REVIEW ARTICLE

BLOOD CONSERVATION IN ANAESTHESIA AND SURGERY - A REVIEW

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Summary

Dangers to blood transfusion exist even when stringent methods are used to screen blood before transfusion. These dangers include blood transfusion reactions and the transmission of bacteria, viruses and protozoa to patients. Blood conservation adopts strategies that restrict the transfusion of homologous blood to patients. Conservation starts in the preoperative period and includes the diagnosis and management of anaemia. Augmentation of the preoperative haemoglobin can be achieved by using a combination of iron preparations, vitamins, protein supplementation, erythropoietin and treatment for malaria in suspected patients. Maintenance of the intravascular volume during surgery can be achieved using colloids and crystalloids. Blood conservation techniques, including induced hypotension, use of anti-fibrinolytics and acceptable forms of autologous blood transfusion reduce the need for allogeneic blood transfusion. Blood conservation methods are also important in critically ill patients and includes, accepting lower haemoglobin levels, restricting the amount of blood taken during phlebotomy and the use of erythropoietin/ erythropoietin receptor agonists.

Key words: Blood conservation, allogeneic blood, erythropoietin.

Introduction

The concept of blood conservation is an adopted strategy that restricts the transfusion of allogeneic blood and also deals with other alternatives to increase oxygen delivery in patients. This has been championed by Jehovah's witnesses and also physicians involved with transfusion medicine. As a religious sect Jehovah's Witnesses do not accept the transfusion of blood and blood products as well as the technique of preoperative blood deposit. However, they accept certain forms of autologous blood transfusion and will therefore benefit from blood conservation[1,2]. Because blood conservation is not commonly practised in most hospitals in the developing world patients requiring such management may have to be referred to centres that are experienced in such procedures[2,3].

The scourge of HIV/AIDS and hepatitis have made the transfusion of homologous blood even less acceptable for most patients in developing countries. Transfusion of allogeneic blood has been associated with tumour recurrence in patients by tumour immunomodulation[4]. Most oncologists would, if possible, refrain from the transfusion of allogeneic blood. The scarcity of resources, including ready availability of blood in the West-African sub region makes the management of patients using the technique of blood conservation even more important and has stimulated this review article.

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Cardiac Output and Oxygen Delivery in Anaemia

Transfusion of blood in anaemia increases the oxygen content of blood that together with adequate cardiac output improves oxygen delivery to tissues. Loss of blood means loss of haemoglobin therefore reduction of the oxygen carrying capacity of blood. It is however known that loss of blood causes a compensatory increase in cardiac contractility and the heart rate which results in an increase in the cardiac output[5,6]. Reduction in the haematocrit (Hct) will cause a reduction in the blood viscosity resulting in better micro-vascular bed perfusion. This compensatory measure is even better when the intravascular volume is maintained by using fluids.

Various workers have used gelatine, dextran, hydroxyethyl starch, albumin and crystalloids as replacement fluids[6-9]. Although this does not increase the oxygen content of blood, restoration of the circulating volume will increase the cardiac output and therefore the oxygen delivery to the tissues.

Oxygen delivery to tissues with normal haemoglobin is about three times more than the body requires. As the haematocrit declines to about 25% there is an increase in oxygen extraction from the tissues and a rightward shift of the oxygen dissociation curve. Studies have shown that patients with a HCT of 20-22% and a low haemoglobin around 4.0g/dl have had sur-

gery without an associated increase in mortality[10-11]. Patients with significant systemic disease like ischaemic heart disease, renal impairment and peripheral vascular disease neither tolerate low haemoglobin levels nor reduced oxygen delivery[12]. The amount of dissolved oxygen in the blood can be increased significantly in severely anaemic patients with the administration of oxygen under hyperbaric conditions and this has been used clinically[13].

Preoperative Preparation and Counselling

It is important for surgery to be properly planned and this means a multidisciplinary approach to the problem of blood conservation by the anaesthetist, surgeon, physician and the blood transfusion technician. This collective approach is used in many centres where blood conservation is routinely practised and this has led to the refinement of management of patients such as Jehovah's witnesses who refuse blood transfusion[8,9,14,15]. In most developed countries, blood conservation has become the norm during anaesthesia and surgery. The surgical procedures as well as the need to institute blood conservation procedures and the alternatives should be fully explained to the patients[16].

