Although we have not achieved optimal transfusion practice in this country, others are dealing with the issues raised in this symposium. The Canadian Blood Committee has taken a major interest in the cost and the utilization of blood products and has set about to try to understand and predict blood product utilization in the future. Not only have they looked at the problems of plasma fractionation, but they are also considering the implications of the introduction of new synthetic blood products such as recombinant Factor VIII, the potential implications of erythropoietin, and the usefulness of blood substitutes such as pyridoxalated Hb solution. These are among the many issues awaiting evaluation and introduction into our complex blood program.

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Indications for perioperative blood transfusion in 1990

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Rational transfusion practices are determined by clinical evaluation and utilization of appropriate laboratory tests. While the trend toward more conservative transfusion practices is laudable, blood transfusions should not be withheld because of fear of transfusion-transmitted disease. The blood supply is safer than ever before and advances in monitoring and laboratory testing are facilitating scientific approaches to blood administration.

L'évaluation clinique et l'utilisation appropriée de tests de laboratoire permettent une approche rationnelle des transfusions sanguines. La tendance vers une approche plus conservatrice face aux transfusions est louable toutefois, on ne devrait pas indûment restreindre l'usage des transfusions par crainte des maladies qu'elles peuvent transmettre. Les stocks sanguins sont de plus en plus sécuritaires et l'amélioration du monitorage et des tests de laboratoire permettent une approche scientifique de la pratique transfusionnelle.

Approximately two-thirds of red blood cell transfusions are administered in the perioperative period, most by anaesthetists. In addition, a considerable proportion of the platelets and plasma are given to surgical patients.

Traditional transfusion practices are being reevaluated, primarily because of the fear of transfusion-transmitted disease. More conservative transfusion practices can also be attributed to concerns about the immunomodulatory effects of homologous transfusion. Although the mechanism is unclear, cancer patients who are transfused perioperatively have a worse prognosis than those with similar pathology who are not transfused. In addition, homologous transfusion may impair host defenses against bacterial infection and increase the risk of postoperative infection.[1]

Most recommendations for current transfusion practices are based on the statements of the Consensus Conferences on Perioperative Red Blood Cell Transfusion[2] Platelet Therapy,[3] and Fresh Frozen Plasma[4] sponsored by the National Heart, Lung and Blood Institute. While these recommendations are the best available, further research is needed to provide a more scientific basis for transfusion practices.

The introduction of plastic bags and tubing in the 1950s led to the development of component therapy in the 1960s. The contemporary transfusion service can now provide 25 or more different blood products. Reliance on component therapy has led to more efficient utilization of the blood supply. Without fractionation, specific components will not be available when needed. Administration of unnecessary components is also avoided. Since the storage requirements for components differ, separation also permits each to be stored at optimal temperature to ensure maximal therapeutic benefit.

There has been a resurgence of interest in the use of fresh whole blood, especially related-donor transfusion in cardiac surgery patients.[5] However, the identification of fatal graft-versus-host disease in several nonimmunocompromised patients has tempered this enthusiasm.[6] While irradiation of donor blood may eliminate this problem by inactivating lymphocytes responsible for the disorder, it is unlikely that the use of fresh whole blood will become widespread because of the logistics of collection and testing as well as the lack of proven efficacy.[7]

Indications for red blood cell transfusion

It has been traditional for anaesthetists to insist that patients

have haemoglobin (Hb) concentrations of 10 $g \cdot dl^{-1}$ or greater.[8] This arbitrary "10/30 rule" was based on theory and custom, not clinical or experimental evidence. Although extensive clinical experience has shown that patients with lower Hb levels can safely undergo anaesthesia and surgery, little information is available in the literature to substantiate the safety of anaesthetizing anaemic patients.[9]

When deciding whether to transfuse, the physician must consider first the aetiology of the anaemia and whether it is acute or chronic. Acute blood loss triggers a number of compensatory mechanisms designed to maintain blood flow to vital organs, especially the heart and brain. These mechanisms include stimulation of the adrenergic nervous system, release of vasoactive hormones, hyperventilation, reabsorption of fluid from the interstitium into the vascular space, a shift of fluid from the intracellular to the extracellular compartment, and renal conservation of water and electrolytes.[10]

Acute blood loss has profound effects on cardiac output, the primary determinant of tissue perfusion. Cardiac output is directly proportional to the venous return to the right side of the heart (preload). Preload increases during acute blood loss as a result of adrenergically mediated venoconstriction of the systemic venules and small veins. Mobilization of blood sequestered in this circulatory bed, which can represent 50% or more of the total blood volume, results in an increase in stroke volume. Heart rate also increases as a result of sympathetic nervous system stimulation. If blood loss continues, constriction of the vascular sphincters in the circulatory beds of the skin, skeletal muscle, kidney, and splanchnic viscera occurs. These mechanisms can restore cardiac output to or toward normal within 60–120 sec, unless blood loss exceeds the ability of the organism to compensate.

