell salvage combined with leucocyte depletion filtration to remove amniotic fluid from operative blood loss at caesarean section. *Int J Obs Anesth;* 8; 79-84
- Hall M. (2000 – 2002) Why Mothers Die – Report on confidential enquiries into maternal deaths in the United Kingdom. Chapter 4 (Haemorrhage). *Confidential Enquiry into Maternal and Child Health (CEMACH);* p91-92
- Obstetric Anaesthetists Association (OAA)/Joint Association of Anaesthetists of Great Britain and Ireland (AAGBI) (2005) Guidelines for Obstetric Anaesthetic Services revised Edition; p25
- Obstetric Anaesthetists Association (OAA) (2007) Survey of UK Maternity Units
- National Institute For Health & Clinical Excellence (NICE) (2005) Intraoperative Blood Cell Salvage in Obstetrics – Guidance *http://www.nice.org.uk/nicemedia/pdf/ip/IPG144guidance.pdf*
- Waters J.H. Biscotti C. Potter P.S. Phillipson E. (2000) Amniotic fluid removal during cell salvage in the cesarean section patient. *Anesthesiology;* 92; 1531-1536

Other

- American Association of Blood Banks – Standards for Perioperative Autologous Blood Collection and Administration 3rd Edition (ISBN-978-1-56395-248-7)

Self Directed Learning

Is ICS used in your organisation for cases of malignancy?
If yes, what procedures are performed using ICS?

Do you keep leucodepletion filters in your department?

If yes, describe how to prime the filter.

Do you use ICS in obstetrics in your organisation?

Section 8

Practicalities – Blood Collection

Aim

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

Learning Outcomes

- To identify the equipment used for blood collection and describe the function of each component
- To describe the steps required in preparing for and commencing blood collection
- To name the two main types of anticoagulant used in ICS, describe their function and mechanism of action
- To describe methods of maximising blood salvage
- To identify areas for potential problems during blood collection

Introduction

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

During the blood collection phase of ICS, blood lost during surgery is aspirated from the surgical field, mixed with anticoagulant to prevent clotting, filtered to remove large particulate debris and stored in a collection reservoir ready for processing.

8.1 Decision to Collect Blood

The decision to collect blood is often based on a number of factors including:

- The anticipated blood loss for a particular surgical procedure
- Patient has risk factors for bleeding
- The presence of low preoperative haemoglobin
- Patient's religious or other objection to receiving allogeneic (donor) blood

Collect Only – In situations where it is difficult to predict if the blood loss will be large enough to be processed, it's good practice to set the ICS system for "collect only" whereby only the equipment required for blood collection is prepared. The processing set can be loaded later if a sufficient volume of blood has been collected for processing.

8.2 Equipment

The equipment listed in Table 3 is required for blood collection.

Table 3. Blood Collection Equipment

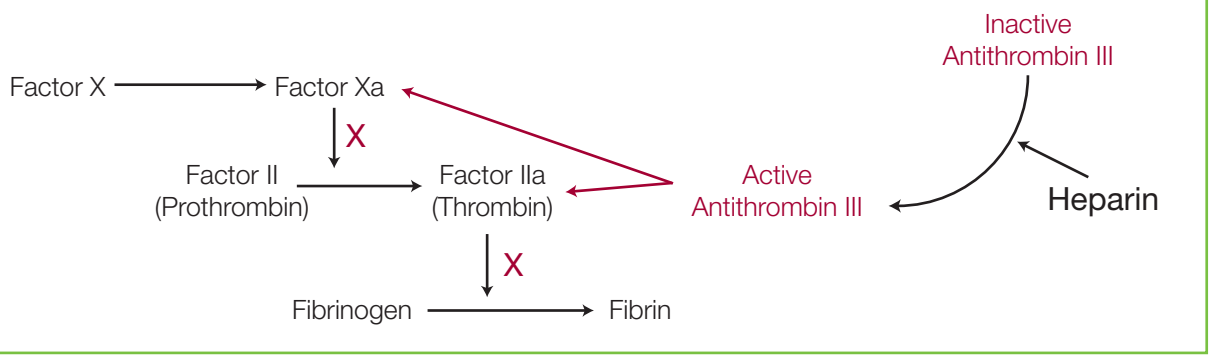
Equipment	Function
Anticoagulant (heparin saline (30,000iu/l) or Citrate (ACD-A)	To prevent clotting of salvaged blood.
Aspiration & anticoagulation line (A&A line) machine specific/sterile	Dual lumen suction line that delivers anticoagulant to the point of blood collection within the surgical field, and aspirates blood and anticoagulant away from the surgical field into the ICS system. The design of the A&A line prevents anticoagulant entering the 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 must be attached to a separate suction unit or the 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 the recording of procedure specific details.

8.3 Anticoagulant

To prevent clotting, the aspiration and anticoagulation line (A&A line) delivers anticoagulant to the point of collection within the surgical field. Blood aspirated from the surgical field mixes with the anticoagulant as it enters the A&A line and is therefore anticoagulated before it enters the collection reservoir. If the rate of flow of the anticoagulant is insufficient, the salvaged blood will clot. This may result in contamination of the processed blood and/or may prevent processing. Types of anticoagulant used are:

- Heparin saline:
  - 30,000iu heparin/1,000ml intravenous (IV) normal saline (0.9% NaCl)
  - Heparin works by activating Antithrombin III which in turn *inactivates* both Factor Xa and Factor IIa (Thrombin) in the coagulation cascade (Figure 11). This prevents the conversion of Fibrinogen to Fibrin and the formation of clots.
  - The recommended ratio is approximately 1:5 e.g. 20ml of anticoagulant to 100ml of blood (check your machine manufacturer recommendations)

Figure 11. Heparin Mechanism of Action



Heparin anticoagulant – will be ineffective if the patient suffers from Antithrombin III deficiency. It is recommended that a citrate anticoagulant is used for these patients.

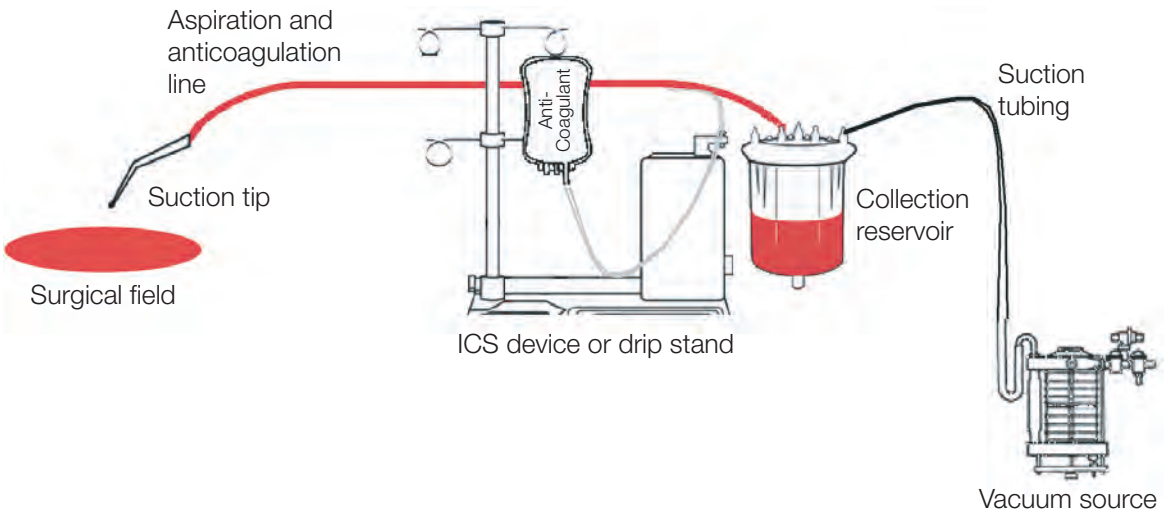
- Acid citrate dextrose anticoagulant (ACD-A):
  - Citrate based anticoagulant
  - Pre-prepared
  - Citrate based anticoagulants work by binding to free calcium in the blood. Calcium is a required cofactor in the activation of clotting factors; the action of the citrate removes calcium from the coagulation cascade, therefore preventing clot formation by inhibiting the coagulation cascade.
  - The recommended ratio is approximately 1:7 e.g. approximately 15ml of anticoagulant to 100ml of blood (check your machine manufacturer recommendations)

Citrate anticoagulants – fluids containing calcium e.g. Hartmann's, (if used for irrigation) may inhibit citrate based anticoagulants and should be avoided.

