Preoperative assessment of transfusion requirement in surgery Personalized approach

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Blood donation and transfusion practice have been dramatically effected by recent changes in the medical and public perception of risks and benefits of blood transfusion. Allogeneic transfusion had been traditionally considered as an effective therapeutic intervention, but the fear of contracting blood-borne infectious diseases led to the attitude to regard allogeneic blood transfusion as an out-come to be avoided. Although the current blood supply is safer than ever owing to improved donor screening and testing (1,2), allogeneic blood transfusion still involves the risks of causing immunological modifications (3-7) and it is always likely that disease transmission will occur (8-11).

Moreover the introduction of stricter criteria for blood donor selection decreases the availability of donor blood for transfusion. The subsequent reduction in the number of donors and the limited shelf-life of blood have prompted the adoption of strategies to save this precious, limited and perishable resource and to limit the exposure to the risks of allogeneic blood such as a strict observance of the Maximum Surgical Blood Order Schedule (MSBOS) for the requests (12) and a reassessment of the indication for blood transfusion (13). In addition, the use of donor blood in surgery can be substantially reduced by the introduction of autologous blood (AB) transfusion programs. In many Countries, an increase of the use of AB has been documented (14). Transfusion of AB, when possible, is the preferred form of blood replacement for elective surgery. Techniques used to obtain AB include pre-operative AB donation (15,16), acute normovolemic hemodilution (ANH) (17,18), intra-operative (IOS) and post-operative salvage (POS) (19,20).

All these techniques are an attractive way to obtain AB as their feasibility, safety and efficacy in reducing the use of allogeneic blood has been demonstrated in many large clinical studies. Moreover, recently rHuEPO has been approved for use in surgery as it has been demonstrated that it is effective in increasing a patient's red blood cells (RBCs) production in a short period before the operation (so that the amount of autologous blood that can be collected is increased prior to surgery), in correcting anemia preoperatively (so that also patients with low baseline hematocrit can participate in PABD programs) and, consequently, in reducing blood transfusion requirement (21,22).

In the last few years, however, much has changed. The improvement in the safety of allogeneic blood together with the current pressure on cost-containment have provoked a debate on the utilization of alternatives to allogeneic blood. Consequently, to define the precise role of the alternatives techniques in modern transfusion practice, it is necessary to optimize their efficay and restrict their utilization to the patients that really need them.

Primarily responsible for the higher cost of autologous blood and its variations according to procedure results mainly from the units that are collected in excess of the real need. Thus the use of the alternative techniques before low-transfusion risk elective surgery is inappropriate and should be avoided since it is costly, time consuming and can also involve unnecessary health risks to the patients during the donation procedure.

The first step is to identify procedures associated with low transfusion requirements. A reasonable and practical approach one can adopt would be to base decisions about the need for PABD on the maximum surgical blood order schedule (MSBOS) (12) for the procedure in the hospital at which surgery is to be performed. When patients are candidate to an operation prior to which a type and screen procedure is usually performed, these might be discouraged from predeposit autologous blood. Autologous blood collection should be limited to surgical procedures in which the need for blood transfusion has already been clearly established. However, also in procedures where PABD is appropriate, collection in excess of transfusion, although considered inevitable to provide sufficient blood to meet the need of most patients should be kept to a minimum. A widely utilized strategy to define the number of autologous blood units to collect for each surgical procedures is the schedule of optimal preoperative collection of autologous blood (SOPCAB), suggested by Axelrod et al (23), that takes into account the number of blood units (autologous and allogeneic) transfused to each patient throughout the entire hospital stay for each surgical procedure. The number of units to be collected is determined by the physical capability of the patients, but ideally is equal to the number of units of autologous blood that would guarantee that at least 80-90% of the patients would avoid completely the exposure to allogeneic blood. In our Institute the use of these strategies has allowed to contain the overall wastage of autologous blood below 15%, with a range from 6% to 15% according to the different surgical procedures .

Although valuable to obtain an appropriate management of blood inventory, MSBOS and SOPCAB give no indication on the appropriateness of transfusion indication and on the transfusion need of a specific patient.

Algorithm to define the patient's transfusion requirement

In order to optimize the utilization of all the alternatives to allogeneic blood transfusion we defined a new and more personalized approach of utilization of all the methods to obtain autologous blood in order to offer to each single patient what is really proven to be effective in reaching the main goal of an autotransfusion program, i.e. avoidance of the use of allogeneic blood (24). This new approach is aimed to personalize the patient's transfusion requirement taking into account the two parameters from which it depends, i.e. the perioperative blood loss and the volume of blood that the specificpatient can tolerate to lose before blood transfusion support is indicated.

The perioperative blood loss can be calculated through a constantly updated analysis of the real blood loss occurred in each patient undergoing a specific surgical operation performed by a specific surgical team. This can be obtained performing a retrospective analysis of the patients operated during the last 6-12 months prospectively. The surgical RBCs loss occurring in each patient is given by the circulating RBCs volume reduction from presurgery to a properly determined postoperative time, plus the volume of RBCs transfused during this period. In our setting we decided to consider as postoperative reference the patient's RBCs mass 5 days after surgery as at that time the patient is normovolemic, postoperative bleeding has stopped and blood transfusions is a rare event.

