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Audit of autotransfusion in spine surgery

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Summary. *A prospective evaluation has been undertaken of 382 patients undergoing reconstructive spine surgery during a thirty-six month period. Acute normovolaemic haemodilution and haemapheresis for blood component sequestration was used in 80 patients in the operating theatre. An average of two units each of freshly collected autologous red cells and fresh plasma together with a therapeutic dose of a plateletpheresis product were prepared for each patient prior to surgical incision. The same supplies and equipment were subsequently used for conventional blood salvage and autotransfusion. The other 302 patients received salvaged blood only. Of the total blood transfused, autologous red cells comprised 87% of sequestration and 49% of autotransfusion-only patients. Each group received the same total perioperative red blood cell support. The cost for one red cell equivalent by intraoperative autologous transfusion was competitive with that of providing one unit of cross-matched allogeneic red cells. As compared with salvage alone, sequestration combined with salvage was even more cost effective and decreased reliance on allogenic products and preoperative autologous blood donations. The rate of transfusing autologous blood products was markedly increased.*

Résumé. *Cette étude prospective rapporte 382 patients qui ont subi une chirurgie réconstructive de la colonne durant une période de 36 mois. Quatre-vingt (80) patients ont subi une hémodilution normovolèmique et une sequestration de produits sanguins sous anesthesie générale dans la salle d'opération. Une moyenne de deux unités de globules rouges autologues, de plasma frais et une unité de plaquettephérése thérapeutique ont été préparées avant l'intervention chirugicale. L'équipement utilisé pour la sequestration des produits sanguins a été ensuite utilisé pour une auto-transfusion conventionelle. Les autres 302 patients ont reçu seulement une autotransfusion. De toutes les unités transfusees le sang autologue etait de 87% dans le groupe sequestré et 49% dans le groupe seulement autotransfusé. Chaque groupe a reçu le même total de globules rouges comme support de base pendant l'operation. Le coût de récuperation des globules rouges était comparable au coût d'une unite de globules rouges allogéniques. Le coût de la sequestration et de l'autotransfusion comparé à celui de l'autotransfusion seule a demontré une diminution du coût des produits sanguins allogéniques et de celui de l'obtention préopératoire de sang autologue. Les produits sanguins autologues s'avérent done aussi rentables.*

Introduction

The potential for transmitting viral infection has changed attitudes to the management of blood transfusion [1]. Intraoperative autologous transfusion (autotransfusion) decreases the use of allogeneic red blood cells in spine surgery [2–4]; the red cells must be transfused only to the patient from whom the blood was collected [5]. Red cell washing devices employed for autotransfusion in the operating room may also be used for instrument assisted blood component separation (sequestration) [6]. Immediately prior to surgery, in the operating theatre, up to 30% of the estimated total blood volume can be collected safely and sequestered by haemapheresis from a patient with a normal red cell mass [7–9], using acute isovolaemic haemodi-

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lution. The blood components are separated into autologous red cells, plasma and plateletpheresis without delaying the start of the operation [10]. An intraoperative haematocrit of 24% is well tolerated, without adverse effects [8, 9]. Our study was designed to determine the impact, safety and cost effectiveness of performing sequestration followed by autotransfusion, as compared with performing autotransfusion alone. The transfusion rates of autologous and additional allogeneic blood products were evaluated.

Patients and methods

The protocol was approved by the authors' Hospital Institutional Review Board. Patients between the ages of 15 and 80 years undergoing reconstructive spine surgery were recruited for the study and prior informed consent was obtained. Inclusion criteria for sequestration were a projected surgical blood loss of 800 ml or more, a preoperative haematocrit of at least 35% and a platelet count greater than 150,000 per ul. Patients with evidence of cardiovascular or cerebrovascular disease, pre-existing coagulopathy, malignancy or infection of the spine were excluded. Those intending to donate autologous blood were also excluded because the red cell mass may have been decreased artificially. After induction of general anaesthesia, a radial artery catheter was inserted in order to monitor blood pressure directly. An 8 French Swan Ganz introducer was placed in the internal jugular vein. Electrocardiographical parameters, the direct arterial blood pressure, the central venous pressure, temperature, oxygen saturation and end tidal carbon dioxide tension were monitored. Prior to the surgical incision, blood was withdrawn from the Swan Ganz introducer for sequestration. An equilavent volume was replaced using colloid and crystalloid expanders to maintain normovolaemia. The patients were divided into two groups, namely those having sequestration following by autotransfusion or autotransfusion alone. During surgery all blood products were returned only to the respective patients from whom they had been prepared, pre-transfusion testing being waived.

