Utilisation of Blood Components in Cardiac Surgery: A Single-Centre Retrospective Analysis with Regard to Diagnosis-Related Procedures

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Keywords

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Summary

Background: More blood components are required in cardiac surgery than in most other medical disciplines. The overall blood demand may increase as a function of the total number of cardiothoracic and vascular surgical interventions and their level of complexity, and also when considering the demographic ageing. Awareness has grown with respect to adverse events, such as transfusion-related immunomodulation by allogeneic blood supply, which can contribute to morbidity and mortality. Therefore, programmes of patient blood management (PBM) have been implemented to avoid unnecessary blood transfusions and to standardise the indication of blood transfusions more strictly with aim to improve patients' overall outcomes. **Methods:** A comprehensive retrospective analysis of the utilisation of blood components in the Department of Cardiac Surgery at the University Hospital of Münster (UKM) was performed over a 4-year period. Based on a medical reporting system of all medical disciplines, which was established as part of a PBM initiative, all transfused patients in cardiac surgery and their blood components were identified in a diagnosis- and medical procedure-related system, which allows the precise allocation of blood

consumption to interventional procedures in cardiac surgery, such as coronary or valve surgery. **Results:** This retrospective single centre study included all in-patients in cardiac surgery at the UKM from 2009 to 2012, corresponding to a total of 1,405–1,644 cases per year. A blood supply was provided for 55.6–61.9% of the cardiac surgery patients, whereas approximately 9% of all in-patients at the UKM required blood transfusions. Most of the blood units were applied during cardiac valve surgery and during coronary surgery. Further surgical activities with considerable use of blood components included thoracic surgery, aortic surgery, heart transplantations and the use of artificial hearts. Under the measures of PBM in 2012 a noticeable decrease in the number of transfused cases was observed compared to the period from 2009 to 2011 before implementation of the PBM initiative (red blood cells $p < 0.002$; fresh frozen plasma $p < 0.0006$; platelets $p < 0.00006$). **Conclusion:** Until now, cardiac surgery comes along with a significant blood supply. By using a case-related data evaluation programme, the consumption of each blood component can be linked to clinical performance groups and, if necessary, to individual patients. Based on the results obtained from this retrospective analysis, prospective studies are underway to begin conducting target / actual performance comparisons to better understand the individual decision-making by the attending physicians with respect to transfusions.

Introduction

In many hospitals that provide comprehensive medical care, the usage of blood components during cardiac surgery is much greater than the average blood product demand in most other medical disciplines [1–6]. Today, blood transfusions have become more and more accepted as a major quality indicator in cardiac surgery [7–9]. In Germany, the number of cardiac operations continues to increase, even in patients older than 80 years [10]. This trend has been partially affirmed in other countries as well [11]. Due to the increased number of surgical interventions and their progressive complexity, particularly in higher-developed countries [1, 4, 12–16], the demand for blood products has increased globally, as noted by a demographic analysis [17]. Additionally, older patients require more blood transfusions [14, 18, 19] as a result of progress in medical sciences and therapeutic options [17]. Additionally, the demographic ageing of the population in higher developed countries may even reduce the number of younger individuals without illness who have preferentially been recruited as voluntary blood donors [4, 12, 14, 15, 20, 21].

Several anticipatory efforts to moderate the consequences of these demographic changes have been made by blood donation establishments and hospital-related programmes of patient blood management (PBM) [6, 22, 23]. For example, the prophylactic treatment of pre-operative anaemia with iron deficiency through the intravenous application of iron was applied to reduce the peri-operative [23–26] and intensive care demand [27] of red blood cell (RBC) transfusions. In the past, autologous RBC transfusions were installed to reduce the use of allogeneic blood and its potential adverse effects [28, 29]. Additionally, the general improvement in surgical techniques and several blood loss-minimising techniques, such as intra-operative blood salvage, have been implemented, particularly in cardiothoracic surgery, in which blood use has traditionally been high [23]. Moreover, liberal or restrictive transfusion regimens have been compared in intensive care units or at-risk cardiovascular patients [30, 31]. In these studies, patients treated with a restrictive transfusion policy, which indicates a RBC supply only for patients with symptoms of anaemia or with haemoglobin levels below 8 g/dl, did not suffer from a higher morbidity and/or mortality than the patients with a liberal transfusion threshold (haemoglobin up to 10 g/dl). Furthermore, the reduction of RBC transfusions in cardiac surgery could also be realised by point-of-care diagnostics to prevent or treat coagulopathy at an early stage. [32].

