ORIGINAL ARTICLE

Effects of patient blood management in pediatric heart surgery

Efectos del tratamiento sanguíneo del paciente en cirugía cardíaca pediátrica

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Abstract

Objective: *Multidisciplinary patient blood management practices reduce costs of blood products and transfusion-related complications in hospitals. Hospital costs are high in pediatric cardiac surgery patients because high hematocrit levels are usually needed; the need for blood products is high due to complex and long surgical procedures; the length of stay in the intensive care unit (ICU) is long, and the use of treatment modalities such as dialysis and ECMO is common in this patient population.* **Methods:** *In this retrospective study, we investigated the effects of the use of the multidisciplinary patient blood management protocols on the use of blood products and associated costs by comparing the outcomes of the protocol implemented in the year 2019 to the blood product use and costs of the previous year. In our clinic, 414 patients were operated on in 2019; 230 of them were males and 184 of them were females.* **Results:** *Transfusions carried out in adherence to such protocols have reduced mortality rates along with a decline in hospital costs.* **Conclusions:** *We, too, achieved a 10% reduction in blood product costs per patient after the implementation of the multidisciplinary patient blood management protocol.*

Keywords: *Pediatric blood management. Open heart surgery. Congenital heart disease. Blood costs. Hospital costs.*

Resumen

Objetivo: *Las prácticas multidisciplinarias de manejo de la sangre del paciente reducen los costos de los productos sanguíneos y las complicaciones relacionadas con las transfusiones en los hospitales. Los costos hospitalarios son altos en pacientes pediátricos de cirugía cardíaca porque generalmente se necesitan niveles altos de hematocrito; la necesidad de hemoderivados es alta debido a los procedimientos quirúrgicos largos y complejos; la estancia en la unidad de cuidados intensivos (UCI) es larga y el uso de modalidades de tratamiento como la diálisis y la ECMO es común en esta población de pacientes.* **Métodos:** *En este estudio retrospectivo; Investigamos los efectos del uso de los protocolos multidisciplinarios de manejo sanguíneo del paciente sobre el uso de hemoderivados y los costos asociados comparando los resultados del protocolo implementado en el año 2019 con el uso de hemoderivados y los costos del año anterior. En nuestra clínica se operaron 414 pacientes en 2019; 230 de ellos eran varones y 184 mujeres.* **Resultados:** *Las transfusiones realizadas en cumplimiento de dichos protocolos han reducido las tasas de mortalidad junto con una disminución de los costos hospitalarios.* **Conclusiones:** *Nosotros también logramos una reducción del 10% en los costos de los productos sanguíneos por paciente después de la implementación del protocolo multidisciplinario de manejo de sangre del paciente.*

Palabras clave: *Manejo de sangre pediátrica. Cirugía a corazón abierto. Cardiopatía congénita. Costos de sangre. Costos hospitalarios.*

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Introduction

Blood transfusion is a life-saving treatment in many types of emergency and elective surgery. Transfusion of blood and blood products may be inevitable in pediatric patients undergoing open heart surgery because of hemodilution, hemolysis, and insufficient hemostasis[1]. This patient group accounts for a considerable number of patients undergoing cardiac surgery and they have a significant share in the consumption of blood products[2].

Hospital costs are of major concern in ensuring the quality, improvement, and accessibility of health-care services. In our country, every individual is under the auspices of the social security institution until the age of 18. Causes of high hospital expenses in pediatric cardiac surgery patients compared to adults include higher costs of operations and longer follow-up periods in inpatient and intensive care units. Reasons for using blood products in high quantities in pediatric cardiac surgery patients include the requirement for high hematocrit levels, the high need for blood products due to complex and long surgical procedures, long periods of intensive care unit (ICU) stay, and the widespread use of treatment modalities such as dialysis and ECMO in this patient population. All these factors are eventually associated with increased costs[3].

"Patient Blood Management" (PBM) has come to the fore in blood transfusion procedures because of increases in complications and costs. The term was first used in 2007 and the implementation of the process has introduced a new approach to transfusion procedures[4]. PBM is defined as an evidence-based multidisciplinary approach developed to optimize the care for patients needing transfusions and to perform blood transfusions when indicated and appropriate based on the evaluation of available options[5].

