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An analysis of a preoperative pediatric autologous blood donation program

Merv Letts, MD; Richard Perng, BSc; Brian Luke, MD; James Jarvis, MD; Louis Lawton, MD; Steve Hoey, MD

Objective: To determine the efficacy of a pediatric autologous blood donation program.

Design: A retrospective study of patient charts and blood-bank records.

Setting: The Children's Hospital of Eastern Ontario, Ottawa, a tertiary care, pediatric centre.

Patients: One hundred and seventy-three children who received blood transfusions for a total of 182 procedures between June 1987 and June 1997.

Interventions: Autologous and homologous blood transfusion required for major surgical intervention, primarily spinal fusion.

Main outcome measures: Surgeons' accuracy in predicting the number of autologous blood units required for a given procedure, compliance rate (children's ability to donate the requested volume of blood), utilization rate of autologous units and rate of allogeneic transfusion.

Results: The surgeons' accuracy in predicting the number of autologous units required for a given procedure was 53.8%. The compliance rate of children to donate the requested amount of blood was 80.3%. In children below the standard age and weight criteria for blood donation the compliance rate was 75.5%. The utilization rate of autologous units obtained was 84.4% and the incidence of allogeneic transfusion was 26.6%.

Conclusions: There was a high rate of compliance and utilization of predonated autologous blood in the children in the study. Preoperative blood donation programs are safe and effective in children, even in those below the standard age and weight criteria of 10 years and 40 kg.

Objectif : Déterminer l'efficacité d'un programme de dons de sang autologue en pédiatrie.

Conception : Étude rétrospective de dossiers de patients et de banques de sang.

Contexte : Hôpital pour enfants de l'est de l'Ontario, à Ottawa, centre de soins tertiaires en pédiatrie.

Patients : Cent soixante-treize enfants qui ont reçu des transfusions pour un total de 182 interventions, entre juin 1987 et juin 1997.

Interventions : Transfusion de sang autologue et homologue nécessaire pour une intervention chirurgicale majeure, principalement une fusion des vertèbres.

Principales mesures de résultats : Exactitude avec laquelle les chirurgiens ont pu prédire le nombre d'unités de sang autologue nécessaires pour une intervention donnée, taux de conformité (capacité des enfants de donner le volume de sang demandé), taux d'utilisation d'unités de sang homologue et taux de transfusion de sang allogène.

Résultats : L'exactitude avec laquelle les chirurgiens ont réussi à prédire le nombre d'unités de sang autologue nécessaire pour une intervention donnée s'est établie à 53,8 %. Le taux auquel les enfants ont pu donner le volume de sang demandé a atteint 80,3 %. Chez les enfants qui n'avaient pas l'âge et le poids normaux pour donner du sang, le taux de conformité s'est établi à 75,5 %. Le taux d'utilisation des unités de sang autologue obtenues a été de 84,4 % et l'incidence des transfusions de sang allogène a atteint 26,6 %.

Conclusions : L'étude a révélé un taux élevé de conformité et d'utilisation du sang autologue donné au préalable chez les enfants. Les programmes de dons de sang avant une intervention sont sûrs et efficaces chez les enfants, même chez ceux qui n'ont pas l'âge et le poids normalisés, soit 10 ans et 40 kg.

From the Division of Orthopedics, University of Ottawa, Ottawa, Ont.

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Correspondence to: *Dr. Mervyn Letts, Department of Surgery, Children's Hospital of Eastern Ontario, 401 Smyth Rd., Ottawa ON K1H 8L1*

Orthopedic procedures are often extensive and may be associated with significant blood loss necessitating transfusion. Since the emergence of the human immunodeficiency virus (HIV), the trend has been away from allogeneic transfusions in favour of autologous transfusions. The use of allogeneic blood also carries a small but significant risk of viral infections and of immune-mediated reactions. Infection rates for HIV (1:913 000), hepatitis B (1:63 000 and hepatitis C (1:103 000) are significant in themselves and must be considered in the context of the additional and growing risk of non-A, non-B, non-C hepatitis and other rarer forms of viral infection, including HTLV-1.[1–3] Although screening tests have improved immensely, they are still not 100% accurate or effective.[4] These risks are of particular economic and emotional significance in children, especially when one considers the long-term costs of caring for an infected individual from childhood until death, which may be decades later. Other risks of allogeneic blood transfusions include alloimmune hemolysis, allergic reaction, immunization to foreign antigens, graft-versus-host disease, transfusion-induced immunosuppression and exposure to new or unknown infectious or noxious agents.[5]

Autologous blood transfusion (ABT) eliminates these risks. Furthermore, predeposit autologous transfusion eliminates the reliance on banked allogenic blood and reduces public apprehension of transfusions associated with surgery. The transfusion of autologous blood has an additional, albeit less tangible, advantage because it allows patients to participate directly and positively in the management of their health.