To avoid unnecessary or inappropriate blood use, several years ago national and international transfusion guidelines have been established in numerous medical disciplines, including cardiac surgery. These guidelines are subjected to a systematic review process by a panel of experts to safeguard state-of-the-art methods in science and technology [33–35]. However, there is an increasing body of evidence suggesting a significant gap between the release of guidelines and their acceptance by professional authorities who are responsible for ensuring their in-house implementation. Therefore, transfusion practices in general and for cardiac surgery continue to vary from hospital to hospital and from physician to physician [9, 32, 35–37].

To further improve blood utilisation at the University Hospital Münster (UKM), the board of management decided to implement a PBM programme in close cooperation with experts in transfusion medicine and anaesthesiology. One of the long-term objectives of this programme was to improve adherence to the (inter-)national guidelines and in-house transfusion algorithms aiming at the avoidance of needless blood transfusions and transfusion-related adverse events and to reduce the transfusion-associated costs. To achieve this goal, a retrospective study was performed linking blood utilisation to diagnosis- or medical procedure-driven groups in order to analyse the blood component consumption within all medical departments of the UKM in detail [6].

Material and Methods

Database

The Institute of Transfusion Medicine and Transplantation Immunology documents each actual transfusion of allogeneic blood components on a per-case basis for all in-patients at the UKM. These data comprise the type of blood component (RBCs, fresh frozen plasma (FFP) and platelets collected by apheresis (PLTs)), the number of issued and transfused bags and the dates of production, issuance and application for all medical departments. Autologous blood donations were excluded from this report due to low donation numbers. The blood components of the in-patients who stayed in the hospital over the turn of the year were numerated for the year of discharge. After the editorial deadline, the consumption data reported in this study may vary by approximately 0.1% due to slight changes in the final allocation of the cases or transfusions to the Department of Cardiac Surgery according to the terminal reconciliation with the health insurances. The privacy and security of the patients' data presented in this article were protected by the precautionary anonymisation of all patient data.

Data Processing

The data processing considered various case-related data (e.g., gender, age, length of stay, diagnoses, medical procedures, diagnosis-related groups, costs for the different types of blood components etc.). These case-related patient data were allocated to the performing medical department within a standardised process developed by the Department of Medical Management [38, 39]. This allocation represents an algorithm that ensures a comprehensible and reliable assignment of cases to enable the hospital management to plan, monitor and control the number of operations during in-patient treatment. The main criteria of the allocation are: the complexity of a surgical procedure and the length of stay in a special medical department, e.g., in the Department of Cardiac Surgery [38, 39]. After allocation to the medical department of main performance, the case-related data undergoes a further classification structure to create a transparent platform of information for the clinician. This system of clinical performance groups (KLG = 'klinische Leistungsgruppe(n)') was developed in the Department of Medical Management [38]. The aim of the KLG system is to support all departments of the UKM, using administrative and economic data on the department level. As a result, the structure of the KLG system is independent of the G-DRG (German diagnosis-related groups) system. This separation is very important to support the different departments by monitoring and controlling their clinical data. The structure of the G-DRG-system changes every year. If the case-related data were reported based on G-DRGs, the case reports of different years could not be compared. To fulfil its purpose, the KLG system for the Department of Cardiac Surgery consists of 15 main clinical performance groups (e.g., heart transplantation, aortic surgery, valve surgery etc.). If necessary, the main groups can be further differentiated into subclasses (valve surgery: conventional or minimally invasive procedures). Within the KLG system, each in-patient case is assigned to only one group of clinical performance. The allocation process follows a given hierarchy that considers complex cases first. Cases of lower complexity or non-surgical treatments are ac-

