CLINICAL USE OF BLOOD

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Allogenic transfusion - blood transfused from a donor
Autologous transfusion - blood transfused from the patient
Normovolaemia - normal circulating blood volume

Blood used correctly can be life saving, used inappropriately it can endanger life. It is important to remember that blood transfusion is only one part of the patient's management. The decision to transfuse blood or blood products should always be based on a careful assessment of clinical and laboratory indications that transfusion is necessary to save life or prevent significant morbidity.

While the responsibility of providing and ensuring access to safe blood lies with the Blood Transfusion Services, the final responsibility for the blood transfusion lies with the clinicians (Anaesthetists, Surgeons, Obstetricians, and Physicians) who must make the correct decision depending on the clinical condition of the patient. In the operating room it is most often the anaesthetist, rather than the surgeon who makes the decision for blood transfusion. As anaesthetists are involved with a wide range of specialities including Trauma, Intensive Care, and often teach students at the undergraduate and postgraduate level, they may actively facilitate the appropriate clinical use of blood.

AVAILABILITY OF BLOOD FOR TRANSFUSION

All anaesthetists need to be aware of the global status of blood transfusion. Even when blood is considered safe by current standards, it may contain unknown pathogens.

- In developed countries all donated blood is screened for blood borne pathogens. In developing countries only 53 % of the donated blood is tested for HIV and hepatitis B; a much smaller proportion is screened for hepatitis C.
- Between 5-10% of HIV infections worldwide are transmitted through the transfusion of contaminated blood and blood products. Hepatitis B and C viruses, syphilis and other infectious agents such as Chaga's disease infect many more recipients of blood products.
- Blood is in short supply. The 20% of the world population living in developed countries have access to 60% of the world blood supply. The 80% of world population living in developing countries have access to only 20% of the world blood supply of safe and tested blood.

OXYGEN CARRIAGE IN BLOOD

Oxygen is carried in the blood in two forms. Most is carried combined with haemoglobin but there is a very small amount dissolved in the plasma. Each gram of haemoglobin can carry 1.31ml of oxygen when it is fully saturated. Therefore every litre of blood with a Hb concentration of 15g/dl can carry about 200mls of oxygen when fully saturated (occupied) with oxygen (PO_2 >100mmHg). At this PO_2 only 3ml of oxygen will dissolve in every litre of plasma. When considering the adequacy of oxygen delivery to the tissues, three factors need to be taken into account, haemoglobin concentration, cardiac output and oxygenation.

Oxygen delivery to the tissues

The quantity of oxygen made available to the body's tissues in one minute is known as the oxygen delivery and is equal to the cardiac output x the arterial oxygen content.

Oxygen delivery (mls O_2/min) = Cardiac output (litres/min) x Hb concentration (g/litre) x 1.31 (mls O_2/g Hb) x % saturation

In the normal adult this works out as: 5000ml blood/min x 200mlO_2/1000ml blood = 1000ml O_2/min.

The effect of haemorrhage on the oxygen supply

Several factors contribute to decreased oxygen supply to the tissues following haemorrhage. These are summarised in the following equation:

❺Cardiac Output x ❺Hb x ❺Saturation =❺O_2 supply to the tissues

When significant blood loss occurs, the fall in oxygen carrying capacity of blood together with the reduction in blood volume cause a fall in oxygen delivery. If intravenous therapy is started to maintain **normovolaemia**, a normal or increased cardiac output may occur which enables an adequate oxygen continue. Replacement of blood loss with crystalloids or colloids also results in dilution of the blood components or haemodilution. Initially this reduces the viscosity of blood, which improves capillary blood flow and cardiac output, enhancing the supply of oxygen to the tissues. Therefore the key objective is to ensure normovolaemia at all times during the course of a surgical procedure. When the Hb falls below 7-8g/dl the cardiac output can no longer compensate for the anaemia and blood transfusion is usually necessary.