The typical (minimum) flow rate for anticoagulant is around 45-60 drops per minute for ACD-A and around 60-80 drops per minute for heparin saline. The anticoagulant flow rate may need to be increased during the procedure to accommodate increased levels of bleeding, this can then be returned to the minimum flow rate once bleeding is under control. Minor adjustments to the flow rate of the anticoagulant may be necessary throughout the duration of the procedure to accommodate varying levels of bleeding.

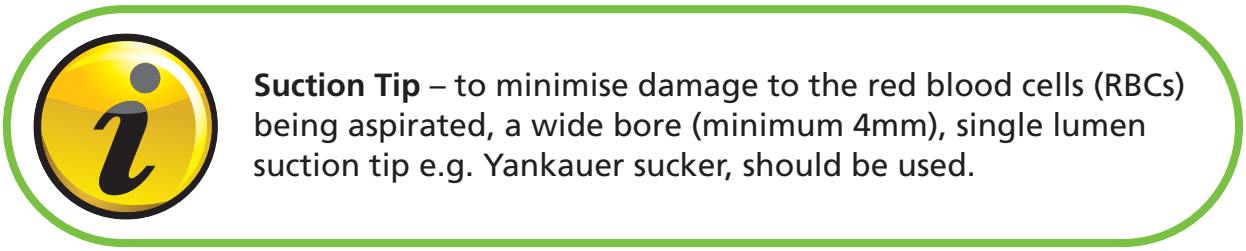
8.4 Preparation of Equipment for Blood Collection

Figure 12. "Collect Only" Set Up



The set up of the blood collection equipment for ICS is represented in Figure 12.
As discussed earlier in this section, the practical set up of the equipment for ICS is specific to the machine in use. However, the basic principles and theory are the same. The main steps in the preparation of the blood collection equipment are outlined below. Clean/aseptic technique should be used as appropriate and protective clothing should be worn in accordance with local policy.

A&A Line/Suction Tip	• Pass aseptically to the scrubbed person within the sterile field. • Ask them to attach a large bore/single port suction tip to the A&A line.



Suction Tip – to minimise damage to the red blood cells (RBCs) being aspirated, a wide bore (minimum 4mm), single lumen suction tip e.g. Yankauer sucker, should be used.

Anticoagulant	• Aseptically add 30,000iu of heparin to 1,000ml of IV normal saline (0.9% NaCl) and label clearly with an appropriate "drugs added label" *or* select a bag of pre-prepared citrate anticoagulant. In both cases check the expiry date of the products before use. • Hang the anticoagulant on the drip stand on the machine or the drip stand with the collection reservoir bracket on if the machine is not available.
Collection Reservoir/Autologous Transfusion Label	• Load the collection reservoir into the bracket on the machine or drip stand. • If appropriate (see manufacturer's instructions) **clamp off the port that leads to the processing line.** • Enter the patient's details (from the patient's identification band) onto the autologous transfusion label (Appendix 3) and attach it to the collection reservoir.

Labelling the collection reservoir – to avoid errors in patient identification, an autologous transfusion label should be completed at the patient's side, at the start of *blood collection*. The patient's details should be taken from the identification band attached to the patient. The label should be securely attached to the collection reservoir. If a processing set is subsequently loaded into the machine (see section 9), the autologous transfusion label should be transferred to the reinfusion bag immediately, or a new label completed and attached to the bag.

Vacuum Source/ Suction Tubing	• Attach the suction tubing to the vacuum source either on the machine or the theatre wall suction, making sure there is a secure connection. • Attach the other end of the suction tubing to the appropriate port on the collection reservoir (see manufacturer's guidelines).
Connect A&A Line	• Prior to the start of the operation, ask the scrub person to pass the spiked end of the A&A line out of the sterile field. • Attach the wide bore line to the appropriate port on the collection reservoir (see manufacturer's guidelines). • Close the roller clamp on the small bore line and spike the line into the port on the anticoagulant bag.
Turn on Vacuum	• Turn on either the machine vacuum, (if available see manufacturer's guidelines), or the wall vacuum source. • Regulate the vacuum to approximately –100mmHg to –150mmHg (follow your manufacturer's guidance).

Vacuum Levels – High vacuum levels cause haemolysis (destruction of the RBCs). Maintaining low vacuum levels minimises haemolysis and maximises the red blood cells available for reinfusion.

Prime A&A Line/ Collection Reservoir	• Fully open the roller clamp on the A&A line. • Allow approximately 100ml – 150ml of anticoagulant to run through the line to prime the collection reservoir.
Regulate Anticoagulant Flow	• Regulate the flow of anticoagulant to approximately one drop per second.
Begin Blood Collection	• Inform the surgical team that blood collection can begin. • Record the time blood first enters the collection reservoir.

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.

8.5 Blood Collection

During the blood collection phase, it may be necessary for the operator to make minor adjustments to the system:

- Regulating the vacuum – it may become necessary during periods of high blood loss to increase the level of the vacuum at the request of the surgical team. The vacuum should be returned to a standard level, (approximately –100mmHg to –150mmHg) as soon as the bleeding is under control. This will minimise damage to the RBCs.
- Regulating the anticoagulant flow – the flow rate of the anticoagulant must be regulated depending on the level of bleeding. Insufficient anticoagulant will result in the system clotting off.
- Monitoring the volume of blood loss – when using a "collect only" system, the cell salvage operator must decide if it is appropriate to process the blood based on the volume of blood collected (see Section 9).

IV Grade fluids – Remember, anything that is aspirated from the surgical field could potentially go back into the patient's circulation. Only IV grade fluids should be aspirated into the ICS system. To avoid contaminating the ICS blood, the standard theatre suction should be used for aspirating when non-IV substances are being used within the surgical field. e.g. orthopaedic cement, betadine, antibiotics not licensed for IV use etc.