Table 1. Number of transfused patients and blood in cardiac surgery

Patients	RBC			FFP			PLT		
	T/A	units	U/T	T/A	units	U/T	T/A	units	U/T
2009 (N = 1,533)	849 (55.4%)	5,998	7.1 ± 9.9	384 (25.0%)	4,276	11.1 ± 15.1	319 (20.8%)	914	2.9 ± 3.9
2010 (N = 1,505)	912 (60.6%)	6,965	7.6 ± 10.2	444 (29.5%)	5,331	12.0 ± 14.9	405 (26.9%)	1,147	2.8 ± 3.1
2011 (N = 1,405)	839 (59.7%)	6,691	8.0 ± 10.1	336 (23.9%)	4,175	12.4 ± 16.4	269 (19.1%)	887	3.3 ± 4.0
2012 (N = 1,644)	886 (53.9%) ^a	7,253	8.1 ± 11.7	369 (22.4%) ^a	5,106	13.8 ± 18.5	296 (18.0%) ^a	994	3.4 ± 3.9

T/A = Proportion of transfused patients out of all in-patients; U/T = average amount of units in transfused patients.

^aNoticeable decrease of transfused cases in 2012 compared to 2009–2011: RBC $p < 0.002$; FFP $p < 0.0006$; PLT $p < 0.00006$.

counted for in descending order. The KLG system provides necessary information on the Department of Cardiac Surgery regarding the numbers and the case mix within the main clinical performance groups and allows comparing these data with those of the previous year. In every group, additional specific patient data are displayed (e.g., diagnoses, medical procedures, G-DRG etc.). All steps of the methods described are based on individually developed structures and processes of the UKM.

Data Reporting

The data are updated monthly, allowing for a representation of the number of transfused blood components per time interval for each department of the UKM and for each KLG. Comparisons to the preceding year's figures are issued quarterly and annually. Therefore, a longitudinal analysis of the use of blood components comparing different years of observation is possible. A further differentiation according to individual diagnoses (e.g., surgical or non-surgical treatment; specific medical procedures; age; gender; special features, such as the duration of mechanical ventilation) can be realised without difficulty, as can the analysis of single cases. Thus, a differentiated view of the specific circumstances pertaining to any blood supply in the hospital is possible [38].

Statistical Methods

The comparison of the two time periods (2009–2011 vs. 2012) is carried out using Fisher's exact test for qualitative variables. All tests are two-sided. If a p value is smaller than 5%, we conclude that a statistically noticeable difference can be observed. We do not use the term 'significant' with intent, since this is a retrospective analysis – thus the results of the statistical tests are to be interpreted in an exploratory, and not in a confirmatory sense – and since an adjustment for multiple testing is not applied. Categorical variables are described in absolute and relative frequencies. Continuous variables are described by mean values.

Results

The data used in this retrospective analysis included all in-patient data from 2009 to 2012 who were treated in the Department of Cardiac Surgery at the UKM; this group comprised an average of approximately 3% (2.9–3.3%) of all UKM in-patients. The case mix index of this discipline continuously increased during the observation time (2009: 6.68, 2010: 7.13, 2011: 7.31 and 2012: 7.39). In our institution, approximately one fourth of all RBC (25.7–29.3%) and FFP units (20.0–30.7%) and one eighth (12.0–14.3%) of all PLT units are used for cardiac surgery patients. Understandably, the department generates approximately 20% (17.6–21.2%) of the total costs associated with the allogeneic blood supply, which represents the second highest 'position' of all UKM disciplines (the first position is occupied by the Department of Haematology/Oncology).

Fig. 1. Clustered numbers of transfused blood units in cardiac surgery.

a RBCs, **b** FFP, **c** PLTs.