Blood component sequestration (sequestration)

The ELMD 500 autotransfusion device (Medtronic Electromedics Inc., Parker, CO) was used for sequestration in order to separate the blood components. The same equipment and supplies were subsequently used to continue with autotransfusion using heparin as the anticoagulant for collecting blood from the sterile field.

Haematocrit, coagulation tests and transfusion protocol

A transfusion trigger was based on a haematocrit above 24%, especially if there was the prospect of a continuing blood loss. Postoperatively, allogeneic red blood cells were transfused when the haematocrit was less than 24% and/or patients had symptoms of anaemia. The haematocrit was also measured on the first and third day after operation and on the day of discharge from hospital. The prothrombin time, activated partial thromboplastin time and fibrinogen levels were used to determine the presence of coagulopathy. Postoperative bleeding, secondary to deficiencies in coagulation factors, was corrected by transfusion of allogeneic fresh frozen plasma, autologous plasma and cryoprecipitate. The exposure of the patient to allogeneic products was calculated from the sum of all which were transfused. The total amounts transfused, the rates of transfusion for each patient, and the rates of transfusion of autologous and allogeneic blood products were compared. The total volumes of red cells returned were ranked in descending order. The impact of the salvaged blood products on allogeneic blood transfusions and the consequences of when one and two red cell units were used were assessed.

Cost factors

The average cost for the autotransfusion service was calculated by dividing total costs of autotransfusion (labour and supplies) for all patients served in the three years by all autotransfusion procedures performed during the same period. The average cost per re-transfused red cell unit equivalent was calculated by dividing the total autotransfusion cost for all operations by the total number of red cell unit equivalents which were retransfused. The cost of each red cell unit equivalent by autotransfusion was compared with the per unit cost of cross-matched autologous or allogeneic red cells.

Statistics

Data for sequestration and autotransfusion were analysed in separate groups using a non-paired *t*-test and a t-test for independent samples of unequal size, as appropriate. A *P*-value <0.05 was considered to be significant.

Results

The patients in both the sequestration and the autotransfusion-only groups were comparable for age, sex, duration of the operation and preoperative haematocrit (Table 1). A comparison of the pre- and post-operative haematocrit showed no significant differences (Table 2).

Sequestration and autotransfusion data

After rapid priming, sequestration was completed and the blood components separated; the start of the operation was not delayed. The mean volumes and quality control of autologous sequestered blood products are shown in Table 3. The haematocrit of sequestered red cell units was consistently 85%. At least one unit equivalent (330 ml of salvaged autologous saline sus-

Table 1. Details of the patients

	Sequestration	Autotransfusion
Patient numbers	80	302
Age in years Mean±standard deviation	39±15	43±16
Males	46	175
Females	34	127
Duration of surgery (h) Mean±standard deviation	8.0±6.8	7.6±3.5

There were no significant differences (students *t*-test for unpaired data)

pended red cells) was transfused respectively to 78% of the sequestration and 84% of the autotransfusion-only patients.

Autotransfusion quality control

One red cell unit equivalent of salvaged blood was present in 330 mL with a haematocrit of 65%, having been processed from an estimated blood loss of 800 ml. Consistent potency of the recovered red cell products was demonstrated by the blood unit haematocrits. The red cell 2,3 diphosphoglycerate levels (2.1±0.2 µmol/dl) and adenosine triphosphate concentrations (51.8±3.5 µmol/dl) of representative samples were within normal acceptable ranges. The pH measurement of washed red cells was consistently at or slightly above 7.400.

Table 2. Perioperative monitoring of anaemia

	Sequestration	Autotransfusion
Hematocrit % (Mean±standard deviation)		
Preoperative	40.1±5.7	39.0±7.0
Postoperative day 1	30.9±5.0	30.1±4.8
day 3	27.3±7.0	27.4±4.3
Discharge	30.5±5.0	30.3±5.0

There were no significant differences (students *t*-test for unpaired data)

Table 3. Details of autotransfusion

	Blood product volumes	
	Sequestration (80 patients)	Autoransfusion only (302 patients)
Estimated blood loss (ml)	2185±1505	2166±1846
Total volume returned (ml)	874±667	913±824
Total red cell units equivalents	194	835
Per patient red cell unit equivalents	2.4±2.0	2.8±2.5
Haematocrit quality control	59.5±5.6%	61.2±5.7%

Autotransfusion data (mean±standard deviation) in patients groups. There were no significant differences (students *t*-test for independent samples of unequal size)

Evaluation of all red cell transfusions

The amount of blood products transfused are shown in Table 4. Sequestration patients received significantly less peri-operative allogeneic red cell transfusions (0.68 units per patient versus 2.83 unit per patient; $P<0.001$) and significantly more autologous red blood cells than autotransfusion-only patients (4.53 units per patient versus 2.76 units per patient; $P<0.0004$). The same per patient total red cell support was given to the two groups (5.21 red cell per sequestration patient versus 5.59 red cell per autotransfusion patient; $P<0.361$). The autotransfusion only patients received significantly greater total allogeneic blood product exposures (4.51 per patient), than the sequestration group (1.00 per patient; $P<0.0001$). The average duration of surgery in sequestration and autotransfusion patient groups was the same ($P<0.18$, Table 1).