8.6 Maximising Blood Collection

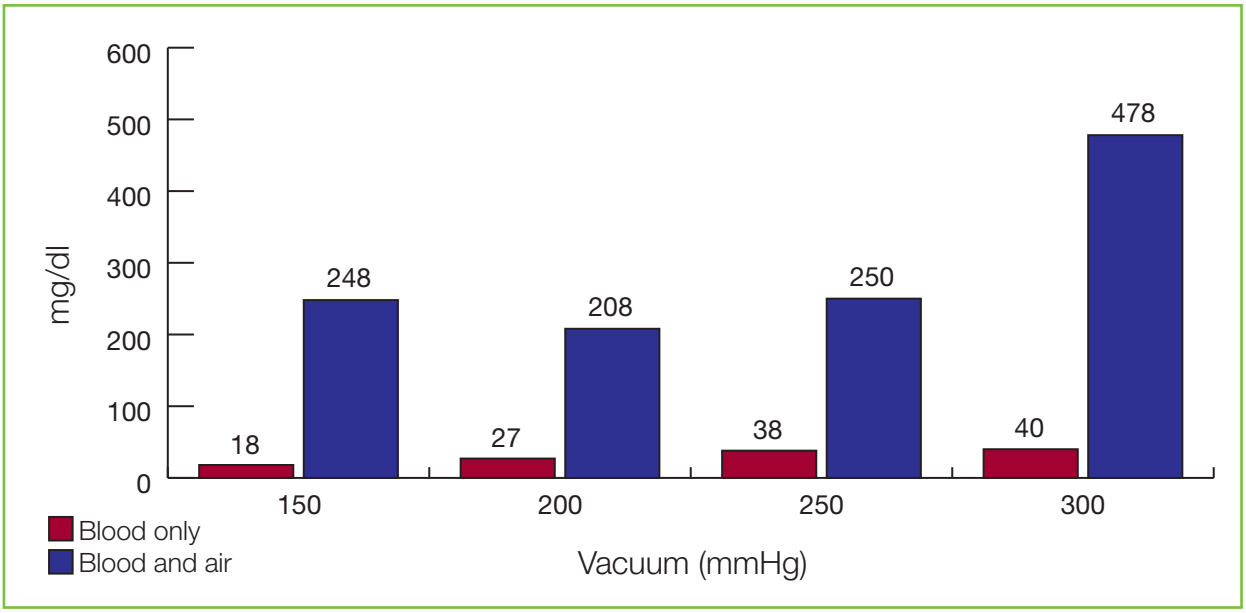
There are several techniques that can be used to maximise the volume of RBCs available for reinfusion. These include:

- Low vacuum level – Maintaining a low vacuum level minimises haemolysis, and therefore maximises the RBCs available for reinfusion. High vacuum levels cause RBC haemolysis, which can be measured by the concentration of plasma (free) haemoglobin (haemoglobin that has been released from haemolysed RBCs).
- Suction technique – where possible, the suction tip should be immersed in the blood and not skimmed across the surface of tissues or pools of blood. Skimming results in a large quantity of air mixing with the aspirated blood, this air interface causes haemolysis and therefore reduces the number of viable RBCs available for reinfusion.

Graph 1 (below) shows plasma haemoglobin at different vacuum levels and using two types of suction technique. The graph demonstrates that when blood only is aspirated (i.e. when the suction tip is immersed in a pool of blood), even high vacuum levels do not result in excessive RBC haemolysis. This supports increasing vacuum levels during excessive bleeding.

However, when blood and air are aspirated, as occurs naturally during most of the ICS process, even low vacuum levels result in excessive haemolysis and therefore reduces the available RBCs for reinfusion.

Graph 1. Changes in Plasma Haemoglobin from Baseline Measurements[1]



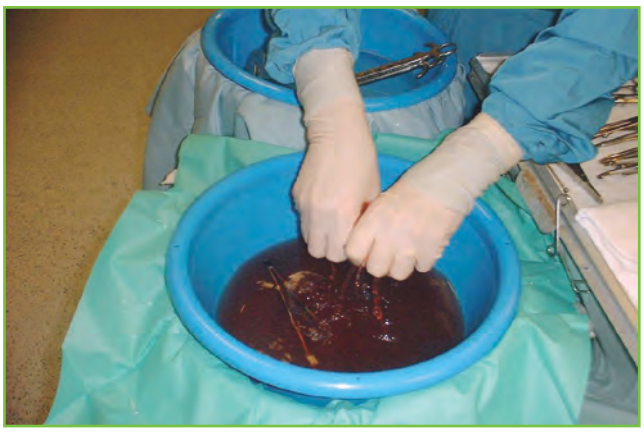
- Suction tip – as already mentioned, a wide bore, single lumen suction tip minimises damage to the RBCs during collection
- Swab washing – see below

8.7 Swab Washing

Swab washing (Figure 13) allows blood that would normally be lost in swabs to be salvaged during ICS and can significantly increase the volume of RBCs for reinfusion.

- Equipment:
  - Sterile bowl
  - 1,000mls IV normal saline (0.9% NaCl)

Figure 13. Swab Washing



Swabs are placed in a bowl, within the sterile field, containing 1,000mls IV normal saline (0.9% NaCl). The swabs are left for approximately five minutes and are then gently (to avoid damaging the RBCs) squeezed out. The swabs are then disposed of as per department protocol. At the end of the procedure (or sooner if necessary) the swab wash is suctioned into the ICS reservoir and processing is undertaken as normal (see section 9).

In high blood loss procedures, it may be appropriate to suction the swab wash into the ICS reservoir before the end of the procedure, to allow the blood to be processed and returned to the patient. Once the contents of the bowl have been aspirated into the collection reservoir, a further 1,000mls of IV normal saline (0.9% NaCl) should be added to the sterile bowl to allow swab washing to continue.

Ensure the swab wash bowl is maintained within the sterile field.

Ensure no substances not intended for IV use enter the swab wash bowl e.g. Betadine soaked swabs.

8.8 Troubleshooting

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

- Loss of suction:
  - Check the vacuum source
  - Check the suction tubing is securely connected to the vacuum source and the collection reservoir
  - Check the A&A line is securely connected to the collection reservoir
  - Check the A&A line has not been clamped or otherwise obstructed
- Clotting in the collection reservoir:
  - Check the anticoagulant is still flowing
  - Increase the anticoagulant flow rate
  - If excessive clotting has occurred it may be necessary to change the collection reservoir. This can be difficult and will result in a loss of ICS while the problem is solved, and a loss of the blood that has been collected up to that point. Therefore, this should only be undertaken as a last resort.
- Contamination with non-IV substances:
  - Contamination of the salvaged blood with substances not intended for IV use should be discussed 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). A clinical decision on how to proceed should be made by this lead clinician. A list of potential contaminants and their associated problems can be found in the UK Cell Salvage Action Group document "Technical Factsheet 9 – Contraindications to ICS"[2].
  - The decision to use blood that is potentially contaminated with bacteria, amniotic fluid or malignant cells should be made by the clinicians caring for the patient, taking into account the latest evidence and consideration of the risks and benefits of proceeding for the individual patient.

8.9 Documentation

The documentation required during the blood collection includes:

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

Key Points

- The main equipment for blood collection includes an A&A line, a collection reservoir and anticoagulant.
- The operator must maintain awareness throughout the procedure in order to prevent errors occurring.
- In order to maximise blood collection, a number of techniques can be used in conjunction with one another e.g. low vacuum levels, swab washing and suction technique.

References

1. Gregoretti, S. (1996) Suction-Induced Haemolysis at Various Vacuum Pressures: Implications for Intraoperative Blood Salvage. *Transfusion;* 36:57-60
2. UK Cell Salvage Action Group (2008) Technical Factsheet 9 "Contraindications to ICS". *Better Blood Transfusion Toolkit* *www.transfusionguidelines.org.uk*

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 1 – Swab Washing
  2 – Anticoagulation
  3 – Blood Collection
  6 – Use of ICS in Jehovah's Witness Patients

Other

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

Self Directed Learning

List the procedures in your department where ICS blood collection is routinely set up.

What type of anticoagulant is used in your department?

List the types of machine used in your department.