In addition, we analysed the proportion of patients who received blood transfusions and calculated the mean consumptions of RBC, FFP and PLT units per transfused patient (table 1). We observed a relatively constant demand of blood supply over the study

Table 2. Gender distribution for transfused patients in cardiac surgery

Patients			RBC				FFP				PLT			
year	F, no.	M, no.	T/A		U/T		T/A		U/T		T/A		U/T	
			F	M	F	M	F	M	F	M	F	M	F	M
2009	485	1,048	65.2	50.9	6.4	7.5	26.4	24.4	9.1	12.1	21.0	20.7	2.7	2.9
2010	457	1,048	66.1	58.2	6.9	8.0	28.2	30.1	10.2	12.7	26.7	27.0	2.5	3.0
2011	470	935	63.6	57.8	7.3	8.4	23.4	24.2	10.9	13.1	16.6	20.4	3.4	3.3
2012	543	1,101	59.1	51.3	7.1	8.8	21.9	22.7	12.7	14.4	15.8	19.1	3.5	3.3

F = Female, M = male; T/A = proportion of transfused patients out of all in-patients; U/T = average amount of units in transfused patients.

Table 3. Proportion of transfused patients and blood consumption in a total of eight clinical performance groups of cardiac surgery

	2009		2010		2011		2012	
	T/A	U/T	T/A	U/T	T/A	U/T	T/A	U/T
RBC								
Coronary surgery	66.9	5.2	75.8	5.5	73.0	6.2	70.4	5.5
Valve surgery	75.5	7.1	85.3	8.2	83.9	8.9	70.7	9.0
Thoracic surgery	32.2	7.9	37.4	7.6	31.7	6.5	27.6	6.8
Cardiac devices	89.9	19.0	100.0	26.4	94.4	24.9	100.0	27.5
Heart transplantation	88.9	30.8	100.0	35.6	100.0	35.4	100.0	41.4
Aortic surgery	75.0	11.3	79.1	7.6	91.8	12.0	79.2	14.3
Children < 16 years	80.3	4.8	80.3	3.1	79.3	4.8	63.6	3.5
Others	14.7	7.5	12.7	6.6	20.4	5.1	20.8	6.3
FFP								
Coronary surgery	20.8	8.8	30.5	9.0	19.0	11.1	20.6	10.3
Valve surgery	38.1	9.3	45.0	12.1	32.7	11.4	31.7	13.5
Thoracic surgery	9.5	17.1	10.9	15.6	9.2	10.7	7.1	13.4
Cardiac devices	74.1	27.6	90.9	24.3	83.3	28.9	92.2	19.3
Heart transplantation	77.8	31.5	100.0	30.9	100.0	31.0	100.0	27.7
Aortic surgery	71.4	13.1	55.8	12.3	79.6	16.0	63.9	23.6
Children < 16 years	72.4	6.3	69.0	7.1	68.3	7.3	53.2	5.3
Others	5.3	11.2	3.1	7.2	3.0	8.6	2.8	18.7
PLT								
Coronary surgery	19.4	2.0	33.7	2.0	17.8	2.9	20.7	2.0
Valve surgery	29.4	2.2	43.5	2.5	26.7	3.2	23.0	3.4
Thoracic surgery	7.5	5.3	7.8	4.2	6.8	2.1	5.5	4.4
Cardiac devices	55.6	6.0	81.8	5.8	55.6	7.9	76.2	4.7
Heart transplantation	83.3	5.0	100.0	7.8	100.0	6.9	100.0	7.9
Aortic surgery	64.3	2.4	46.5	3.0	73.5	3.3	54.2	4.8
Children < 16 years	51.3	4.3	29.6	2.3	37.8	2.6	31.2	1.7
Others	4.3	2.8	1.2	4.7	1.7	3.2	1.7	7.8

T/A = Proportion of transfused patients out of all in-patients; U/T = average amount of units in transfused patients.

period of 4 years, resulting in a frequency of >50%, about 25% and about 20% of all cardiac surgery patients receiving RBC, FFP and PLT units, respectively. The overall average number of blood units per transfused patient amounted to approximately 8 RBC, 12 FFP and 3 PLT units (table 1). However, on January 1, 2012 the PBM initiative started at our hospital with the introduction of a periodical reporting system for blood component utilisation combined with interviews of the transfusion commissioned clinicians. Therefore, we observed a noticeable decrease in the number of transfused cases in 2012 compared to the period from 2009 to 2011

without PBM measures (transfusions of RBCs $p < 0.002$; of FFP $p < 0.0006$; and of PLTs $p < 0.00006$).