The patient's circulating RBCs volume can be calculated through appropriate formulas that take into account the patient height, weight and hematocrit. The volume of allogeneic RBCs transfused can be easily defined as each units contains around 200 ml of RBCs; the volume of RBCs present in autologous blood units can be easily calculated knowing the volume of blood collected and donor/patient hematocrit value at the time of collection. Similarly, for perioperative salvaged blood the volume of RBCs transfused can be calculated taking into account the volume of washed RBCs transfused and the average hematocrit of salvaged blood after the washing cycle.

Once determined the total RBCs loss of about 40-50 patients the value to assign the predicted surgical RBCs loss for each procedure, subdivided for each surgical team can be the mean, median or the appropriately selected percentile value of the distribution. In our setting we decided to consider as expected blood loss the value corresponding to the 80th centile of the distribution.

The formulas to calculate perisurgical RBCs loss and an example of their application are reported in table 1.

Table 1.
Mathematical formulas to define the perioperative RBCs loss and example of their application

Perioperative RBC loss (L of RBCs)	=	Circulating RBC volume (C-RBCs-V) reduction (from presurgery to postoperative day 5) plus the RBC volume transfused;

= C-RBCs-V $_{presurgery}$ - C-RBCs-V $_{day\ 5\ postop.}$ + volume of RBC transfused,

where:

C-RBC-V (in L of RBC) = Predicted Blood Volume (PBV) x Hct;

PBV = female = 0.3561 x height (m)^3 + 0.0338 x weight (kg) + 0.1833

male = 0.3669 x height (m)^3 + 0.03219 x weight (kg) +0.6041

Consequently :

Predicted RBC loss = PBV (Hctpresurgery - Hctday 5 postop) + liters of RBC transfused

Example

Male, 72Kg, height 1.72m, preoperative Hct = 0.36; Hct value 5 days after surgery = 0.29; transfused with 2 autologous blood units

(volume: 400mL; hematocrit 0.40 and 0.38, respectively)

PBV = [0.3669 x (1.72)^3] + [0.03219 x (72)] +0.6041 = 4.789

Surgical blood loss = 4.789 x (0.36 - 0.29) + (400 x 0.4 + 400 x 0.38)

= 4.789 x 0.07 + (0.160 + 0.152) = 0.335 + 0.312 = 0.647 L di RBC

The volume of blood that the patient can tolerate to lose depends upon the baseline circulating RBCs mass (that in turn depend on baseline Hct and the body mass) and the circulating RBCs mass that gives a value of Hct compatible with the clinical and cardiocirculatory condition of the patients. Patient who are in young age and good general condition can safely tolerate low Hct/Hb value (21-24% of Hct) while those who are elderly or suffer from cardiovascular or respiratory diseases affecting oxygen delivery to the tissues have to be maintained to higher Hct/Hb values (27-30% of Hct). Once determined the patient's baseline hematocrit and the minimal acceptable Hct value for the patient the volume of tolerated RBCs loss can be determined according to the formula reported in table 2

Table 2.
Mathematical formulas to define the volume of tolerated RBCs loss and an example of their application

Tolerated Blood Loss = Volume of RBCs loss to reach an accepted minimal Hct value
Tolerated Blood Loss (L of RBC) = (PBV x $Hct_{baseline}$) - (PBV x $Hct_{min.\ accepted}$)
being :
PBV = Predicted Blood Volume
$Hct_{minimal\ acceptable}$ = minimal Hct value compatible with the clinical condition of the patient.
Example
Female, 41 years old, good general conditions, weight 61Kg, height 1,70m;
preoperative Hct = 0,42;minimal aceptable Hct = 0,27
PBV = [0.3561*(1.7)^3] + [0.03308*61] +0.1833 = 3.951 L
Tolerated RBCs Loss = 3.951 x (0.42 - 0.27)
= 3.951 x 0.15
= 0.592 L di RBC

The difference between the predicted blood loss and the tolerated blood loss is the transfusion requirement of the patient expressed in mL of pure RBCs (Table 3).

Table 3.
Mathematical formulas to define the expected transfusion need and an example of their application.