Section 9

Practicalities – Blood Processing

Aim

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

Learning Outcomes

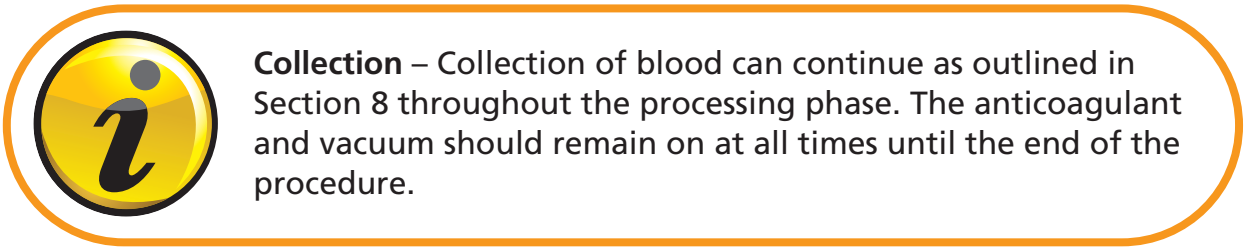
- To identify the steps taken in making the decision to process
- To list the equipment used for blood processing and describe the function of each component
- To describe the steps required in preparing for and commencing blood processing
- To describe the risks of overriding the automatic functions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

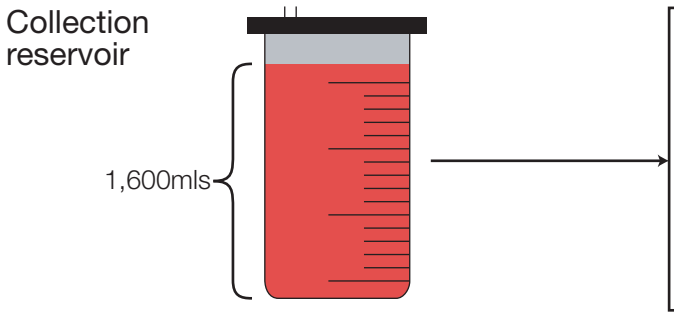
Adequate blood loss relates to two issues:

- 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:

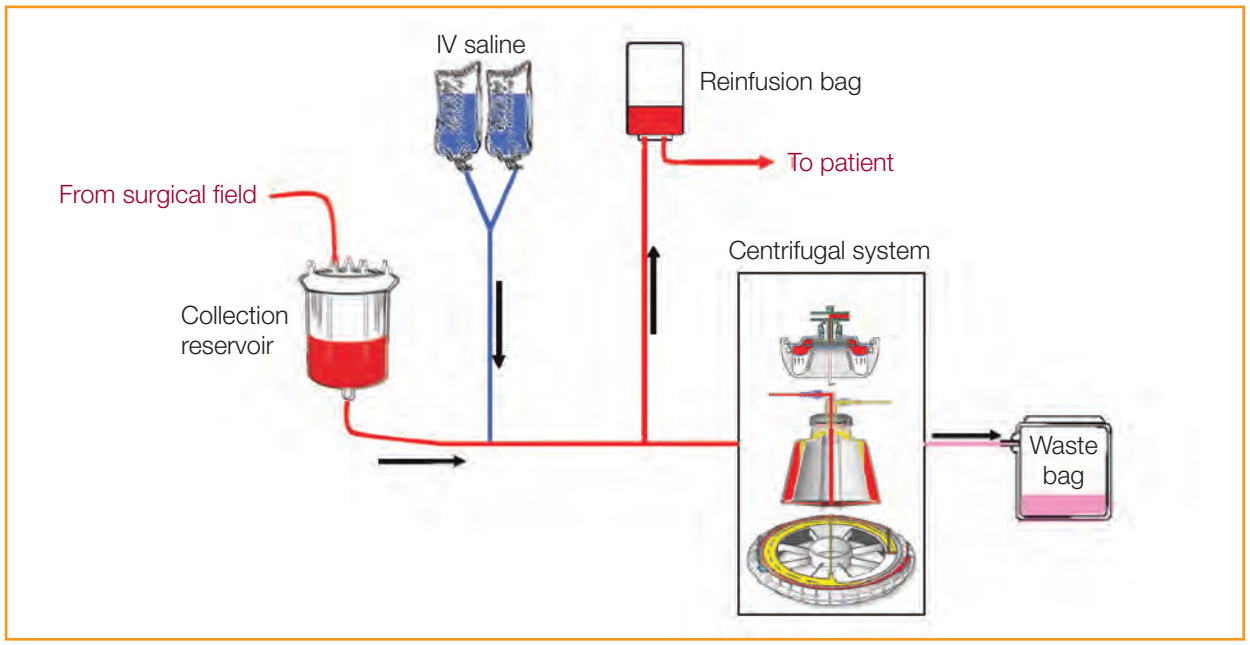
Smaller bowls – Will take longer to process a large volume of blood, as the blood is processed in small batches.

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

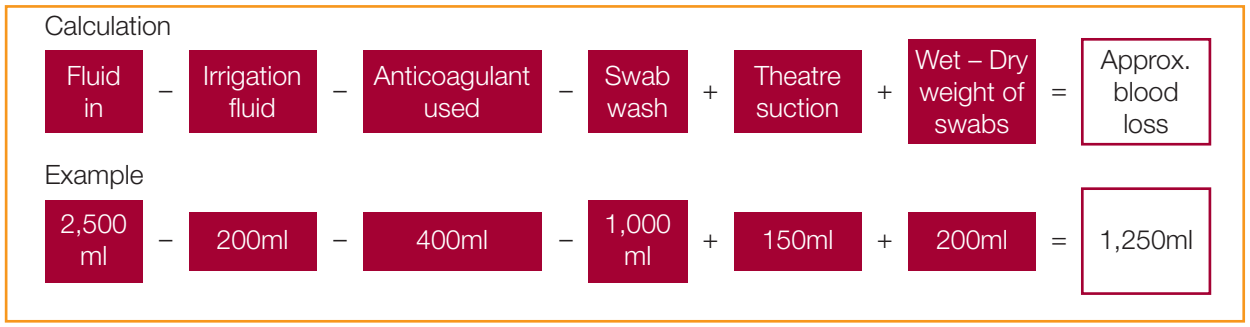
At the end of the procedure, when all of the blood from the collection reservoir has been processed, an estimate of the volume of blood the patient has lost during the procedure can be made using a simple calculation.

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

Self Directed Learning

If a bowl system is used within your department, what size bowls are available?

Are there guidelines in your department that describe for which procedures "Collect Only" equipment should be set up and for which procedures the full kit (collection and processing) should be set up? If so, for what/when would you set up the entire kit before the procedure starts?

Section 10
Practicalities – Reinfusion

Aim

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

Learning Outcomes

- To identify the equipment used for reinfusion and describe the function of each component
- To describe the composition of the final product for reinfusion
- To list the steps and describe the process of preparing for and commencing reinfusion
- To identify the conditions for reinfusion

Introduction

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

10.1 ICS End Product

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

- Red blood cells (RBCs)
- Intravenous (IV) normal saline (0.9% NaCl)

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

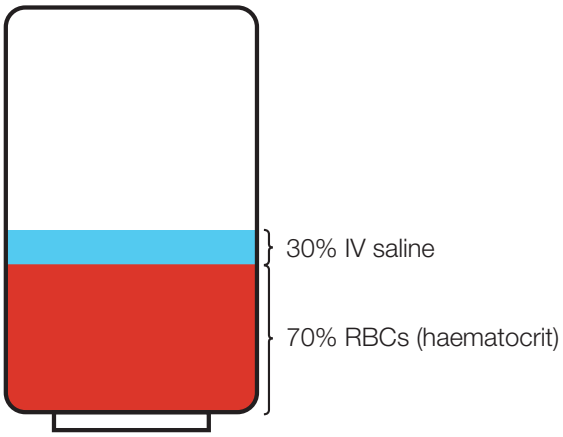
- Platelets
- Clotting factors
- Anticoagulant
- Microaggregates
- Other cells/proteins aspirated into the system from the surgical field
- Contaminants – if these have been aspirated into the system from the surgical field e.g. betadine

These are present in such small quantities that they are unlikely to cause any adverse effects. However, appropriate precautions should be taken e.g. using an appropriate filter for reinfusion (see 10.4). Information on the clearance rates of different ICS machine can be found on the Machine Specification document on the Better Blood Transfusion Toolkit website (*www.transfusionguidelines.org.uk*).