In figure 1, the spectrum of the total units for each blood component given per transfused case is shown in greater detail. Notably, the data suggest that RBC units are ordered more likely in double packs than FFP or PLT units. Approximately 5 and 25% of the transfused patients received only one and two RBC units during their hospital stay, respectively, whereas almost 20% of the transfused patients in cardiac surgery were treated with more than 10 RBC units. The transfusion pattern of FFP utilisation was different in that

roughly 10% of the transfused patients received 1–3 FFP units, corresponding to approximately 250–750 ml of volume. Similar to RBCs, a significant portion of the cardiac surgery patients (up to one third) were treated with more than 10 FFP units. Most of our patients required no PLT transfusion during cardiac surgery. If appropriate, two thirds of the patients generally receive one or two units.

Approximately 85% of all in-patients at the Department of Cardiac Surgery were 40 to 80 years old. As shown in figure 2, using the example of the RBC supply, there was an indicator that older patients (70–80 years) have a higher likelihood of requiring trans-

Fig. 2. Age distribution of transfused patients in cardiac surgery (exemplary for RBC supply).

fusion or receive greater amounts of blood units in the case of transfusion. During the first year of life, children more frequently require a blood supply. The gender distribution of all in-patients, the frequency of transfused patients and the applied blood units are indicated in table 2. As expected, the majority of the cardiac surgery patients were male (nearly two thirds). The conspicuous feature in regard to overall blood consumption was the higher rate of females receiving RBC transfusions, which we observed continuously during the entire study period. In contrast, the demand for FFP and PLT units was basically identical in both genders. Irrespective of receiving RBC or FFP units, men require more units per case, on average, than women.

All cardiac surgery patients enrolled in this retrospective study were assigned to 16 clinical performance groups. For the 7 most frequent and important clinical performance groups (coronary surgery, cardiac valve surgery, thoracic surgery, aortic surgery, cardiac transplantation, use of cardiac devices and cardiac surgery in children younger than 16 years), the percentage of transfused patients and the average number of blood units per transfused case are given in table 3. Not surprisingly, the highest transfusion rates were indicated in patients with heart transplantations (nearly 100% for RBCs), followed by cases that used cardiac assist devices (approximately 75–100%), independent of the type of blood component. In line with this observation, most of the blood units per patient were required for heart transplantations (about 30 RBC units) and the use of cardiac assist devices (>20 RBC units), followed by aortic, valve and thoracic surgeries (about 10, 8 and 7 RBC units, respectively).

Table 4. Proportion of transfused patients and blood consumption in the clinical subgroups of coronary surgery and valve surgery

	2009		2010		2011		2012	
	T/A	U/T	T/A	U/T	T/A	U/T	T/A	U/T
<i>Coronary surgery</i>								
RBC								
Conventional	68.4	5.3	76.9	5.6	74.2	6.4	72.1	5.6
Minimally invasive	47.7	4.1	50.0	2.8	55.3	3.4	59.3	5.1
FFP								
Conventional	21.1	9.1	31.0	9.1	20.1	11.5	21.0	10.9
Minimally invasive	13.6	5.0	23.8	5.8	5.3	4.5	16.9	6.5
PLT								
Conventional	19.6	2.0	35.0	2.0	18.7	3.0	22.7	2.0
Minimally invasive	15.9	1.6	9.5	1.5	10.5	1.2	6.8	3.0
<i>Valve surgery</i>								
RBC								
Conventional	77.4	7.0	88.1	8.0	85.2	8.6	71.4	8.2
Minimally invasive	60.0	7.0	66.7	6.6	76.9	5.9	66.7	10.7
FFP								
Conventional	36.7	9.6	45.5	11.1	30.8	11.1	29.6	13.3
Minimally invasive	20.0	5.6	28.6	8.3	15.4	10.0	33.3	16.0
PLT								
Conventional	29.0	2.3	44.0	2.5	24.7	2.9	22.6	3.2
Minimally invasive	16.0	1.0	28.6	2.2	15.4	1.5	16.7	2.0
T/A = Proportion of transfused patients out of all in-patients; U/T = average amount of units in transfused patients.								