PBM should include the treatment process of the patient as a whole. Therefore, ensuring the effectivity of PBM can be achieved by the active participation of the surgery and anesthesiology departments and of the administrators of the surgical suite and ICU, by establishing appropriate communication across all participating units, by receiving support from hospitals and even from country health system administrators, by adequate funding, and by implementing the computer technology adequately. PBM needs multidisciplinary management but there are not many studies about this subject matter in pediatric patients[6,7]. Treatment of iron deficiency in the pre-operative period, reduced bleeding in surgery, coagulopathy correction, cell salvage, short cardiopulmonary bypass (CPB) times, and making transfusion decisions based on predetermined threshold values are the methods reported to be associated with reduced numbers of transfusions in adult patients. It has been suggested that such approaches would be appropriate for pediatric patients planned to undergo cardiac surgery[8].

Several methods can be used in studies about the unit cost of blood products. Such cost assessments involve a spectrum between bottom-up (micro-costing) and top-down (gross costing) approaches. Each component of the parameters used in micro-costing (such as laboratory tests, drugs, or labor hours) is identified separately and unit costs are found for each. A hybrid model to involve both micro-costing and gross costing can be used, too, for cost calculations[9].

In our study, we aimed to present our rates of use and disposal of blood and blood product wastages in pediatric cardiac surgery and to present the effects of our activities for the improvement of blood transfusion processes on the use and costs of the blood and blood product use between the years 2018 and 2019.

Materials and methods

The study included 855 patients who underwent surgery in the pediatric cardiovascular surgery department of Health Sciences University Kartal Koşuyolu Yüksek ihtisas Training and Research Hospital in the period from January1, 2018, to December 31, 2019. Medical files of patients were reviewed retrospectively.

In the pediatric cardiovascular surgery department of our hospital, there are 37 patient beds in total. Of these beds, 12 are in ICU and 25 were in the inpatient unit. When needed, the following blood products are supplied by the Turkish Red Crescent (TRC) at specified prices; including erythrocyte suspensions (ES), pediatric erythrocyte suspensions (PES), fresh frozen plasma (FFP), pooled platelet (PPLT), apheresis platelets (APLT), cryoprecipitate (CRYO), and fresh whole blood (FWB). The major component of the costs of blood and blood product use comprises the payments to TRC. No price increases were introduced by TRC in the years 2018 and 2019 as per the contract issued between TRC and our hospital's management. Table 1

Table 1. The blood product prices defined by TRC

The Turkish red crescent blood products price list for the years 2018 and 2019		
USD ($)*	**2018-2019**	
ES	32.18 $	32.18 $
PES	14.87 $	14.87 $
FFP	10.22 $	10.22 $
PPLT	56.04 $	56.04 $
CRYO	6.15 $	6.15 $
APLT	48.64 $	48.64 $
WB	8.51$	8.51 $

*1 USD = 7.44 TL.
APLT: apheresis platelet suspension; CRYO: cryoprecipitate; ES: erythrocyte suspension; FFP: fresh frozen plasma; PES: pediatric erythrocyte suspension; PPLT: pooled platelet; WB: whole blood.

shows the blood product prices defined by TRC (Table 1).

Activities to implement the PBM protocol to improve transfusion processes were commenced in our clinic in 2018. The protocol has been in effect in our hospital since January 1, 2019. As per the protocol; a "pediatric transfusion team" was built consisting of a pediatric cardiovascular surgeon (PCVS), an anesthesiologist, a physician in charge of the transfusion center, a specialist physician in charge of the intensive care, and hemovigilance nurses. The team held meetings to develop planning and implementation strategies and to implement practices to reduce transfusion and complication rates in accordance with the protocol. Problems in the following procedures including the blood ordering system, the transport and storage of blood products, and the transfusion and disposal procedures were identified and revised. Adhering to relevant guidelines, work flowcharts were developed and implemented according to the characteristics of our hospital. At regular intervals, theoretical and practical training was provided to all personnel involved in the PBM process. During this process, a scheme was developed and implemented to specify the type and the number of blood products that might be transfused to pediatric patients scheduled for cardiac surgery (Table 2).

The number of blood products to be ordered for pediatric patients preoperatively was determined by the RACHS scoring system[10]. Additional needs of patients were identified for patients with low birth weight, for newborns, and for patients with coexisting risk factors. The number of blood product orders by RACHS scores is shown in the table.

Table 2. Pre-operative preparation scheme

	ES	FFP	Whole blood
RACHS 1	1	1	0
RACHS 2-3	2	2	0
RACHS 4-5-6	2	2	1
Other*	As needed	As needed	As needed

*Other: Newborn, low birth rate, sepsis, comorbidities, etc.
RACHS: Risk adjustment for congenital heart surgery.