If contamination of the salvaged blood by substances not intended for IV use has occurred, this should be discussed 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). A clinical decision regarding reinfusion should be made by this lead clinician.

The decision to use blood that is potentially contaminated with bacteria, amniotic fluid or malignant cells should be made by the clinicians caring for the patient, taking into account the latest evidence and considering the risks and benefits for the individual patient.

Figure 17. Haematocrit



The haematocrit of the final product can vary, however, providing the manufacturer's guidelines have been followed and the machine has been run in automatic mode, the haematocrit is likely to be around 50-70% (Figure 17).

Coagulopathy – ICS blood contains almost no platelets of coagulation factors. Therefore, in cases of massive haemorrhage it is likely that the patient will require allogeneic (donor) blood components, e.g. platelets, fresh frozen plasma, cryoprecipitate and possibly even allogeneic (donor) RBCs.

10.2 Prescribing ICS Blood

The reinfusion of ICS blood should be prescribed by the responsible clinician on the documentation approved within your hospital.

Procedural problems – The responsible clinician should be made aware of any problems that have occurred during the process e.g. contamination of the collection reservoir with non-IV substances, so that the decision to reinfuse under these circumstances can be made based on the relative risks and benefits.

10.3 Equipment

The equipment listed in Table 5 is required for the reinfusion of ICS blood.

Table 5. Blood Reinfusion Equipment

Equipment	Function
Reinfusion bag machine specific	The RBCs are sent to the reinfusion bag at the end of processing.
Standard Blood Administration Set	Used to connect the reinfusion bag/filter to the patient's IV access.
Appropriate additional filter (if clinically indicated – see 10.4)	Filters the RBCs as they are being reinfused.

10.4 Filters

There are a number of filters (Table 6 – on following page) available which can be used for ICS blood reinfusion. The type of filter used should comply with local policy as well as national and manufacturer's guidelines. In most cases, a standard 200µm blood administration set is sufficient. The use of other filters in addition to blood administration set may be advocated in the following specialities:

- **Obstetrics & Malignancy** – the use of Leukoguard® RS filter (Pall Medical), a leucodepletion filter, is advocated in Obstetrics & Malignancy. The flow rate is slow and the maximum capacity per filter is around 450ml. This filter however is the only one that has been shown to effectively remove contaminants specific to these settings.
- **Orthopaedic surgery** – there is a theoretical concern that fat globules released from bone marrow could result in fat embolism syndrome if reinfused. However, there is currently no evidence to support this. As a precaution, the use of a lipid depleting microaggregate filter is recommended as best practice in operative procedures where there is a high risk of fat embolism. The risk of fat embolism can also be decreased by leaving the last few millimeters of ICS blood in the reinfusion bag.

Table 6. Filters for ICS Blood Reinfusion

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

Regardless of the type of filter or giving set used for reinfusion of ICS blood, the instructions supplied with the filter/giving set should be followed e.g. if the maximum volume capacity of the filter has been reached and there is blood remaining in the reinfusion bag, the filter should be disconnected and a new filter connected and primed.

Further information on the use of filters can be found in the Technical Factsheets available to download at *www.transfusionguidelines.org.uk*.

10.5 Reinfusion

"Storage"

ICS blood is untested and intended only for the patient from whom it was collected. Labelling of the reinfusion bag (and collection reservoir if a "collect only" system has been used) should be carried out near to the patient (to avoid errors) as early on in the procedure as possible (see Sections 8 and 9).

In accordance with recommendations from Serious Hazards of Transfusion (SHOT) for allogeneic (donor) blood, (see Section 5), the following guidelines for the "storage" of ICS blood should be followed:

- The reinfusion bag should be kept beside the patient at all times
- The reinfusion bag **should not** be placed in a refrigerator

Time Limits

The collection, processing and reinfusion of salvaged blood should be completed within the timeframes recommended by the manufacturer. This should be in accordance with guidance from the American Association of Blood Banks (AABB) and the organisation's transfusion policy.

The AABB Guidelines recommend the reinfusion times for cell salvaged blood as follows:

- Intraoperative Cell Salvage:
  - four hours from the completion of processing
- Postoperative Cell Salvage:
  - six hours from the start of collection *(applicable when Intra-operative Cell Salvage machines are used to salvage blood postoperatively)*

Any blood that has not been transfused within the timeframe specified in the guidelines should be disposed of in accordance with local policy for dealing with liquid biohazardous waste.

The expiry time of the ICS blood should be clearly recorded on the autologous transfusion label (Appendix 3).

Disconnecting the Reinfusion Bag

Reinfusion of ICS blood can occur either while the reinfusion bag is still attached to the processing set or once the reinfusion bag has been disconnected.

- **Attached** – When the reinfusion bag contains ICS blood, the appropriate filter/giving set should be attached to the giving port on the reinfusion bag, primed with the ICS blood and then connected to the patient's IV cannula. This can be done while the reinfusion bag is still attached to the processing set. The same reinfusion bag may fill and empty many times during an operation.

Reinfusion line – The reinfusion line from the processing set should remain open for this set up. Clamping the line will prevent the transfer of further processed RBCs to the reinfusion bag, and could also cause a build up of pressure in the reinfusion line. This could result in spillage from the connector on the reinfusion line/bag or centrifugal system.

- **Disconnected** – When all lines are securely clamped, the reinfusion bag is disconnected from the processing set. An appropriate filter/giving set is subsequently attached to the giving port on the reinfusion bag, primed and attached to the patient's IV cannula. This is normally carried out when the reinfusion bag is full or at the end of the procedure. If there is more blood in the collection reservoir to process, a replacement reinfusion bag is attached to the processing set.

Disconnect in standby – The reinfusion bag should not be disconnected while the machine is processing. The operator should wait until the machine returns to standby, or should pause the process (if applicable on the machine in use) if the reinfusion bag is too full to allow the blood being processed to be transferred to it.

10.6 Administration of ICS Blood

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

Pre-transfusion Checks	• Reinfusion of the salvaged blood should follow standard blood transfusion practice. The responsible clinician should prescribe salvaged blood for reinfusion in the same manner as for allogeneic blood. • Baseline observations should be recorded in the patient's clinical record prior to commencing the reinfusion of ICS blood. This is usually carried out by the anaesthetist as part of the anaesthetic record that is routinely completed in theatre. • The patient details (name, date of birth and unique identification number) on the autologous label attached to the reinfusion bag should always be carefully checked against the details on the identification band attached to the patient prior to commencing reinfusion of the ICS blood. If the identification band is inaccessible during surgery, due to surgical drapes, patient identification should be undertaken as per local protocol for these circumstances. • The expiry time on the autologous transfusion label attached to the reinfusion bag should be checked prior to commencing reinfusion of ICS blood. Expired blood should be disposed of according to hospital policy. • Check the reinfusion bag for any signs of leakage, clots or abnormal colour.

Administration of ICS Blood	• A giving set/filter, appropriate to the type of surgery, should be used for reinfusion (see 10.4). • The rate at which the red cells are reinfused can be adjusted using a clamp on the administration set and by adjusting the height of the reinfusion bag. • Observations should be carried out and recorded in the patient's clinical record at least 15 minutes from the start of reinfusion and on completion of the reinfusion.
Documentation	• Reinfusion of salvaged blood should be documented in the appropriate section of the patient's clinical record as specified in the organisation's transfusion policy. The autologous transfusion label contains a peel out section which should be completed at the time of reinfusion and can be used for this purpose.

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.

Pressure Cuffs – Manufacturers advise NOT to use a pressure cuff as there is a risk of air embolus from the air in the reinfusion bag. Some devices may also detect a back pressure if the reinfusion line is open.