Cost considerations

The calculated costs for both patient groups are shown in Table 5. The average cost of processing one salvaged red cell unit by autotransfusion only was $97.47. When assessing the volume of red cells returned, if less than one red cell unit equivalent was deleted, a cost reduction to $84.38 was demonstrated.

Table 4. Perioperative transfusion of all blood products

	Salvaged autologous	Allogeneic transfusions				Totals		
		Perioperative				Exposures		Transfused
	RBC unit Equivalents	RBC units	PLT units	PLS units	CRY units	Total Donors	Donors/ Patient	RBC units
Sequestration (80 patients)								
Blood products transfused	362	54	0	23	3	80	1.00*	416
Patients transfused	76	26	12	1				76
Units per patient	4.53*	0.68*	–	0.29*	–			5.21
Percent autologous of total								87%*
Autotransfusion only (302 patients)								
Blood products transfused	835	856	61	395	54	1366	4.51*	1691
Patients transfused	294	176	26	69	34			294
Units per patient	2.76*	2.83*	–	1.31*	–			5.59
Percent autologous of total								49%*

* $P<0.05$; RBC=red cells; PLT=platelets; PLS=plasma; CRY=cryoprecipitate

Table 5. Annualized cost considerations in spine surgery

	Sequestration (BCS)	Salvage (IAT only)
Total costs for spine patients (Labor and supplies)*	$21,560	$81,389
Numbers of cases	80	302
Salvaged RBC unit equivalents	362	835
Cost per RBC	$59.55	$97.47
Need for additional allogeneic plasma and platelets	No	Yes

* Cost adjustment for sequestration and standby procedures were averaged amongst all cases

At the authors' institution, the comparative costs are $88.92 per allogeneic and $118.13 per autologous cross-matched red cell unit. Sequestration further reduced the per unit red cell cost to $59.55 and, in addition, fresh autologous plasma and plateletpheresis for re-transfusion were produced, enabling a large reduction in the use of allogeneic blood products.

Another unmeasured outcome was a reduction in the hidden costs associated with allogeneic transfusions resulting in fewer post-transfusion complications. In those patients with insufficient blood loss for processing, the total allogeneic blood product cost per patient was $249.49, or 90% of the cost of sequestration. Furthermore, during sequestration, autologous plasma and platelets were prepared simultaneously at no extra cost, eliminating the need for allogeneic products.

Discussion

Sequestration patients received significantly more autologous blood products and less allogeneic red cells, plasma and platelets compared with autotransfusion-only patients. Acute normovolaemic haemodilution was accomplished without complications. A minimum of one red cell unit equivalent was returned in the majority of patients. Washed red cell volumes of less than one unit equivalent proved to be less cost-effective and were used only if clinically indicated.

During the period of this study, more than half of untransfused pre-operative autologous deposit red cell units collected from non-study patients became outdated, adding unnecessarily to costs [6]. Manual intervention in processing blood is error prone [11] and autotransfusion may reduce the potential for such error. Autologous products may decrease complications in patients with infection or malignancy and accelerate post-operative recovery and healing; in turn, this may affect the length of hospital stay [12–14]. Thus, autotransfusion with sequestration is an attractive option in reconstructive spinal surgery.

All blood products prepared by sequestration or autotransfusion were regularly re-transfused in the operating theatre. There was less need for conventional donor screening and testing of preoperative autologous deposits, leading to further cost savings to the blood bank. In some patients large volumes of salvaged, washed red cells, as well as supplemental allogeneic red cell transfusions, predisposed to the development of haemodilutional coagulopathy. Patients thought to be at risk of major blood loss during surgery will benefit from preoperative preparation of autologous blood products by sequestration [10]. This process has proved to be cost effective and reduces significantly the amount of transfused allogeneic fresh frozen plasma. Red cell salvage by autotransfusion is subsequently continued at no extra cost. Any transfused allogeneic red cell supplements are also recycled by autotransfusion, further diminishing allogeneic donor exposures.