Patients were evaluated according to pre-operative, intraoperative, and post-operative transfusion needs. Patients with iron deficiencies and blood diathesis were diagnosed in the pre-operative period and treated according to the underlying etiology. To achieve intraoperative hematological optimization; reductions in crystalloid use, minimization of operative times, and normothermia maintenance were achieved through the use of cell salvage and similar devices and appropriate anesthesiological procedures. Adult red blood cell suspensions were continued to be used in patients when it was predicted that they might need transfusions. PES was used in ICU in patients with appropriate body weight. In the post-operative period, patient management was performed by administering prophylaxis for potential GIS bleeding, maintaining normothermia, taking precautions for infection control, and preventing secondary bleeding and treating associated causes. Different transfusion schemes were applied to cyanotic and acyanotic patients. Multidisciplinary evaluations were performed to standardize indication decisions and for the conduct of procedures. Target hematocrit values were not defined but the PBM team determined target hematocrit values according to the clinical condition of the patient. Feedback was collected about all implemented practices; deficiencies were identified, and revisions concerning the identified deficiencies were made.

Descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, and maximum) were used in the statistical analysis. The study was approved by the local ethics committee. This study was carried out in accordance with the ethical principles of the Declaration of Helsinki (Ethics committee approval's issue date and number).

Results

In our clinic, 414 patients were operated on in 2019. Of these patients, 230 were male and 184 were female. The mortality rate was 7.4% (n = 31) in 2019. The mean length of stay in ICU was 5.6 days (1-74 days); the mean age of the patients was 5.91 years (2 days-17 years), and the mean length of stay in the inpatient unit was 4.7 (1-35) days. Extracorporeal membrane oxygenation (ECMO) was used 16 times. Stroke developed in 2 (0.48%) patients.

In the year 2018, which is the previous year before the implementation of the protocol, 441 patients were operated on in our clinic. Of these patients, 222 were male and 219 were female. The mortality rate was 8.8% (n = 39) in our clinic in 2018. The mean length of ICU stay is 6.7 (minimum 1-maximum 156) days. The mean age of the patients was 5.73 years (3 days-17 years). The mean length of inpatient unit stay was 5.1 (minimum 1-maximum 27) days. The number of ECMO use was 18 and the number of patients developing stroke was 3 (0.68%) in 2018.

Our study was conducted in the same center and the data of two consecutive years were compared to each other. Of the patients operated on in the years 2018 and 2019, the mean RACHS scores were 3.11 and 3.07, respectively.

The numbers of blood product use in cardiovascular surgery patients in our clinic in 2018 and 2019 are presented in figure 1. The change in the number of blood product use between the years 2018 and 2019 is presented in table 3. While the rates of ES, WB, PPLT, and CRYO use decreased, the rates of FFP and apheresis increased. The use of PES started in 2019.

Total costs of blood product use were 86,708.21 USD and 72,723.61 USD in 2018 and 2019, respectively. Costs are presented in table 4. The average cost of blood products per patient decreased from $ 196.61 in 2018 to $ 175.66 in 2019 resulting in a decline of approximately 10.65%.

The examination of blood product disposal rates revealed that the rates of disposal decreased for all types of blood products, the highest reduction occurred in the disposal of FFB, and the observed reductions reflected on costs favorably (Table 5).

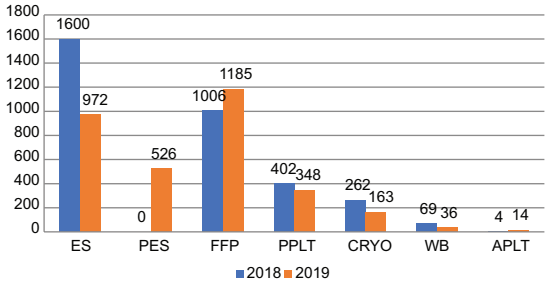


Figure 1. *Numbers of used blood products in the years 2018 and 2019. APLT: apheresis platelet suspension; CRYO: cryoprecipitate; ES: erythrocyte suspension; FFP: fresh frozen plasma; PES: pediatric erythrocyte suspension; PPLT: pooled platelet; WB: whole blood.*

Table 3. Total use, use per patient, and the change in use by years

	2018	2019	The mean number of uses per patient in 2018	The mean number of uses per patient in 2019	Percentage change (%)
ES	1600	972	3.62	2.34	–35.3%
PES	0	526	0	1.27	*
FFP	1006	1185	2.28	2.86	+25.4%
PPLT	402	348	0.91	0.84	–7.8%
CRYO	262	163	0.59	0.39	–33.8%
WB	69	36	0.15	0.086	–44.5%
APLT	4	14	0.009	0.033	+272.8%

*Paediatric ES was not in use in 2018.
APLT: apheresis platelet suspension; CRYO: cryoprecipitate; ES: erythrocyte suspension; FFP: fresh frozen plasma; PES: pediatric erythrocyte suspension; PPLT: pooled platelet; WB: whole blood.