Blood volume replacement

To maintain blood volume, intravenous fluids should be given:

- Crystalloids such as normal saline or Ringer's lactate solution leave the circulation more rapidly than colloids. Use 3 times the estimated volume of blood lost.
- Colloids should be infused in an amount equal to the volume of blood lost.

- 5% dextrose produces little effect on blood volume and should not be used for acute blood loss.

Indications for blood transfusion

The judgement on what is an adequate preoperative haemoglobin level for patients undergoing elective surgery must be made on an individual patient basis. It should be based on the clinical condition of the patient and the planned procedure. Accurate estimations of the blood loss and appropriate replacement are necessary to use blood appropriately.

Estimating blood loss

In order to maintain blood volume accurately, it is essential to continually assess surgical blood loss throughout the procedure especially in neonates and children where even a very small amount lost can represent a significant proportion of blood volume (table 1).

Table 1

Blood	**volume**
Neonates	85-90ml/ kg body weight
Children	80ml/ kg body weight
Adults	70ml/ kg body weight

Calculating blood loss in theatre:

- Weigh a dry swab.
- Weigh blood soaked swabs as soon as they are discarded and subtract their dry weight (1ml of blood weighs approximately 1gm).
- Subtract the weight of empty suction bottles from the filled ones.
- Estimate blood loss into surgical drapes, together with the pooled blood beneath the patient and onto the floor.
- Note the volume of irrigation fluids, subtract this volume from the measured blood loss to estimate the final blood loss.

Monitoring for signs of hypovolaemia

Many of the autonomic and central nervous system signs of significant hypovolaemia can be masked by the effects of general anaesthesia. The classic picture of the restless, tachycardic, confused patient who is hyperventilating (air hunger), in a cold sweat and complaining of thirst is not a presentation under general anaesthesia. Hypotension may result from a number of causes, but hypovolaemia should always be suspected.

BLOOD TRANSFUSION

The decison to transfuse blood can be made in two ways:

- **Percentage method.** Calculate the patient's blood volume. Decide on the percentage of blood volume that could be lost but safely tolerated, depending on the clinical condition of the patient, provided that normovolaemia is maintained (table 2).

- **Haemodilution method.** Decide on the lowest acceptable Hb or Haematocrit (Hct) that may be safely tolerated by the patient (table 2). Using the following formula to calculate the allowable volume of blood loss that can occur before a blood transfusion becomes necessary. Replace blood loss up to the allowable volume with crystalloid or colloid fluids to maintain normovolaemia. If the allowable blood loss volume is exceeded, further replacement should be with blood.

$$\text{Allowable blood loss} = \frac{\text{Blood volume} \times (\text{PreopHb} - \text{Lowest acceptable Hb})}{\text{Average of Preop and Lowest Acceptable Hb}}$$

Whichever method is used, the decision to transfuse will depend on the clinical condition of the patient and their ability to compensate for a reduction in oxygen supply. This is particularly limited in patients with evidence of severe cardiac or respiratory disease or pre-existing anaemia. The methods described are simple guidelines which must be altered according to the clinical situation. Further blood loss should be anticipated, particularly postoperatively. Whenever possible, transfuse blood when surgical bleeding is controlled. This will maximise the benefits of the transfusion.

What are the alternatives to allogenic blood transfusion?

If you anticipate that the planned surgery will result in sufficient blood loss to require transfusion consider whether any of the following are appropriate.

Autologous transfusion

Preoperative donation. A unit of the patient's own blood is collected every 5 - 7 days prior to the day of surgery. The blood is tested, labelled and stored to the same standard as allogenic blood and the patient is prescribed oral iron supplements. Up to 35 days preoperatively, a total of 3- 4 units of stored blood may be collected and then re-infused during surgery. This technique needs good organisation, and is not widely used.