Medical history and clinical investigation

Enquiries into details of previous surgeries will enable a fair anticipation of blood loss. A history of inherited or acquired bleeding disorders must be fully investigated. Menorrhagia, rectal bleeding and helminthic (hookworm) infestation may indicate the possibility of iron deficiency anaemia. Drugs that affect haemostasis such as non-steroidal anti-inflammatory drugs, coumarins, and other platelet aggregation inhibitors must be sought for on positive direct enquiry. All systemic diseases must be investigated and treated appropriately. Clinical examination must look out for anaemia, bleeding tendencies with skin manifestation of lesions like ecchymosis, petechial haemorrhages and haematomas. Hepatomegaly and splenomegaly may indicate haemoglobinopathy, haematological malignancy or other chronic anaemia. Severe hypertension may predispose to severe bleeding during surgery and the blood pressure must therefore be controlled before surgery. Pertinent investigations include a full blood count and sickling, blood urea and electrolytes and where indicated blood film comment, liver function tests, serum ferritin, folic acid and vitamin B12 levels.

Maximising preoperative haemoglobin

History and laboratory investigations

The patient should be seen at the pre-anaesthetic clinic, and adequate preparations made for the surgery. This clinic assesses the cardiorespiratory risks of surgery and potential problems that will preclude certain blood conservation methods. These diseases include ischaemic heart disease, hypertension, peripheral vascular disease, renal impairment and thrombotic strokes[12]. The haemoglobin, sickling status and iron levels may be checked. Sickle cell anaemia is common in tropical as well as certain Mediterranean regions and the combination of sickle cell anaemia and refusal of allogeneic blood may increase morbidity[17].

Haematinics and Erythropoietin

Administration of iron tablets in appropriate doses will increase the haemoglobin in patients with low or low normal haemoglobins if the cause of the anaemia is iron deficiency by 1g per week. Where oral iron is not tolerated, parenteral iron, preferably iron sucrose[18]may be effective in raising the preoperative haemoglobin. In patients with significant iron deficiency, however, most workers use a combination of iron and preoperative erythropoietin (EPO) to ensure the expected rise of haemoglobin by 1g per week[14, 24-28]. The doses of EPO used range between 150-600iu/kg/week[9, 18-28]. In Ghana patients being prepared for cardiac surgery and other operative procedures are given a combination of haematinics, EPO of 150iu/kg/week, nutritional supplementation and antimalarials where necessary[**9, 19**]. EPO has also been used successfully in anaemic pregnant women and this reduced the need for blood transfusion during delivery[**21**].

The use of EPO in patients with haemoglobinopathies is however controversial. Some workers have combined EPO and hydroxyurea in sickle cell patients to increase the percentage of haemoglobin F in patients with sickle cell disease who refuse to have allogeneic blood transfusion[21, 29].

Malaria is endemic in most tropical and subtropical areas and this may cause severe anaemia by haemolysis especially in children and this can be reduced by malaria prophylaxis in selected groups[26]. Helminthic infestation, common in developing countries would need treatment. Hook worm infestation in particular, would cause iron deficiency anaemia and must be looked for and treated especially in patients coming from farming communities.

Blood Conservation Methods

Autologous blood transfusion

Autologous blood transfusion is the collection and subsequent infusion of the patient's own blood. This includes preoperative autologous blood donation (PABD), acute normovolaemic haemodilution and blood salvage. Jehovah's Witnesses do not accept preoperative blood deposit. However they may accept acute normovolaemic haemodilution (ANH) so far as there is no break in the continuity of the harvested blood with their circulation[15-16].