The blood utilisation in the coronary surgery and valve surgery clinical subgroups are depicted in greater detail in table 4. In minimally invasive coronary surgery, fewer patients require blood transfusions, and these transfusions comprise less blood units compared to conventional treatment. In valve surgery, this effect was less pronounced but was also verifiable for minimally invasive procedures.

Discussion

Several efforts have been made to assess and standardise the utilisation of blood components in cardiac surgery [33, 34]. However, the application of blood components is controversially discussed in this discipline, particularly the usefulness of general transfusion triggers, such as a haemoglobin level less than 7–8 g/dl [40]. Transfusions of RBCs in cardiac surgery might be reduced when transfusion-responsible physicians follow transfusion algorithms more strictly and consider the impact of point-of-care diagnostics. Therefore, both the implementation of specific transfusion guidelines and standard operating procedures for hospital-internal use are highly recommended [32, 41]. However, until now, standardised and restrictive transfusion regimens have not been realised extensively in cardiac surgery, particularly in older patients who commonly suffer from several co-morbidities.

Consequently, the PBM programme in Münster was initiated to investigate compliance with the German guidelines and their defined restrictive indication criteria for transfusions. Based on a computerised recording of all transfusion cases, we periodically report on the utilisation of blood components to the clinical departments for different groups of their medical diagnoses and procedures. We discuss these written reports with the responsible physicians of each department and continuously and collectively pursue the development of the consumption figures of blood products over time. Therefore, each department is empowered to prevent unnecessary transfusions in its medical sub-disciplines if required.

Without a doubt, many interventions in cardiac surgery are not feasible without a blood supply. Understandably, blood transfusions contribute significantly to saving lives. However, according to several cardiosurgical studies using other interventions, a reduction or even an avoidance of allogeneic blood transfusions is discussed to improve the patients' outcome [9, 36, 37]. Thus, blood transfusions in cardiac surgery might be associated with augmented morbidity and mortality, whereas the cause-and-effect relations remain unknown.

Currently, a very low risk for transfusion-associated infections with viruses such as HIV, HBV and HCV has been achieved using very sensitive and specific nucleic acid amplification tests. However, several authors believe that the transfusion of allogeneic RBCs is burdened with adverse effects other than infectious risks, and there are suspicions that these transfusions are associated with an increase of the rates of myocardial infarction, atrial fibrillation, stroke, renal failure and prolonged artificial ventilation as well as with a prolonged hospital stay [42–46]. However, the results ob-

tained from these retrospective analyses are not self-explanatory and do not allow any conclusions concerning the causality between blood supply and increased morbidity or mortality. On the other hand, prospective studies were rarely performed and often lacked the randomisation or sufficient statistical power due to the size of the patient cohorts. In a recently published detailed sub-analysis of the prospective randomised TRACS study [36], Galas et al. [47] compared the outcomes of 502 patients with and without RBC transfusions in the first 72 h after elective coronary artery bypass graft. There were no differences except for a prolonged hospital stay, between the transfused and non-transfused patients. In contrast to our study, the patients in the above mentioned study were supplied with 'fresh' RBCs that had been stored up to 3 days in a simple citrate solution without leukodepletion, which may bear an inherent risk for transfusion-associated adverse events, making comparisons with other studies difficult.