Normovolaemic haemodilution. Removal of a predetermined volume of the patient's own blood immediately prior to the start of surgery. The blood is taken via a large cannula into a blood donation bag, which should be labelled and stored at room temperature for reinfusion within 6 hours. The blood is simultaneously replaced with crystalloid or colloid to maintain the blood volume. During the surgery the haemodiluted patient will lose fewer red cells for a given blood loss, and the autologous blood collected can subsequently be reinfused, preferably when surgical bleeding has been controlled. These fresh units of autologous blood will contain a full complement of coagulation factors and platelets. Current guidelines suggest that acute normovolaemic haemodilution should be considered when the potential surgical blood loss is likely to exceed 20% of the blood volume. Patients should have a preoperative haemoglobin of more than 10g/dl and not have severe cardiac disease.

Blood salvage

Blood salvage is the collection of shed blood from the wound or body cavity and its subsequent infusion into the same patient. Contraindications to salvage include blood contaminated with

Table 2

Patient condition	Healthy	Average	Poor
Percentage method Acceptable loss of blood volume before transfusion method	30%	20%	<10%
Haemodilution	Hb 7-8g/dl Hct 21-24%	8- 9g/dl 24-27%	10g/dl 30%

bowel contents, bacteria, fat, amniotic fluid, urine, malignant cells and irrigation fluids. One should not reinfuse salvaged blood more than 6 hours old, since haemolysis of red cells is likely to be complete.

Methods of blood salvage:

- Gauze filtration: using aseptic technique, blood is collected with a ladle or small bowl and filtered through a gauze into a bottle containing anticoagulant.
- Simple suction collection systems: suction pressure should be as low as possible to avoid hemolysis of red cells.
- Automated suction collection systems (cell savers): are commercially available and are routinely used for many operation associated with substantial blood loss in some countries. They collect, anticoagulate, wash, filter and re-suspend red cells in crystalloid fluid prior to re-infusion. The high cost of the equipment limits availability.

Minimising peri-operative blood transfusion

Preoperative. The screening and treatment of anaemia should be a key component of the preoperative management of elective surgical patients. Oral iron (ferrous sulphate 200mg three times a day (tds) for an adult and 15mg/kg/day for a child), will raise the haemoglobin level by about 2gm/dl within about 3 weeks in a patient with iron deficiency anaemia. If there are vitamin deficiencies these should also be corrected with oral folic acid (5mg daily) and injected vitamin B12 (hydroxocobalamin).

In theatre. The best way to avoid the need for transfusion is by minimising blood loss. A number of simple anaesthetic and surgical techniques may be used to achieve this objective. They include:

Anaesthetic techniques:

- Avoid hypertension and tachycardia due to sympathetic overactivity by ensuring adequate levels of anaesthesia and analgesia.
- Avoid coughing, straining and patient manoeuvres, which increase venous blood pressure.
- Avoid hypercarbia causing vasodilatation which will increase operative blood loss.
- Use regional anaesthesia, such as epidural and spinal anaesthesia where appropriate
- Avoid hypothermia in the perioperative period.
- Controlled hypotension in experienced hands.

Surgical techniques:

- Training, experience and care of the surgeon is the most crucial factor.
- Meticulous attention to bleeding points - use of diathermy
- Posture - the level of the operative site should be a little above the level of the heart e.g. Trendelenberg position for lower limb, pelvic and abdominal procedures. Head-up posture for head and neck surgery. Avoid air embolism if a large vein above heart level is opened during surgery.
- Tourniquets- the inflation pressure of the tourniquet should be approximately 100-150mmHg above systolic blood pressure of the patient. Tourniquet should not normally be used in patients with sickle cell disease or trait.
- Vasoconstrictors - infiltration of the incision site with adrenaline (with or without local anaesthetic agent). Avoid vasoconstrictors in end arteries e.g. fingers, toes and penis.
- Postoperative period - Give adequate analgesia because the postoperative pain can cause hypertension and restlessness, which can aggravate bleeding. E.g. following limb surgery, postoperative elevation will reduce swelling, control venous blood loss and reduce pain. Give iron supplements (ferrous sulphate 200mg tds) to restore Hb level.