Preoperative Autologous blood donation (PABD)

Preoperative autologous blood donation is the collection and storage of the patients own blood prior to elec-

tive surgery where significant blood loss is expected. A unit (450mls) of blood is collected at intervals of 7 days. Iron supplements, nutritional supplements and EPO can be used to increase the yield of blood donated[20-21, 25]. By the time of surgery as much as 4-5 units of blood may be available for use in the perioperative period[20]. Ansah *et al* have shown that over a ten year period (1993-2003) there has been a 16 fold increase in the preoperative blood donation at the Korle bu Teaching Hospital in Accra for patients coming for gynaecological and orthopaedic surgery[27]. PABD has been used for paediatric, cardiac and neurosurgery among others[21, 22]. PABD has also been used for pregnant women who are expected to have massive haemorrhage during delivery and this reduces their dependence on allogeneic blood[21]. During PABD patients are involved in their own management and there is reduced risk of viral infections, isoimmunisation and other adverse blood reactions. Rare blood groups do not have to wait for a special match and there is a reduction in the alleged risk of tumour recurrence with allogeneic blood (immunomodulation)[4].

Acute normovolaemic haemodilution

This consists of the collection of a predetermined volume of blood and the subsequent reinfusion after haemostasis has been secured. The amount of blood to be removed during haemodilution is determined by the Gross formula shown below [30]:

V = EBV x (HCTi – HCTf) / HCTav

Where V = amount of blood removed, EBV = estimated blood volume, HCTi = initial haematocrit, HCTf = final haematocrit, and HCTav = average of HCTi and HCTf.

Moderate acute dilution to a haematocrit of 30% is well tolerated so far as the adequacy of the circulating volume is maintained by fluid replacement[6,7]. Research has shown that a haematocrit of 20-25 is relatively safe in patients with no significant cardiorespiratory disease[9,11]. Hypoperfusion during ANH may lead to impaired tissue perfusion with serious consequences[6,7]. ANH has been used successfully in children for spinal and other surgeries[5,,11,31].

Recommendations for fluid replacement during ANH include crystalloids, colloids like hydroxyethyl starch, gelatins and dextrans[7,9,30,32]. Albumin is not universally accepted by all Jehovah's Witnesses and preoperative consent must be sought before this is transfused[1]. Hydroxyethyl starch and gelatin may cause coagulopathies, renal failure in the susceptible and are relatively expensive[33]. In most instances, crystalloids are adequate as replacement fluids in infusions of 3ml for each ml of blood removed[8,9,11].

Hypervolaemic haemodilution

This involves the in vivo dilution of erythrocytes by creating hypervolaemia using asanguinous fluids in an attempt to reduce erythrocyte blood loss and is an option in patients who refuse ANH[32]. Where blood loss is expected to be greater than 10ml/kg or 1000ml, intravenous fluids of 40ml/Kg are given fast to reduce the Hct to 20-22%. Precaution must be taken in patients with significant cardiac or renal disease as large fluid shifts may result in cardiac decompensation or fluid overload. Kumar and Van Hemelen have used this method safely in healthy patients without allogeneic transfusion for extensive surgery[32,34].

Intra-operative and post-operative blood salvage

This is now routinely used in developing countries and may be accepted by Jehovah's Witnesses if a closed circuit is used for transfusion[35,36]. This involves the collection and processing of the patients own blood and re-transfusion without a break in the continuity of the circuit. Cell savers, which are used for intraoperative blood salvage are expensive and need technical assistance to run. However smaller and more useful devices are becoming available on the market at a fraction of the cost of cell savers. Low prime circuits and autologous priming of cardiopulmonary bypass circuits have been employed for cardiac surgery to reduce homologous transfusion[9,37,38].

Controlled hypotension

Controlled hypotension is defined as a reduction in the systolic blood pressure to between 80-90mmHg or a mean arterial blood pressure of 50-70mmHg in a normotensive patient[39]. This is a technique that is used intra-operatively to reduce surgical blood. Deliberate or controlled hypotension can be achieved by use of posture, that is, the head-up position, some pharmacological agents or regional techniques like epidural and spinal anaesthesia [40]. Controlled hypotension can be used in conjunction with other blood conservation techniques[11,41]. Lim *et al* found out that combining normovolaemic haemodilution with hypotensive anaesthesia almost halved the amount of blood transfused during surgery[42,43].