ABT may be defined as the "general term used to describe a procedure by which previously donated blood is re-transfused into the same donor or patient."[3] ABT may involve any of the following: preoperative donation of blood, perioperative normovolemic hemodilution and intraoperative blood salvage. Cowell and Swickard[2] in 1974, were the first to report on ABTs in children, and others have since expanded the base of knowledge available to surgeons.[5–13]

ABTs require an organized program to allow for blood collection and storage. Blood loss must be anticipated on a case-by-case basis, and surgery schedules must be planned so as to permit autologous blood donation but avoid wasting blood already collected. Furthermore, ABTs do not prevent septicemia from bacterially contaminated units, clerical or laboratory errors and nonhemolytic transfusion reactions caused by plasma factors generated during storage.[3] The cost per unit of predonated autologous blood tends to be significantly higher than that for allogeneic blood.[12,13]

A pediatric orthopedic autologous blood preoperative donation program has been in existence at the Children's Hospital of Eastern Ontario (CHEO) since 1987.

This study had 4 objectives as follows: to evaluate the results of the preoperative blood donation program at CHEO; to determine the program's success in avoiding allogeneic transfusions; to examine the ability of surgeons to predict the number of units that would be required for the procedures performed; and to analyse the ability of the child to predonate the requested amount (compliance rate).

Patients and methods

Between June 1987 and June 1997, 173 children (119 girls, 54 boys) donated blood before they underwent a total of 182 procedures at CHEO (Table I). Initially, to be considered eligible for ABT program, children had to be 10 years of age, weigh a minimum of 45 kg and have a minimum predonation hemoglobin of 110 g/L. These conditions were subsequently modified as the program proceeded, so that children weighing under 45 kg and under 10 years were eligible provided they maintained a minimum hemoglobin of 110 g/L and were able to withstand the weekly phlebotomy schedule.

Parents and children were prepared through education. Informed consent was obtained. The number of autologous units each child was to donate was set by the attending surgeon. Owing to the 35-day rule governing the viability of donated blood, surgeons could only request a maximum of 4 units of autologous blood and a weekly phlebotomy schedule was then established for each patient.

The volume of blood donated varied with the weight of the child. Children who weighed more than 45 kg donated 1 unit (400 mL) weekly, and for children weighing less than 40 kg the weekly donation volume was adjusted according to the Canadian Red Cross Society's (Canadian Blood Services) pediatric scale for blood donation. Elemental iron supplementation was recommended but was not mandatory, since it has been demonstrated that elemental iron supplementation in autologous blood donation has no discernibly significant effect on the erythopoietic response in the donors with normal hematologic values.[1]

Each patient's age, weight, diagnosis, procedure, surgical time, number of autologous and allogeneic units transfused, perioperative blood loss, complications and ability to donate the number of requested units were documented. A noncompliant patient was defined as one who was unable to provide the total number of units requested by the surgeon.

The criterion for transfusion was the loss of 15% of the child's total blood volume during surgery; replacement was then unit replaced for unit lost.

FINDINGS

The mean age for the 119 girls was 13.7 years (range from 8 to 18 years) and for the 54 boys was 14.9 years (range from 9 to 19 years). Across both sexes, the mean body weight was 53.2 kg (range from 23.2 to 120 kg). The mean weight for girls was 50.7 kg and for boys was 58.7 kg; 53 children weighed less than 45 kg, below the initially established minimum weight.

One hundred and thirty-six children had various forms of scoliosis (106 idiopathic, 24 neuromuscular, 6 congenital), 15 had spondylolisthesis, 4 had DDH and the remaining 18 had other orthopedic diagnoses. The 182 orthopedic procedures performed are listed in Table I. Nine patients underwent 2-stage procedures (e.g., anterior fusion followed by posterior fusion).

Surgeons requested a total of 599 units, of which patients were able to donate 577 (96.3%) (Table II). Of the 173 children, 139 were able to donate the units requested of them, for a compliance rate of (80.3%) (Table III). Of these compliant children, 40 weighed less than 40 kg, 75.5% of the 53 patients in this subgroup. Each patient donated an average of 3.2 units of autologous blood.

A noncompliant patient was defined as one who was unable to provide the total number of units requested by the surgeon. Thirty-four (19.6%) children were classified as non-compliant. The majority of these (30 children) were in the category of children unable to donate 4 units requested (24.8% noncompliance in this category). By comparison, only 12.1% of patients were non-compliant in the 3-unit category. Patients requested to donate 1 or 2 units were 100% compliant (Table IV).