Antifibrinolytic drugs:

- Drugs, which inhibit the fibrinolytic system and encourage clot stability, have been used in certain operations (e.g. repeat cardiac operations) to reduce operative blood loss, but are not widely used. Aprotinin, tranexamic acid are used when indicated.

Antiplatelet drugs:

- Drugs affecting platelet function e.g. Aspirin and NSAIDs (non steroidal anti-inflammatory drugs) should be discontinued 10 days prior to surgery associated with significant blood loss.

COMPLICATIONS OF MASSIVE BLOOD TRANSFUSION

Definition: Massive blood transfusion is the replacement of blood loss equivalent to or greater than the patient's total blood volume in less than 24 hrs:

- 70ml/kg in adults
- 80-90ml/kg in children or infants

It is often the underlying cause, and the end result of major haemorrhage, that cause complications, rather than the transfusion itself.

Complications include:

- **Acidosis** is more likely to be the result of inadequate treatment of hypovolaemia than the effects of transfusion. Normally the body can easily neutralise the acid load from transfusion. The routine use of bicarbonate or alkalinising agents based on the number of units transfused is unnecessary.

- **Hyperkalemia** is rarely of clinical significance (other than neonatal exchange transfusions).

- **Citrate toxicity and hypocalcaemia.** Citrate toxicity is rare, except in large volume, rapid transfusion of whole blood. Hypocalcaemia particularly in combination with hypothermia and acidosis can cause a reduction in cardiac output, bradycardia and other arrhythmias. Citrate is usually rapidly metabolised to bicarbonate. It is therefore, unnecessary to neutralize the acid load of transfusion. There is very little citrate in red cell concentrates and red cell suspensions.

- **Hypothermia** can occur with rapid administration of large volumes of blood or replacement fluids directly from the refrigerator. With rapid transfusions use a blood warmer.

- **Depletion of fibrinogen and coagulation factors.** Plasma undergoes progressive loss of coagulation factors (Factors V and VII) during storage unless stored at -25° C or colder. Red cell concentrates and plasma- reduced units lack coagulation factors, which are found in the plasma component. Following administration of large volumes of replacement fluids there is dilution of coagulation factors and platelets. Massive or large volume transfusions can therefore result in disorders of coagulation. If there is prolongation of the prothrombin time (PT), give ABO- compatible fresh frozen plasma (15ml/kg). If APTT is also prolonged, Factor VII/fibrinogen concentrate is recommended in addition to the fresh frozen plasma (FFP).

- **Depletion of platelets** occurs during storage of whole blood and there is virtually no platelet function after 24 hours. Prophylactic use of platelets is not recommended. Give platelet concentrates only when the patient shows clinical signs of microvascular bleeding or the platelet count falls below $50x10^9$/L. Consider platelet transfusion when the platelet count falls below $20x10^9$/L, even when there is no clinical evidence of bleeding, because there is a risk of spontaneous internal haemorrhage.

- **Disseminated intravascular coagulation (DIC)** may develop during massive blood transfusion although its cause is less likely to be due to the transfusion than to the underlying reason for transfusion, such as hypovolaemia, trauma or obstetric complications.

Management of DIC:

- When DIC is suspected, do not delay treatment while waiting for the results of coagulation test. Treat the cause and use blood products to help control haemorrhage.

- If PT or APTT is prolonged and the patient is bleeding, replace red cell losses with the freshest whole blood available as it contains fibrinogen and most other coagulation factors. Give FFP as this contains labile coagulation factors (1 pack / 15kg body weight i.e. 4-5 packs in adults). Repeat FFP according to the clinical response. This dose is based on preparation of FFP, cryoprecipitate and platelet concentrates from 450ml donations. FFP is always supplied as a separate pack for each donor, cryoprecipitate and platelets preparations are pooled donations.