10.7 Transfusion Reactions

If a transfusion reaction is suspected, STOP the transfusion and seek immediate advice from the lead surgeon and/or anaesthetist. Complete an adverse event form and report the incident to the individual specified in the Organisation's transfusion/ICS Policy.

10.8 Consent for Reinfusion of ICS Blood

As with allogeneic blood transfusion, the intent to salvage and reinfuse blood using ICS should be discussed with the patient during the routine consent for surgery.

For patients who have religious or other objections to receiving blood transfusions, formal, written consent for the reinfusion of ICS blood should always be obtained. Any religious requirement which may result in differences in the way the ICS equipment is set up and run (Sections 8 and 9), should be well documented in the patient's clinical records and adhered to during the procedure.

If the patient carries an Advance Medical Directive, their acceptance/refusal of autologous transfusion procedures may be documented on this form.

10.9 Documentation

The documentation required during blood reinfusion is the same as outlined in Section 8 and 9:

- Autologous transfusion label (Appendix 3)
- ICS data form (Appendix 4)
- Prescription (as per local policy)

Key Points

- ICS blood for reinfusion consists mainly of RBCs suspended in IV normal saline (0.9% NaCl). Other components, such as platelets, may be present in extremely small quantities.
- The reinfusion of ICS blood should be prescribed by the responsible clinician and should follow local policy and national guidelines.
- Care should be taken to:

– identify the correct patient

– ensure the ICS blood is suitable for reinfusion (i.e. not expired or damaged)

– select the correct giving set/filter to use

– record the procedure accurately on the documentation approved by the Organisation

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
  - 4 – Reinfusion of Red Cells
  - 5 – Administration of Reinfused Red Cells
  - 6 – Use of ICS in Jehovah's Witness Patients
  - 7 – Use of Filters
  - 8 – Use in Obstetrics
  - 9 – Contraindications

Other

- American Association of Blood Banks – Standards for Perioperative Autologous Blood Collection and Administration 3rd Edition
- Manufacturers' ICS Machine Specific Guidance
- National Institute for Health & Clinical Excellence (NICE) (2008) Intraoperative red blood cell salvage during radical prostatectomy or radical cystectomy – Guidance *http://www.nice.org.uk/nicemedia/pdf/IPG258Guidance.pdf*
- National Institute for Health & Clinical Excellence (NICE) (2005) Intraoperative Blood Cell Salvage in Obstetrics – Guidance *http://www.nice.org.uk/nicemedia/pdf/ip/IPG144guidance.pdf*

Self Directed Learning

List the procedures (if any) in your department for which a leucodepletion filter is used to reinfuse ICS blood.

Where are leucodepletion filters stored in your hospital?

On what documentation within the patient's clinical record is transfusion recorded within your Organisation?

Section 11
Unloading and Discarding

Aim

- To introduce the basic principles of unloading an Intraoperative Cell Salvage (ICS) machine and discarding ICS disposables

Learning Outcomes

- Identify *when* unloading of ICS machine and disposables is appropriate
- Determine the risks associated with the unloading phase
- Describe the appropriate procedure for safely discarding waste products and disposables that is compliant with your hospital policy

Introduction

At the end of an operation, or when it appears that no more blood will be collected, it is important to communicate with the surgeon and anaesthetist to ascertain that ICS will no longer be required before unloading the ICS machine. When it has been established that there will be no more blood collected:

- Ensure that any blood collected up to that point that is intended for washing and reinfusion, is processed.
- Ensure that salvaged red blood cells (RBCs) have been reinfused to the patient, or that the reinfusion bag is detached from the processing set (see Section 10).

The procedure for unloading disposables is specific to each type of ICS machine and will differ depending on whether you have set up for "collect only" or "full processing." Therefore, the manufacturer's machine specific guidelines on unloading should be followed. The risks associated with this stage are similar irrespective of technical differences in unloading procedures.

Waste products of ICS include; IV normal saline (0.9% NaCl), anticoagulant, and non-RBC components of blood, in addition to contaminated consumables. There is always a risk that blood may be infected. Your hospital will have a procedure for disposal of biological waste/biologically contaminated material.

Standard precautions when handling bodily fluids should be used as per your hospital's Health and Safety Policy.

Below is a list of generic steps involved in the unloading phase of ICS:

- Establish that the operation is over or that no more blood will be collected
- Ensure that all blood intended for processing *is* processed
- Ensure that all salvaged red cells are reinfused or that the reinfusion bag is detached from the processing set
- Complete the data collection sheet for ICS audit
- Refer to manufacturer's guidance for unloading (there may be an unload function)
- Switch off the power supply
- Dispose of the waste bag/waste bag contents according to local policy
- Close off all clamps and seal off any open ports and ensure that any open spikes are covered or removed
- Remove processing set from device and dispose of as clinical waste
- Wipe down the device and remove blood spillages in line with your local policy and the manufacturer's machine specific guidance

The specific technique for removing waste products from the disposable, or alternatively, for securing waste products within the disposable, should be discussed at the practical session and should be compliant with local hospital policy for disposal of contaminated biological waste.

Further Reading

- Organisation's Policies for Health and Safety and Dealing with Biohazardous Material (local)
- Manufacturer's ICS Machine Specific Guidance

Self Directed Learning

What protective clothing/equipment should you wear when performing the takedown stage of ICS in your hospital?

Where can you find your hospital policy for disposing of contaminated waste?

According to your local policy for disposing of contaminated waste, which of the following would be the correct procedure for disposing of ICS waste fluids in your hospital? (Circle one or write a description)

a. Cut open the waste bag and insert solidifying gel/powder and put in clinical waste bag.

b. Aspirate waste bag contents into suction liners and discard as clinical waste.

c. Aspirate waste bag contents into suction liners and insert solidifying gel/powder and discard as clinical waste.

d. Empty waste bag contents into a bucket and pour down waste pipe in the sluice.

e. Seal the consumable set, ensure there are no leaks and place in rigid yellow biohazard containers.

f. Seal the consumable set, ensure there are no leaks and double bag using clinical waste bags.

Other, please describe

In your local policy for dealing with blood spillages, what cleaning fluid should you use to clean blood spillages on the ICS machine?

Glossary

Term	Definition
Antibodies	Proteins, secreted by specialised blood cells, which will either neutralise antigens or activate other systems that will cause the destruction of the cell on which the antigen is carried.
Coagulation	Coagulation is a complex process by which blood forms clots.
Coagulation (clotting) Factors	Clotting factors are proteins manufactured by the liver. The coagulation factors are numbered in the order of their discovery.
Disseminated Intravascular Coagulation (DIC)	Usually there is a balance between the clotting and lysis systems but in this condition the coagulation mechanism is activated inappropriately and in a diffuse way.
Endothelial	The **endothelium** is the thin layer of cells that line the interior surface of blood vessels, forming an interface between circulating blood in the lumen and the rest of the vessel wall.
Extravascular	Situated or occurring outside a vessel or the vessels.
Extrinsic Coagulation Pathway	Extrinsic pathway is initiated at the site of injury in response to the release of tissue factor (factor III).
Haematocrit (Hct)	(Hct) is a measure of the number of red cells found in the blood, stated as a percentage of the total blood volume. The normal range is from 43% to 49% in men, and from 37% to 43% in women.
Haemoglobin (Hb)	(Hb) is a complex protein-iron compound in the blood that carries oxygen from the lungs to the cells and carbon dioxide from the cells to the lungs. Each red blood cell contains 200 to 300 molecules of haemoglobin. Each molecule of haemoglobin contains several molecules of haem, each of which can carry one molecule of oxygen. The normal concentration is between 12.5 and 16g/dl.
Haemostasis	The stopping of bleeding by mechanic or chemical means or by the complex clotting process of the body.
Hyprofibrinogenaemia	Abnormally low level of fibrinogen in the plasma.