In all, 487 autologous units were transfused, with each child receiving an average of 2.7 units. Total (intraoperative and postoperative) usage of predonated autologous units was 84.4.%. Forty-six (26.6%) children required transfusion of allogeneic blood for a total of 118 units, averaging 2.6 units of allogeneic blood per patient whose transfusion needs exceeded the autologously donated units. Total units transfused was thus 605, with a wastage factor for autologous units of 15.6%. Diagnoses of the 46 patients requiring allogeneic blood included 15 with neuromuscular scoliosis, 25 with idiopathic scoliosis and 6 with other diagnoses. Thirty-two of the 139 compliant patients (23.0%) required transfusion of allogeneic units.

Blood loss during surgery, up to 15% of the child's blood volume, was initially replaced by crystalloid solutions . Blood loss greater than 15% was then replaced with autologous blood on a unit for unit loss basis.

The transfusion needs of 17 patients were underestimated, resulting in the need for additional transfusion of allogeneic units, whereas the transfusion needs of 65 patients were overestimated (Table V). The blood requirements of 93 (53.8%) patients were accurately predicted; that is, for compliant patients there was complete use of their donated blood with no reliance on additional allogenic units, and for noncompliant patients the

Table I

Orthopedic Procedures Performed in 173 Children Who Predonated Blood

Procedure	No.
Posterior fusion	
With instrumentation	121
Without instrumentation	13
Osteotomy	
Pelvic	13
Femoral	3
Posterior cervical fusion	2
Thoracoplasty	2
Anterior spinal fusion	13
Other	14
Total	182

Table II

Transfusion Profile

Disposition of blood	Units, no. (%)
Units requested	599 (100)
Units obtained	577 (96.3)
Autologous units transfused	487 (84.4)
Autologous units not transfused	90 (15.6)
Homologous units transfused	118 (20.4)
Total units transfused	605 (101)

Table III

Compliance Rates

Units requested, no.	Surgeons' requests, no.	Compliant children, no. (%)	Compliant children requiring homologous blood, no. (%)
4	121	91 (75.2)	16 (17.6)
3	33	29 (87.9)	11 (37.9)
2	16	16 (100)	4 (25.0)
1	3	3 (100)	1 (33.3)
Total	173	139 (80.3)	32 (23.0)

Table IV

Noncompliance Rates

Units requested, no.	Surgeons' requests, no.	Noncompliant children, no. (%)	Noncompliant children requiring homologous blood, no. (%)
4	121	30 (24.8)	12 (40.0)
3	33	4 (12.1)	2 (50.0)
2	16	0	0
1	3	0	0
Total	173	34 (19.7)	14 (41.2)

sum of the number of actually donated autologous units and the number of allogeneic units given was equal to or greater than the initial request.

DISCUSSION

Our data support the lowering of eligibility criteria for weight and age of donation in children. Historically, restrictions on the age of the patient have been linked to the age at which a child is considered competent to understand the procedure and therefore cooperate and adhere to the phlebotomy schedule despite pain and side effects. Similarly, weight is linked to total blood volume, and the safety involved in withdrawing an excessive blood volume must be considered.

Although the CHEO program initially adhered to the 10-year, 45-kg criteria, we found that younger and lighter children tolerated procedures quite well. In expanding the age and minimum weight for program eligibility, 2 factors were of paramount importance: active patient and parental counselling and education, and use of the Canadian Blood Services' sliding scale in determining the unit size in children under 45 kg. A similar scale in use by the Association of American Blood Banks, based on a minimum weight of 50 kg, has yielded analogous results.[14] Additionally, the use of phlebotomy needles of a size appropriate to a pediatric population and proper collection sets and anticoagulant additives are used to minimize patient discomfort and wastage due to coagulation.

Although the study was successful in dealing with children under 10 years of age, it is with children weighing less than 45 kg that our program has been most successful. Of the 53 patients weighing less than 45 kg, 40 (75.5%) were compliant, a rate that is completely in keeping with the overall compliance rate of 80.3%. An 8-year-old girl was able to donate the 2 units of blood requested by the surgeon, and another child weighing only 23.2 kg was able to donate 4 proportional units of blood (i.e., approximately 852 mL of blood).

Our finding that children under 10 years of age and weighing less than 45 kg can tolerate a weekly phlebotomy schedule is in keeping with results reported by others.[8,9,11] The study of MacEwan and colleagues[8] included autologous blood transfusions in 118 patients weighing less than 45.5 kg who underwent spinal surgery. Similarly, Moran and colleagues[9] reported on ABT in surgery with 35 patients weighing less than 45 kg, and Silvergleid[11] reported on 26 children also weighing less than 45 kg. Such successes, however, depend on strict adherence to a well-developed patient and parent education and guidance program and on adjusting donation volume to body weight. As noted by Thompson and Luban,[14] in the context of dosage, body weight is the more important of the eligibility criteria, as it varies widely even for children of the same age and sex.

Despite the lower age and weight restrictions, the CHEO program has maintained the 110 g/L hemoglobin level as the minimum for autologous blood donation. This criterion were enforced to the point that some patients were forced to become non-compliant.