Discussion

Like the other transfusion centers in Turkey, our center procures blood products from TRC. To find out the costs of blood and blood product use, we used the prices determined by TRC for each product. In our study, we aimed to show the effects of the implementation of the multidisciplinary PBM protocol on hospital blood costs, the rates of transfusion and transfusion-related complications, and mortality in children with congenital heart disease. Compared to the year 2018; in 2019, our PBM practices resulted in reductions in the use of ES, PPLT, CRYO, and WB by 35%, 7.8%, 33%, and 44%, and resulted in increases in the use of FFP and APLT by 25% and 272%, respectively. The cost of blood product per patient was reduced by 10.65%. The importance of PBM has gradually increased in recent years and started to be implemented in many hospitals. The implementation of this process in our hospital reduced blood product use and costs in our hospital.

Table 4. Total costs and mean costs of blood product use per patient

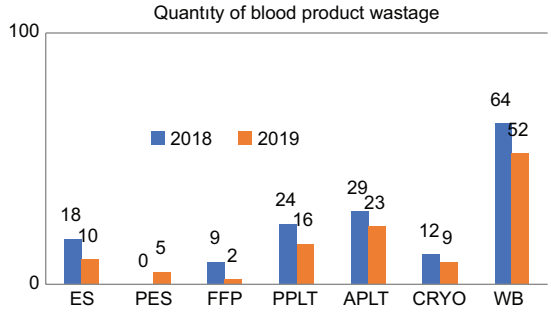
USD	2018 cost	2019 cost
ES	51.494,62	31.282,98
PES	0	7.825,66
FFP	10.291,21	12.122,35
PPLT	22.528,75	19.502,5
CRYO	1.611,44	1.002,53
WB	587,61	306,58
APLT	194,56	680,99
Total cost of blood product use (USD)	**86.708,21**	**72.723,61**
Number of patients	441	414
Mean per patient costs of blood product use	196,61	175,66

Mean saving per patient 10.65%.
1 USD = 7.44 TL.
APLT: apheresis platelet suspension; CRYO: cryoprecipitate; ES: erythrocyte suspension; FFP: fresh frozen plasma; PES: pediatric erythrocyte suspension; PPLT: pooled platelet; WB: whole blood.

Table 5. Quantities of disposal for the years 2018 and 2019

Disposal	2018	2019	Rate of reduction
ES	18	10	0.44
PES	0	5	
FFP	9	2	0.77
PPLT	24	16	0.33
APLT	29	23	0.20
CRYO	12	9	0.25
WB	64	52	0.18

APLT: apheresis platelet suspension; CRYO: cryoprecipitate; ES: erythrocyte suspension; FFP: fresh frozen plasma; PES: pediatric erythrocyte suspension; PPLT: pooled platelet; WB: whole blood.



Despite international guidelines and literature information about PBM in pediatric cardiac surgery, there are differences in clinical practice. While the guidelines and literature information provide opinions, PBM in pediatric cardiac surgery is and should be tailored to the patient and cardiac pathology[11]. In our hospital, we have built a multidisciplinary team and developed the PBM protocol. Thus, we have addressed and carried out PBM in a patient-oriented manner. Concomitantly, we tried to keep the transfusion figures at minimum levels.

In their study on adult cardiac surgery patients, Nuthall et al. found out that transfusion rates decreased after the development of a transfusion algorithm[12]. The numbers of blood product use per patient decreased in our clinic, too, after the implementation of the developed PBM protocol.

Durandy et al. have reported that defining threshold values to decide transfusion in congenital heart surgery patients are not realistic and that the need for transfusion is defined on a patient basis specific to the underlying pathology. Furthermore, they reported that a PBM protocol should be carried out through teamwork[13]. The implementation of the multidisciplinary BPM protocol resulted in reductions in the rates and costs of blood product use per patient in our center, too. It has been reported that transfusions should be performed according to the body weight and needs of pediatric cardiac patients[14]. On reaching a consensus in the multidisciplinary BPM team to administer PES to our pediatric patients with low body weight, we reduced our costs and rates of disposal.