Term	Definition
Immunoglobulin	Also known as antibodies, these are gamma globulin proteins that are found in blood or other bodily fluids of vertebrates, and are used by the immune system to identify and neutralize foreign objects, such as bacteria and viruses. They are typically made of basic structural units – each with two large heavy chains and two small light chains.
Intrinsic Coagulation Pathway	The intrinsic cascade is initiated when contact is made between blood and exposed endothelial cell surfaces.
Iso-oncotic	The same oncotic pressure as capillary oncotic pressure. In the intravascular situation, proteins such as albumin exert osmotic pressure so water does not diffuse out of the vessels and deposit in the tissues.
Oncotic	Plasma proteins are too large to pass through the capillary wall with ease. The oncotic pressure is osmotic pressure exerted by plasma proteins within blood vessels, and tends to draw water into the vascular system. Filtration across capillary membranes is determined by the opposing hydrostatic and oncotic pressures across the capillary membrane.
Prothrombin Complex Concentrate (PCC)	Contains blood coagulation factors II, VII, IX and X.
Thrombocytopenia	An abnormally low platelet count which may indicate a bleeding risk.

Appendix 1

Link to Intraoperative Cell Salvage Competency Assessments

The ICS Competency Assessments are available to download from *www.transfusionguidelines.org.uk*

The following table lists the *theory* competencies relevant to each section of this workbook.

Section	Related Competencies	
	Preparation of Equipment for Intraoperative Cell Salvage (ICS)	Operate Intraoperative Cell Salvage (ICS) Equipment and Reinfuse
1. Using the Education Workbook		
2. Training Pathway	1	
3. Basic Blood Facts		2, 6
4. Blood Conservation	1	
5. Haemovigilance	1	
6. Principles of Intraoperative Cell Salvage	5	8, 9
7. Indications and Contraindications	2, 3, 8	4, 5, 12, 16
8. Practicalities – Blood Collection	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	2, 3, 7, 10, 14, 15, 16
9. Practicalities – Blood Processing	4, 5, 6, 7, 8, 10, 13, 14,	4, 5, 8, 9, 10, 11, 13, 15, 16
10. Practicalities – Blood Reinfusion	1, 3, 5, 6, 7, 10, 13, 14	6, 11, 12, 14, 15, 16
11. Unloading and Discarding	1, 4, 6, 14	11, 17

Appendix 2

Cell Salvage in Jehovah's Witness patients

The information in this Appendix has been adapted from the UK Cell Salvage Action Group Technical Factsheet (6) which is available to download at *www.transfusionguidelines.org.uk*

UK Intraoperative Cell Salvage Action Group

Technical Factsheet 6

Cell Salvage in Jehovah's Witness patients

Area of application

Jehovah's Witnesses (JW) regard blood as sacred. On the basis of this deeply held core value, they decline treatment with allogeneic (donor) blood (red cells, white cells, platelets, and plasma).

With regard to autologous transfusion JW patients make a personal decision whether or not to accept such. This includes all forms of perioperative/intraoperative blood salvage (cell salvage), haemodilution, and postoperative blood salvage. While machines, systems, and arrangements vary, each patient will decide how his/her own blood will be handled in the course of a surgical procedure, medical test, or current therapy. Predeposit (PAD) is not acceptable to Jehovah's Witnesses.

Among those prepared to accept autologous procedures, some may specifically request that the system be set up to allow for continuous connectivity. In such cases, the details outlined below should prove helpful. If no such specific request is received, then the equipment/machinery may be used in the usual way.

Staff

The patient's surgical team and all staff involved in the cell salvage processing.

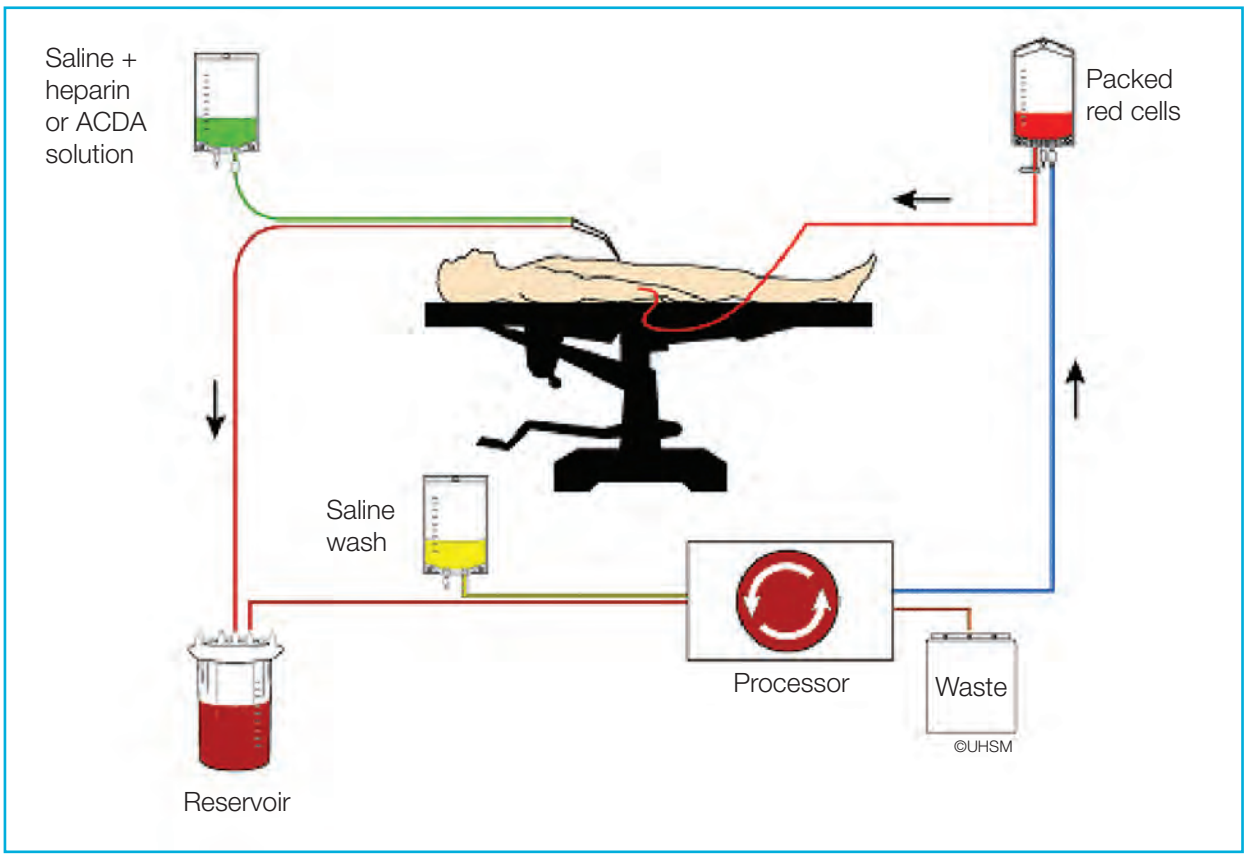
Procedure

Setting up a continuous circuit

Although there will be technical differences between devices, the same general principles apply.

1. Set up the machine for collection and processing with standard disposables (in bowl based machines consider using a low volume bowl to reduce blood stasis).
2. Prime the circuit with saline ensuring that saline enters the reinfusion bag (remember to account for this volume when recording the final reinfusion volume).
3. Attach an appropriate blood administration set to the reinfusion bag. Prime the administration set and connect to the patient via a cannula for reinfusion. Once established, the connection between the patient and the reinfusion bag must not be broken. (Figure 18).
4. Whilst surgery is ongoing, administer the saline at the slowest rate possible to maintain patency of the cannula until processed blood is available.