A patient's outcome after cardiac surgery is closely related to the fact if post-operative infectious complications, such as nosocomial pneumonia, mediastinitis and sepsis, (relative risk 3.5; $p < 0.001$) developed or not. As suggested by Leal-Noval et al. [48], this complication rate might be associated with blood transfusions in a dose-dependent manner. In this study, patients who received blood components had a higher risk of death (13.3 vs. 8.9%; $p < 0.001$) and longer stays in intensive care units (6.1 ± 7.2 vs. 3.7 ± 2.8 days; $p < 0.001$) compared to patients who were not transfused [48].

The general shortage of volunteer blood donations, obvious transfusion-related complications (such as ABO-incompatible transfusions), the spectrum of adverse events mentioned above and increasing transfusion-related costs were all driving forces to promote the development of a more evidence-based haemotherapy. This rationale is the basis of all recently initiated programmes regarding PBM in cardiac surgery, such as that of Shander et al. [22] in Australia or that of our institution. To this end, the UKM initiated a retrospective analysis of blood consumption in cardiac surgery considering specific diagnosis- and procedure-related performance groups (KLGs). The transfusion rate and the absolute number of transfused blood components depend on the severity of the patients' disease, the complexity of the surgical intervention (e.g., heart transplantation) and other accompanying circumstances (e.g., secondary diagnoses). Concomitant diseases, such as myocardial infarction, chronic obstructive pulmonary disease, arterial hypertension, diabetes mellitus, obesity, chronic renal failure and acute or chronic coagulopathies, are critical factors with more or less impact on the pre-operative status of anaemia and/or the overall need for a blood supply. Furthermore, the proportion of emergency patients, surgical procedures with high urgency, and intra-operative factors (e.g., the extension of operation, time of cardiopulmonary bypass circulation and time of ischaemia) are additional variables that may influence the patients' outcome and their stress resistance with respect to allogeneic blood transfusion. The co-morbidities and additional confounding factors mentioned above could not be considered in this retrospective analysis. Therefore, the results presented here can hardly be compared to other university hospitals or to the nationwide average and, consequently, are not suitable as a benchmark.

The data obtained in our retrospective analysis are in agreement with previously published results concerning the overall blood consumption of RBC, FFP and PLT units in cardiac surgery [1–6, 13]. The percentage of patients requiring RBC, FFP or PLT units noticeably decreased after the introduction of the PBM measures in January 1, 2012, whereas significantly more blood (RBCs) per patient was provided in 2012 (7,253 RBC units) compared to 2009 (5,998 RBC units), which might reflect the above mentioned complexity factor. More females than males received RBCs during cardiac surgery (two thirds vs. one half), which may be due to the higher incidence of pre-operative anaemia or a smaller haemoglobin margin in females. Fortunately, our data management system allows the validation of further detailed information regarding patient subgroups or individual patients in clinical performance groups, as illustrated in the 'Results' section. This type of resolution makes it possible to correlate blood consumption closely with the level of a specific diagnosis. As expected, the highest transfusion demand was found in heart transplantation and the use of cardiac devices, both with respect to the proportion of transfusion cases and the number of transfused units. However, due to their infrequency, the total con-

sumption of blood units per year is rather negligible, whereas the conventional cardiac valve surgery and coronary surgery are the two major surgical procedures that are responsible for at least 50–60% of the blood supply required. Meanwhile, we were able to demonstrate that upcoming minimally invasive surgical techniques are associated with reduced blood consumption.

Based on our data, it makes sense to continue PBM measures in cardiac surgery because it is one of the major medical disciplines with high transfusion needs. In respect to the demographic changes and the medical progress in this field, a continuous increase in cardiac surgery is expected worldwide. The joint efforts of interdisciplinary teamwork will continue to identify causes of unnecessary blood transfusions, such as deviations from in-house transfusion policies, to intensify the treatment of pre-operative anaemia and to improve bloodless surgical techniques.

Disclosure Statement

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