In chronically anaemic patients, cardiac output does not change until the Hb decreases to approximately 7 $g \cdot dl^{-1}$.[11] The cardiac output is then increased primarily by augmentation of stroke volume, not tachycardia.

When an increase in cardiac output is not possible or is undesirable, as in patients with coronary artery disease, transfusion may be indicated at higher Hb levels than in fit, young patients. How is the clinician to determine the appropriate "transfusion trigger" for an individual patient? A number of variables must be considered, not only the Hb value. Other determinants of tissue oxygen delivery are the inspired oxygen concentration and pulmonary gas exchange. The oxygen consumption must also be taken into account.

In the ideal 70 kg subject at rest, total body oxygen consumption approximates 250 ml and oxygen delivery 1000 ml per minute. The oxygen extraction ratio is thus 25%, indicative of a four-fold reserve. An oxygen extraction ratio of greater than 50–60% has been suggested as a valid indicator of the need for red blood cell transfusion, based on animal studies.[12,13] These values correspond to haematocrits (Hct) of 10–15%. The absence of morbidity or mortality in normal, unanaesthetized, minimally stressed animals cannot be extrapolated to clinical practice. However, anecdotal reports of survival of severely anaemic patients support these observations.[14]

The advent of invasive monitoring techniques has made possible the measurement of all variables which contribute to oxygen delivery and consumption. Cannulation of a peripheral artery provides access to arterial blood for gas determinations. Sampling of blood from a balloon-tipped pulmonary artery catheter provides true mixed-venous blood concentrations and the addition of a thermistor probe permits the determination of cardiac output by the thermodilution technique. Thus, all the determinations necessary to calculate oxygen delivery and the oxygen extraction ratio are available – at minimal risk. While it is neither necessary nor practical to place these invasive monitors in the vast majority of patients who may require transfusion, they should be used in assessing the need for red blood cell administration when indicated.

Red blood cells should be administered to increase oxygen carrying capacity, not for volume expansion, wound healing, or to improve "well-being." When anaemia is the result of acute blood loss, administration of acellular fluids constitutes initial therapy. Restoration of intravascular volume is far more important than transfusion to any arbitrary Hb level. Adequate oxygen carrying capacity can be met by a Hb level of 7 $g \cdot dl^{-1}$ in most patients if intravascular volume is maintained.[2] In some patients lower Hb levels are well tolerated. Animal studies suggest that wound healing may be impaired at haematocrits (Hct) $<15\%$. There is no evidence that anaemia increases the frequency or severity of postoperative infection or prolongs recovery in surgical patients.[2]

Administration of platelets and plasma

There are two clinical situations in which decisions regarding administration of platelets and plasma must often be made: cardiac surgery and massive transfusion. In neither case is prophylactic administration of either component justified.

Patients undergoing cardiopulmonary bypass exhibit decreased platelet counts and thrombocytopathy during and after surgery. The exact aetiology of the platelet defect remains unclear. However, it has been shown that prophylactic administration of homologous platelets is of no value.[15] There is limited data to support the administration of platelet-rich plasma obtained by plasmapheresis prior to surgery.[16,17] There are no data to justify the prophylactic administration of plasma.

In patients receiving large volumes of red blood cells, so-called massively transfused patients, clinical evaluation must be combined with laboratory studies. In the absence of clinical bleeding, laboratory values alone must not determine therapy. Conversely, in the face of on-going blood loss, administration of platelets and/or plasma may be indicated prior to availability of the results of laboratory tests. The most useful and most readily obtainable laboratory test for predicting bleeding in the massively transfused patient is the platelet count.[18,19] Additional tests of value are the fibrinogen level, prothrombin time (PT), and activated partial thromboplastin time (aPTT).

There is no justification for the prophylactic administration of platelets[20] or fresh frozen plasma (FFP)[21] in massively transfused patients. The guidelines set forth in the NIH consensus conference statements[3,4] should be followed. It must be remembered that coagulopathy in patients receiving massive transfusion correlates more closely with the duration of the volume deficit than with the total volume of blood transfused.[22] Therefore, the most important factor in preventing coagulopathy is early, adequate resuscitation.

A logical approach to evaluation of "abnormal" bleeding is to consider whether it is the result of trauma, transfusion or preexisting disease. Trauma includes that inflicted by the surgeon as well as wounds sustained outside the operating room. Surgical haemostasis is the cure for this type of bleeding.