Controlled hypotension may also be induced by a variety of pharmacological agents notably vasodilators and inhalational anaesthetics. Common vasodilators used include clonidine, sodium nitroprusside (SNP), glyceryl trinitrate, hydrallazine, and trimethaphan ,esmolol, labetolol, dexmedetomidine, fenoldapam and nicardipine[44,45]. Controlled hypotension is contraindicated in patients with liver disease, renal insufficiency, ischaemic heart disease, peripheral vascular disease and patients with previous thrombotic strokes.

Augmentation of clotting in the peri-operative period

The discovery of novel drugs like recombinant factor $V11_a$ has changed the management of the multitraumatised and surgeries involving massive haemorrhage, especially in emergencies[46]. Tranexamic acid, an antifibrinolytic agent in oral doses of 15-25mg/kg or intravenous loading doses of 12-15mg/kg and continu-

ous infusions of 6mg/kg/hour has been used extensively for blood conservation and is relatively cheaper than other antifibrinolytic agents like approtinin and epsilonaminocaproic acid[47,48]. Desmopressin, a synthetic analogue of vasopressin increases the amount of factor VIII and Von Willebrands factor in blood and is useful in patients who have been on aspirin preoperatively, in doses of 0.3ug/kg subcutaneously, intramuscularly or intravenously[49,50].

Oxygen carrying compounds and haemoglobin solutions

There has been a lot of study into oxygen carrying fluids and haemoglobin solutions. This was initially limited to the perfluorocarbons. Initial tests and use were disappointing but the new generation of perfluorocarbons have shown more promise. Haemoglobin solutions, which are an alternative, may not be acceptable to many Jehovah's Witnesses because they are generated from old red blood cells[51]. These synthetic and semi-synthetic agents may however not be available for patients in developing countries mainly because of cost.

Other General Measures

Use of posture, tourniquets, vasoconstrictors

Keeping the surgical site higher than heart reduces venous congestion at the surgical site and reduces bleeding. Infiltration of the incision sites with vasoconstrictors like adrenaline and noradrenaline have been used for decades to reduce capillary bleeding during surgery. Absorption of these drugs from large wounds may cause severe tachycardia and hypertension in certain patients. The use of tourniquets is also indicated for extremity surgery especially on the upper and lower limbs. This reduces bleeding and also reduces the surgical time as the tissues are easily seen by the surgeon. The use of tourniquets are said to be relatively contraindicated in patients with sickle cell disease, peripheral vascular disease and in patients with Burger's or Reynolds disease. Adu-Gyamfi *et al* have successfully used tourniquet in known sickle cell disease patients without any adverse effects[52]. In their study complete exsanguination of the limb was necessary to prevent sickling in these patients.

Surgical technique

Meticulous surgical techniques should be used and surgical devices that coagulate as they cut. These include electrocautery, laser, argon beam coagulator, stereo static radio cutters, microwave coagulating scalpel and the ultrasonic scalpel should be encouraged among surgeons. Laparoscopic surgery which restricts wound size should also be encouraged. For long complex types of surgery staging may be encouraged to allow the haematological systems to recover and the blood coagulation to become normal. Use of fibrin glue, collagen, haemostatic felt and tissue adhesives are known to reduce bleeding by enhancing the coagulation of blood.

Conclusion

With the scourge of HIV/AIDS and Hepatitis infections, blood conservation is becoming increasingly important throughout the world. A multidisciplinary approach to the perioperative management of and proper planning of surgery is necessary. Extensive surgery can be staged to allow patients to recover from anaemia. Augmentation of preoperative haemoglobin may be done using EPO, iron and haematinics which would increase the units donated during preoperative autologous blood donation. Normovolaemic haemodilution, intra-operative and postoperative blood salvage are invaluable for the recovery and re-transfusion of red blood cells. Anti-fibrinolytics have been shown to reduce blood loss and must be readily used. The availability of effective oxygen carrying fluids may make the management of emergencies in these patients easier.

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