Transfusion needs = Total estimated RBC loss - tolerated RBC loss
consequently
= Predicted blood loss - (PBV x $Hct_{baseline}$) - (PBV x $Hct_{min.\ accepted}$)
Example
Female, candidate for THR, 60Kg, Height 1.6m, weight 60kg, Baseline Hct: 0.36, minimal acceptable Hct: 0.27, candidate for total hip replacement with a predicted RBC loss of 800mL of RBC.
PBV = [0.3561x(1.6)^3] + [0.0338 x 60] + 0.1833 = 3.627
Tolerated RBCs loss = (3627 x 0.36) - (3627 x 0.27) = 1306- 980 = 326 mL of RBC
Transfusion needs = 800 - 326 = 474 mL RBCs (=2.6 allogeneic blood units)

When a negative figure is obtained it means that the patient can tolerate to lose a larger volume of blood than it is expected to be induced by the procedure the patient is undergoing. In this case PABD is not indicated and after appropriate information the patient is discouraged from predeposit its own blood. In such cases "Type and screen" procedure will be adopted in order to protect the patient from unexpected high surgical blood loss, perioperative blood salvage with the "stand-by procedure"

is carried out. This procedure consists in mounting the aspiration set and the reservoir at the beginning of the operations and proceed to the washing cycle only when the volume of the blood, collected into the reservoir is considered clinically useful by the anesthesiologist.

When a positive figure is obtained, the figure represents the transfusion need expressed in mL of RBCs. In this case the safest and possibly the most cost-effective transfusion strategy has to be defined to obtain the predicted volume of RBCs necessary to cover the transfusion requirement of the patient. Consequently, beside the use of allogeneic blood, the adoption of the different alternative strategies to reduce allogeneic transfusion requirement in surgical patients have to be taken into account. The currently available alternative strategies can be subdivided into 2 groups according to the mechanism by which they affect transfusion requirement, i.e. by reducing the intraoperative and postoperative RBCs loss or by increasing the volume of RBCs that the patient can tolerate to lose before requiring transfusion support (tab. 4)

Tab 4 Strategies to reduce allogeneic transfusion needs in surgical patients

REDUCTION OF PERIOPERATIVE RBCS LOSS
Correction of coagulation impairment
Less invasive surgical procedures
Optimal anesthesiology techniques
Accurate hemostasis
Use of procoagulant drugs
Use of topical glues
Loss of RBCs-poor blood (ANHD)
Intra and post-operative blood salvage
INCREASE OF TOLERATED BLOOD LOSS
Correct indication of blood transfusion
Lower intra and post-operative transfusion trigger
Expansion of circulating RBCs mass
Preoperative correction of anemia
Preoperative blood donation
rHuEPO stimulation of erythropoiesis
Use of blood substitutes

The choice of the transfusion strategy to be adopted should depend on the type of surgery; the time to surgery, the applicability and efficacy of each specific alternative strategy; the general clinical status of the patient (hematological, cardiopulmonary) and consideration on cost/effectiveness. To help make the choice of the best strategy to be used to fulfill the transfusion need it is necessary to know advantages and limits of each alternative strategy, particularly the net gain, expressed in mL of RBCs, that each strategy can provide in terms of reduction of perioperative RBCs loss or increase of the tolerated RBCs loss. This topic will be discussed in the following paper addressing the characteristics of the different alternative strategies will be

We retrospectively applied the algorithm to 577 patients each of whom predonated 2 or 3 units of autologous blood prior to total hip replacement surgery and subdivided the patients according to the calculated transfusion requirement (tab. 5). It can be observed that in patients with calculated transfusion need higher than 500 mL of RBC (representing less than 5% of total evaluated patients), in spite of the utilization of all the currently available autotransfusion techniques only 68% of the patients avoided the use of allogeneic blood while this figure was more than 95% in the group of patients with calculated transfusion need lower than 200 mL of RBC. In this group of patient with low calculated transfusion requirement an overcollection of autologous blood has been documented as demonstrated by the wastage of about 20% of the autologous units collected.

Tab. 5 Transfusion results in 577 patients operated for total hip replacement subdivided according to the expected transfusion requirement calculated with the algorithm (24)

Transfusion requirement	*< 0*	*0-100*	*100-200*	*200-300*	*300-400*	*400-500*	*>500*
NO of Pts (% of total)	50 (8,7%)	48 (8,3%)	67 (11,6%)	90 (15,6%)	139 (24,1%)	156 (27%)	27 (4,7)
% male	98	93	77	39	6,5	1,3	0
Units predeposited (unit / Pt)	103 (2,0)	109 (2,2)	155 (2,3)	230 (2,5)	355 (2,5)	372 (2,4)	64 (2,4)
Units not transfused	20 (19,4)	21 (19,2%)	29 (18%)	33 (12%)	28 (8%)	19 (5%)	0 (0%)
Pts transfused only auto	98%	98%	95%	85%	82%	80%	68%
Pts with discarded units	16 (32%)	16 (33%)	22 (32%)	26 (28%)	25 (18%)	17 (11%)	0 (0%)
Pts transf. with all AB units with postop Hct<27 %	7 (14%)	9 (18%)	10 (15%)	22 (24%)	51 (37%)	74 (47%)	18 (66%)

If we had applied the algorithm for the choice of the most appropriate blood conservation strategies we would have been avoided unnecessary collection of AB in patients with low transfusion requirement thus saving resources that could have been utilized for a rHuEPO treatment in patients at higher risk to require allogeneic blood transfusion because of low baseline Hct values.

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