Figure 18. Representation of a Continuous Circuit



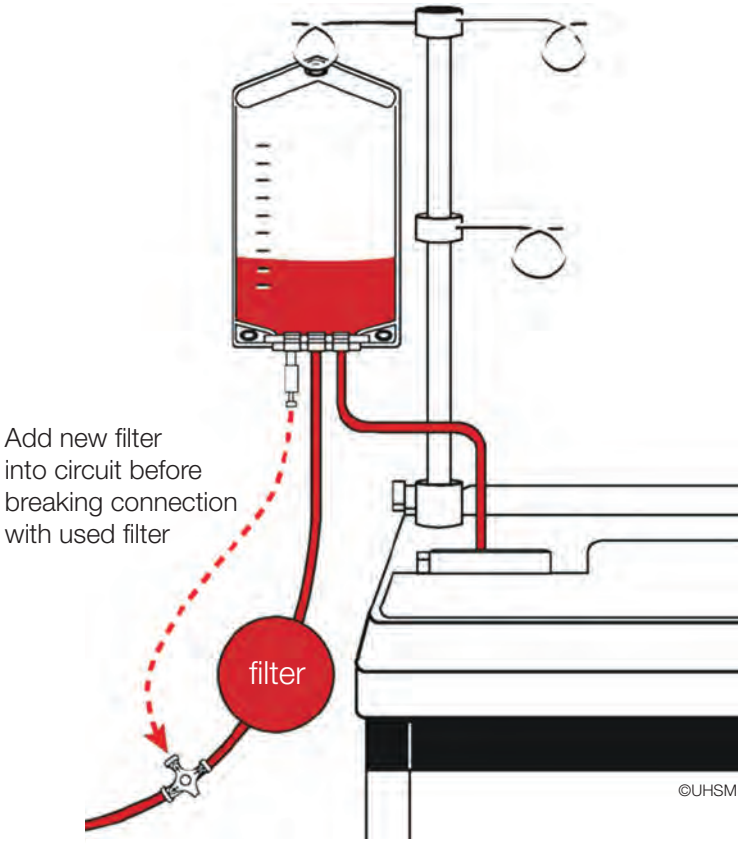
Special requirements

In some cases a leucocyte depletion filter may be needed for reinfusion of the salvaged blood. A standard giving set should be set up with a 3-way tap in line before blood collection begins. The giving set should be primed with saline to complete the circuit. When a volume of blood is ready to be reinfused, the leucocyte depletion filter can be spiked into the second reinfusion port on the reinfusion bag and primed. This is then attached to the 3-way tap, without breaking the circuit. Likewise, because the filters have a maximum throughput of 450mls, a new filter can be added if necessary by replacing the original giving set while leaving the original filter connected. (Figure 19 opposite).

The filter should not be flushed with saline after filtration of the salvaged blood.

When blood loss is rapid, the flow rate through the filter may not be sufficient to transfuse large volumes of blood quickly. Using a filter in each port will double the flow rate. In a worst case scenario the leucocyte depletion filter may need to be isolated from the circuit and replaced with a standard giving set. This must be done without breaking the circuit in order to maintain continuity. During management of life threatening haemorrhage in a JW, if the reinfusion rate of salvaged blood is too slow, even when using two leucodepletion filters, it may be necessary to make a clinical decision to replace the leucodepletion filter with a normal giving set, so that blood can be transfused rapidly to prevent exsanguination.

Figure 19. Replacing a Filter Without Breaking Continuity



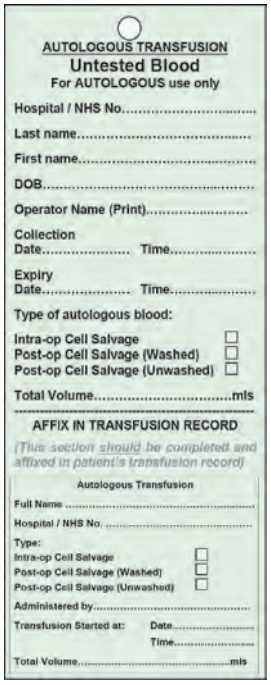
This original factsheet on which this appendix has been based was verified by representatives of the Jehovah's Witness community.

Appendix 3

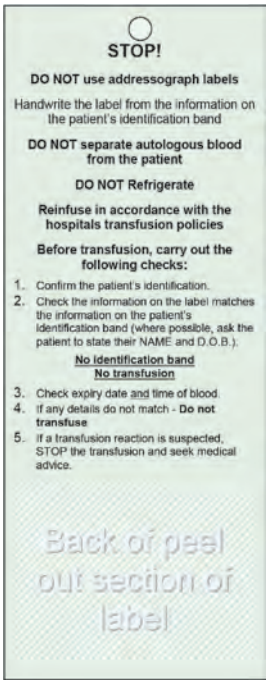
Autologous Transfusion Label

The autologous transfusion label (Figure 20) has been developed by the UK Cell Salvage Action Group to standardize labeling for autologous blood. The labels are supplied by the manufacturers of the Intraoperative Cell Salvage equipment.

Figure 20. Autologous Transfusion Label



Front of autologous transfusion label



Back of autologous transfusion label

Appendix 4

Intraoperative Cell Salvage Data Collection Form

The following (Figure 21) is an example of a data collection form used for Intraoperative Cell Salvage.

Figure 21. Example of an Intraoperative Cell Salvage Data Collection Form

All Wales Intra-Operative Cell Salvage Data Collection Form

This form should be completed for every surgical case where blood has been collected with the intention of intra-operative cell salvage EVEN if the blood collected is not processed.

1. Trust	**Hospital**	For BBT use only

2. Patient Details	**3. Procedure Details**
Hospital number	Name of procedure
Surname	
Forename	Date of operation / /
D.O.B.	☐ In hours ☐ Emergency
Address	☐ Out of hours ☐ Elective
	☐ Malignancy ☐ Infected fields
	☐ Obstetrics ☐ Trauma
	☐ Jehovah's Witness
	Surgeon
	Anaesthetist
	Cell Salvage Operator
Age ☐ Male ☐ Female	Patient died ☐ No ☐ Yes

4. Cell Saver Equipment Used			
☐ BRAT ☐ Electa ☐ Cell Saver 5 ☐ Orthopat ☐ CATS ☐ Other			
Anti-coag used	☐ Heparin	☐ Citrate	☐ Other
Blood filter used	☐ 40µ filter	☐ Leucodepletion filter	☐ None
☐ Collection reservoir		Lot No.	
☐ Harness set		Lot No.	

5. Salvaged Blood Volume Details **Processed Yes ☐ No ☐**		**6. Total No. allogeneic units transfused during hospital stay**	
Intra-op processed (ml)			
Volume of anticoagulant intra-op (ml)		Red cells	
Volume of irrigation used (ml)		FFP	
Volume of swab wash (ml)		Platelets (adult dose)	
Volume salvaged RBC intra-op (ml)		Cryoprecipitate	
Post-op processed (ml)		Other	
Volume of anticoagulant post-op (ml)			
Volume salvaged RBC post-op (ml)			
Time collection started		Pre-Op Hb	
Time re-infusion started		Discharge Hb	

7. Reason if blood was not processed		
☐ Inadequate volume collection	☐ Training purposes	☐ Technical problem

8. Problems / Faults				
Technical	Machine ☐	Bowl ☐	Harness ☐	Software ☐
	Other (Please state)			
Procedural (Operator/Surgeon/Patient)				
	Operator error ☐		Communication failure ☐	
	Training issue ☐		Unforeseen circumstance ☐	

Top copy - – Patient notes **2nd copy** – Audit form – WBS

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NHS
Blood and Transplant

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UK CELL SALVAGE ACTION GROUP

EDUCATION WORKBOOK