The present study demonstrates that autotransfusion costs are comparable with those of allogeneic transfusions. Additional cost saving is expected from the avoidance of the post-transfusion sequelae of allogeneic blood products. The most commonly occurring complications include allosensitisation, acute and delayed haemolytic and febrile non-haemolytic transfusion reactions, immunogenic insult and, rarely, transmission of blood-born viral diseases. The majority of Jehovah's Witnesses accept autotransfusion, if a continuous extra-corporeal circuit is maintained [16]. Autotransfusion is also an effective transfusion option for patients with cross-match difficulties due to rare alloantibodies against high-incidence antigens.

An efficient autotransfusion service in the operating theatre provides an opportunity for monitoring the appropriateness of transfusion practice and for marketing information concerning corrective measures. The involvement of a physician from the blood bank in the operating theatre may improve the bank's standards for quality assurance. When sequestration is performed while the patient is being prepared for operation in the theatre, the time before operation is not prolonged. We found no significant difference in the duration of the period from admission to and discharge from the operating theatre while performing autotransfusion with or without sequestration.

Sequestered autologous plasma and platelets are preferable to saline-suspended red blood cells recovered during salvage. In patients with loss of a large volume of blood, a deficiency of plasma clotting factors or thrombocytopenia due to dilutional coagulopathy is especially important. Autologous products facilitate correction with minimum risk and at a cost comparable with the use of allogeneic blood products. Another potential saving is through a diminished loss of cross-matched units which were not transfused, and valuable time may be saved in the Blood Bank because fewer allogeneic units need to be processed and cross-matched. The costs of this labour may be offset by autotransfusion, and effort can thus be applied to other revenue generating activities. Allogeneic blood products continue to increase in price as new testing and regulatory controls are implemented; in many surgical procedures autotransfusion may contribute to conserving the allogeneic

blood supply. Improved patient care is provided by greater use of autologous blood products in an efficient manner in order to diminish the morbidity of post-transfusion sequelae and to decrease the costs of transfusion therapy.

References

1. Dodd RY (1992) The risk of transfusion-transmitted infection. N Engl J Med 3 27:419–421
2. Flynn JC, Metzger CR, Csencsitz TA (1982) Intraoperative autotransfusion in spinal surgery. Spine 7:432–435
3. Mann DC, Wilham MR, Brower EM, Nash CL (1989) Descreasing homologous blood transfusion in spinal surgery by use of the cell-saver and predeposited blood. Spine 14:1296–1300
4. Simpson MB, Georgopoulos G, Eilert RE (1993) Intraoperative blood salvage in children and young adults undergoing spinal surgery with predeposited autologous blood: efficacy and cost effectiveness. JPO 13:777–780
5. Menitove JE (1997) Perioperative collection. In: Menitove JE (ed) Standards for blood banks and transfusion services, 17th edn. American Association of Blood Banks, Bethesda, MD
6. Blais RE, Hadjipavlou AG, Shulman G (1996) Efficacy of autotransfusion in spine surgery: comparison of autotransfusion alone or together with hemodilution and apheresis. Spine 21:2795–2800
7. Messmer K, Kreimeier U, Intaglietta M (1986) Present state of intentional hemodilution. Eur Surg Res 18:254–263
8. Masihuko T (1991) Perioperative autotransfusion: haemodilution and red cell salvaging. Cand J Anaesth Symposia Report 38:604–607
9. Hur S, Huizenga BA, Major M (1992) Acute normovolemic hemodilution combined with hypotensive anesthesia and other techniques to avoid homologous transfusion in spinal fusion surgery. Spine 17:867–873
10. Shulman G, McQuitty C, Vertrees RA, Conti VR (1997) Acute normovolernic red cell exchange for cardiopulmonary bypass in sickle cell disease. Ann Thor Surg (in press)
11. Lipton KS (1995) AABB position on testing of autologous units. Association Bulletin #95-4, American Association of Blood Banks, Bethesda, MD
12. Murphy P, Heal JM, Blumberg N (1991) Infection or suspected infection after hip replacement surgery with autologous or homologous blood transfusions. Transfusion 31:212–217
13. Blumberg N, Heal JM (1994) Effects of transfusion on immune function. Arch Pathol Lab Med 118:371–379
14. Fernandez MC, Gottlieb M, Menitove JE (1992) Blood transfusion and postoperative infection in orthopedic patients. Transfusion 32:318–322
15. Spence RK, Alexander JB, DelRossi AJ, Cernaianu AD et al. (1992) Transfusion guidelines for cardiovascular surgery: lessons learned from Jehovah's witnesses. J Vasc Surg 16:825–831