- If fibrinogen is low or APTT or thrombin time is prolonged, also give cryoprecipitate, to supply fibrinogen and Factor VIII (1 pack / 6kg body weight i.e. 8-10 packs in adults).

- If platelet count is less than 50 x 109/L and the patient is bleeding, also give platelet concentrates (4-6 packs in adults).

- Heparin is not recommended in bleeding patients with DIC.

BLOOD TRANSFUSION REACTIONS

Most transfusion reactions are mild involving urticaria and moderate pyrexia. Acute, severe reactions may occur in 1-2% of transfused patients. **The most common cause of severe transfusion reactions is patients being given the wrong blood**. This may result from an incorrect sample being sent to the laboratory, a mix up in the transfusion department, but most frequently the wrong blood being transfused on the ward.

In an unconscious or anaesthetised patient, hypotension and uncontrolled bleeding may be the only signs of an incompatible transfusion. Other signs include tachycardia and haemoglobinuria. Even a small volume (10-50ml) of incompatible blood can cause a severe reaction and larger volumes increase the risk. Acute transfusion reactions occur during or shortly after (within 24 hrs) the transfusion. Rapid recognition and management of the reaction may save the patient's life.

Management of a severe reaction under anaesthesia

- Stop transfusion and treat as anaphylaxis
- Replace infusion set with normal saline.
- Maintain airway, give high flow oxygen.
- If there is severe hypotension or bronchospasm give adrenaline either IV (1:10,000 solution in 0.5-1ml aliquots) or IM (1:1000 as 0.01ml/kg body weight). Consider IV corticosteroids and bronchodilators.
- Give IV diuretic e.g. frusemide 1mg /kg.
- Immediately notify blood bank and send the blood pack with the infusion set, fresh urine sample, fresh venous blood sample (1 clotted and 1 anti-coagulated) from a vein opposite the infusion site.
- Asses and treat hypotension with saline 20-30ml /kg over 5 minutes and inotropes (e.g. dopamine).
- Monitor urine output. A falling urine output or a rising K^+, urea, or creatinine are indicative of acute renal failure. Ensure a normal blood pressure (a CVP measurement may be required) and consider further frusemide. Renal dialysis may be required.
- If bacteraemia is suspected (rigors, fever, collapse, no evidence of a haemolytic reaction) start IV broad-spectrum antibiotics.

CHECKLIST FOR GIVING BLOOD

Before you prescribe blood - ask yourself:

- What improvement am I aiming to achieve in this patient's clinical condition? Can I reduce blood loss to minimise this patient's need for transfusion?
- Have I given other treatment (e.g. intravenous replacement fluids, oxygen) before making the decision to transfuse blood?
- What are the specific clinical or laboratory indications for transfusion?
- What are the risks of transmitting HIV, hepatitis, syphilis or other infectious agents through the blood products that are available for this patient?
- Do the benefits of transfusion outweigh the risks of blood transfusion for this particular patient?
- What other options is there if no blood is available in time?
- In the postoperative period will a trained person monitor and respond immediately if any adverse transfusion reactions occur?
- Have I recorded my decision and reasons for transfusion on the patient's chart and Blood Request form?
- Finally, the most important question you should ask before making a decision - would I accept this transfusion in this clinical condition, if this blood was for myself or my child?

Before you give blood - check:

- *Correct patient?* - **check** patient identity against notes and transfusion form
- *Correct blood?* - **check** label on blood and transfusion form
- *Correct group?* - **check** donor blood according to transfusion form
- *Correct date?* **- check** donor blood

Using blood appropriately

As anaesthetists we can make an impact on clinical use of blood beyond the care of our own patients. However small our contribution, we can play an important part in creating the conditions in which the appropriate clinical use of blood is possible. While progress may initially be slow, a regular and systematic review of transfusion practices should demonstrate the effectiveness of change and point to areas where further improvement may be needed.

Further reading

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