The overall noncompliance rate was determined to be 19.7%. Noncompliant children were overwhelmingly (88.2%, 30 of 34) in the group in which 4 units were requested, the remainder falling into the 3-unit category. Non-compliance was owing either to low hemoglobin or hematocrit levels or to adverse patient reactions such as restlessness, poor vein accessibility, effect of blood donation on cir-

Table V

Accuracy of Estimation of Autologous Blood Required for Operation

Units required, no.	Surgeons' requests, no.	Units entirely used, no.	Underestimated, no.	Overestimated, no.
4	121	78	0	43
3	33	9	12	12
2	16	6	4	6
1	3	0	1	2
%	100	53.7	9.8	36.4

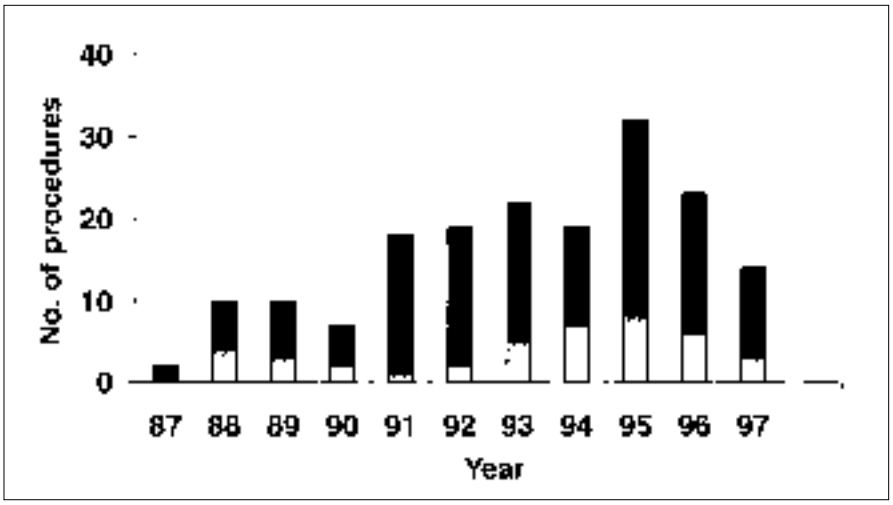

FIG. 1. The number of allogeneic transfusions by year, for the years 1987 to 1997.

culation and adverse incidents related to donation, such as nausea, vomiting and vasovagal symptoms. Family or patient refusal to continue donation was rarely a cause of non-compliance.

In our program, the allogeneic transfusion rate was 26.6% (Fig. 1). By comparison, in pediatric populations, MacEwan and colleagues[8] reported a 37% rate of allogeneic transfusions, Moran and colleagues[9] reported a rate of 11.2%, Colwell and Swickard[2] reported 39% and Silvergleid[11] reported 16%. The low rate of 5.7% reported by Tasaki and colleagues[13] was obtained in a nonorthopedic study population. Whereas we believe we can reduce our homologous transfusion rate with improvements in cell saver technologies, there will always be major surgical procedures in which blood loss will be more extensive than can be collected in the 1 month preoperatively. Tretiak and colleagues[15] analysed the cost of allogeneic versus ABTs in Canada and found that the mean cost of transfusing 1 unit of allogeneic blood was Can$210.00, and each unit of autologous blood was Can$328.00. This difference in price was determined to result from the cost of collection both in hospital and by the Canadian Blood Services and wastage. Wastage is a significant factor because autologous blood can only be transfused to the donor. Increased cost-effectiveness of autologous transfusions can therefore be achieved by minimizing wastage (i.e., maximizing the predictive accuracy of the number of units required) and by improving patient selection.[6] With 90 unused units and by holding constant over the 10-year period Tretiak and colleagues' estimate of Can$328.00 per autologous unit, the CHEO program could have realized a cost savings of nearly Can$30 000 by virtue of improved prognostic abilities.

In discussing the relative costs of allogeneic versus autologous blood, however, we must also bear in mind the arguments advanced by Elawad and associates[16] regarding the long-term economic drain of caring for individuals contracting diseases as a result of virally contaminated allogenic blood. Although it has been argued that autologous donation and subsequent transfusion results in no net gain in red cells and hence brings into question the real efficacy of such a program; there is no question that autologous donations decrease the number of allogeneic units required and eliminates their use in many children.

The CHEO program appears to illustrate the need for a more detailed statistical analysis of units used per procedure, involving children of given weights. This would allow the formulation of standard guidelines for the number of autologous units to be donated for any given procedure and patient profile.

This retrospective study clearly demonstrates the suitability of autologous preoperative donation programs in children who undergo orthopedic surgery. Of particular note is the finding that children who weigh less than 45 kg and are younger than 10 years are viable candidates for the program.

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