As the number of patients needing to undergo cardiac surgery has increased but the number of donors has not increased adequately to meet the needs, it has become more important to avoid blood product wastage. In a study about preventing blood product wastage and reducing the numbers of disposal, Hauk et al. highlighted the importance of PBM protocols, hospital staff training, and preparations carried out on the basis of identified needs[15]. In our clinic, we optimized the pre-operative preparation scheme for the supply of blood products according to the needs and the condition of the patient. Furthermore, together with our multidisciplinary blood management team, we trained all the staffs involved in the process. Thanks to this training, the use and disposal rates of blood products in our clinic have decreased.

In their study on adult patients, Holmes et al. reported that mortality, the length of hospital stay, and infection rates decreased after the implementation of a multidisciplinary protocol[16]. In our pediatric cardiac surgery patients, the mortality rate decreased from 8.8% to 7.4% after switching to the multidisciplinary protocol. Although the decrease has occurred after the implementation of the PBM protocol, it should be

remembered that it might not have served as the only factor standing alone.

Hemodilution under CPB can potentially lower the perfusion pressure, increasing the risk of neurological complications after CPB. If the cerebral blood flow increases to enhance the perfusion pressure, the number of microembolisms reaching the brain increases and the oxygen supply to neurons diminishes[17]. We reduced neurological complication rates and the need for blood products by reducing the perioperative use of crystalloids in our patients.

In a study on adults, Fowler et al. found out that pre-operative anemia was associated with neurological and renal complications, increased need for transfusions, and infections and mortality[18]. We postponed performing elective operations in congenital heart disease patients until the treatment for anemia was completed. Patients were preoperatively evaluated in the PBM team and we ensured that optimal hemogram parameters were achieved as much as possible. Thus, we reduced the numbers of intraoperative use of blood products.

In patients undergoing pediatric cardiac surgery, thrombocytopenia may occur due to CPB, bleeding, coagulopathies, and hemodilution. In their study, Sloan et al. argued that the cause of thrombocytopenia should be investigated by clinicians to avoid unnecessary transfusions[19]. Collaborating with our multidisciplinary team, we adopted our treatment protocols for patients with low platelet counts. Such changes resulted in a reduction in PPLT use by 7.8% per patient. Jobes et al. suggested in their study that the use of WB reduced blood transfusions[20]. Our study demonstrated increased rates of FFP and APLT use despite the decrease in the use of WB in 2019. Although the costs for WB were lower than the costs of APLT affecting the cost calculations unfavorably, the total cost was still low.

In conclusion, PBM is a new approach in blood and blood product transfusions reducing mortality and morbidity rates. PBM use is rapidly expanding in developed countries. Although it is very difficult to change the already established old transfusion habits and to adopt a new approach quickly, good starting points could help the commencement including the implementation of an effective data monitoring program, the use of specialized computer software for PBM, the provision of continuous and interactive training programs, and audit schedules with open comparisons both at the hospital administration and physician practice levels when necessary. To start such activities, an active transfusion committee should be in charge along with hospital administrators, and administrators of health and financial systems for the provision of necessary financial and managerial support.

Costs of allogeneic blood transfusion involve the following components including obtaining appropriate products from donors, testing and preparations, supplying the product to respective clinics and centers, the treatment of transfusion reactions, disposal as medical wastage, and documentation of the procedures. Such processes are associated with a serious economic burden[21]. It is not possible to monitor these processes in hospitals when only a single method is in routine use. Instead, the implementation of an effective monitoring program requires the conduct of a series of studies[22]. Transfusions are associated with increases in the incidences of sepsis, cardiac problems, renal problems, lung damage, prolonged ICU stay, and long periods of stay in the inpatient unit as well as increased mortality and morbidity. Therefore, transfusions are indirectly associated with increased costs[23,24].

Limitations

This is a single-center retrospective study. Costs of labor, serological tests, cross-match studies, and materials used in the in-house supply of blood products, as the other components adding to the total cost, were not included in the study; assuming that their effects on costs remained the same across the years 2018 and 2019. Only the prices paid by the hospital to TRC were included as the major cost component.

Conclusions

In patient blood management, there are no established ranges of limits to indicate a need for blood transfusion in patients undergoing pediatric cardiac surgery. Patient blood management should be tailored for each patient based on consultations with a multidisciplinary team. We are of the opinion that studies about performing timely and suitable blood and blood product transfusions at correct doses to the correct patient with correct indications will pave the way for precise algorithms to be developed. Transfusions to be performed this way will lead to promising outcomes not only for patients but also for hospital costs as well. Indeed, we achieved a 10% reduction in blood product

costs per patient after the implementation of the multidisciplinary patient blood management protocol.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

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