Transfusion-associated bleeding can be the result of a dilutional coagulopathy or of a haemolytic transfusion reaction. Dilutional coagulopathy is unlikely unless transfusion exceeds 1.5 times the blood volume. Determination of the platelet count, PT, aPTT and fibrinogen level will assist in diagnosis and treatment.

Most haemolytic transfusion reactions are the result of improper identification of the patient by the transfusionist, and not of clerical errors in the laboratory. Oozing, hypotension and haemoglobinuria may indicate a haemolytic transfusion reaction. If such a reaction is suspected, the transfusion should be discontinued, identifying information verified, and the laboratory notified immediately. The simplest screening test is examination of a centrifuged blood sample for free plasma Hb. If there is no plasma discoloration, a serious haemolytic reaction is unlikely. On rare occasions haemolysis is the result of mixing of red blood cells with hypotonic solutions. Therefore, if the plasma is discoloured, all intravenous solution containers should be examined to ensure that a hypotonic solution was not used.

Coexisting coagulopathies may be congenital or acquired. Fortunately, most congenital disorders will be identified preoperatively. Therapy for these patients should be determined in consultation with a haematologist. Liver disease is the cause of many acquired coagulopathies. When administration of FFP is necessary, the minimal effective treatment in adults is often 600 to 2000 ml administered over a short period of time.[23]

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Perioperative autotransfusion: haemodilution and red cell salvaging

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We have treated 129 cases of massive haemorrhage during surgery using our combined autotransfusion technique (HAT and SAT). No adverse reactions or complications have been noted and additional homologous blood transfusion has not been required. In addition, circulatory dynamics have been satisfactorily maintained. Although the red cell recycle rate has been maintained at over 85%, the salvaging rate of blood in the operating field has not yet reached 80%. Approximately 30% of the surgical haemorrhage appears to be discarded with surgical sponges or flow out of the operating field. Clearly the cooperation of surgeons is an important factor for success with SAT. Success in autotransfusion may be accomplished by combinations of autotransfusion techniques.

En utilisant une technique per-opératoire combinée d'autotransfusion par hémodilution et récupération des globules rouges, nous avons réussi à éviter toute transfusion de sang homologue lors de 129 épisodes d'hémorragie massive, et ce, sans complication et avec en prime, une stabilité hémodynamique satisfaisante. Toutefois, on perd toujours près de 30% du saignement dans les éponges ou en dehors du champ opératoire. On peut transfuser intacts au delà de 85% des globules rouges récupérés. Evidemment, la collaboration du chirurgien est essentielle à la récupération d'un maximum de globules rouges.

Haemodilutional autotransfusion (HAT) has been used for the treatment of operative haemorrhage in more than 2000 patients during elective surgery in our clinic since 1974. Intraoperative red cell salvaging autotransfusion (SAT) was introduced in 1982. By combining these techniques we have been able to perform extensive and complete intraoperative autotransfusion to avoid homologous blood transfusion.

In this presentation we describe the techniques we have developed. An important principle in the use of these systems is to maximize understanding and cooperation from the surgical team. At the present time we estimate that despite our well-developed autotransfusion protocols approximately 30% of the surgical blood loss is discarded from the operative field (sponges, wall suction). This remains a challenge in the realization of the full potential available from intraoperative cell salvaging.

Haemodilution procedure

We employ HAT (without SAT) when blood loss >400 ml is anticipated. Eight to ten minutes after induction of anaesthesia, 500 ml lactated Ringer's solution are infused into adult patients (Figure 1), after which 600 ml of the patient's blood is withdrawn as rapidly as possible into citrate-phosphate-dextrose (CPD) preservation bags, each holding 200 ml. Next, 600 ml of 6% dextran-70 solution is immediately infused into the patient. Thereafter, if blood loss of >600 ml is anticipated, blood collection and infusion of dextran-70 solution is repeated in the same fashion. If the patient's circulatory condition becomes unstable during the withdrawal of blood, collection is ceased and dextran-70 solution of the same amount as the blood withdrawn is infused. Dextran-70 may be infused simultaneously with blood withdrawal if there is concern for hypovolaemia.

Twelve hundred millilitres of blood should be sufficient in most patients for the treatment of operative blood loss of 1,800–2,000 ml according to our transfusion protocol (Figure 2). Intraoperative red cell salvaging (SAT) using the Haemonetics Cell Saver system is employed when it is anticipated that operative blood loss will exceed 2,000 ml. Haemorrhage of 3,000–4,000 ml