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Increased long term mortality with plasma transfusion after coronary artery bypass surgery

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Abstract

Purpose:

Patients undergoing cardiac surgery often require transfusions of red blood cells, plasma and platelets. These components differ widely in both indications for use and composition. However, from a statistical point of view there is a significant colinearity between the components. This study explores the relation between the transfusion of different blood components and long-term mortality.

Methods:

A retrospective single-centre study was performed including 5261 coronary artery bypass grafting patients, excluding patients receiving more than eight units of red blood cells, those suffering early death (7 days) and emergency cases. Patients were followed up for a period of up to 7.5 years. A broad spectrum of potential risk factors was analysed using Cox proportional hazards survival regression. Non-significant risk-factors were removed by step-wise elimination, and transfusion of red blood cells, plasma and platelets was forced to remain in the model.

Results:

The transfusion of red blood cells was not associated with decreased long-term mortality (HR=1.007, $p=0.775$), whereas the transfusion of plasma was associated with decreased long-term survival (HR=1.060, $p<0.001$), and the transfusion of platelets was associated with increased long-term survival (HR=0.817, $p=0.011$). The risk associated with transfusion of plasma was mainly contributed to patients receiving large amounts of plasma. All hazard ratios are per unit of blood product transfused.

Conclusions:

No association was found between the transfusion of red blood cells and mortality during the study period. However, transfusion of plasma was associated with increased mortality while transfusion of platelets was associated with decreased mortality during the study period.

Key Words: Cardiac Surgery, Transfusion, Plasma, Red Blood Cells, Mortality

Introduction

The benefits and risks of blood transfusions during and after cardiac surgery is the subject of considerable debate in both academic and clinical setting. Associations between blood transfusion and decreased long-term survival have been reported in several retrospective studies [1-8], while other studies have revealed conflicting results [9]. Furthermore, in a previous study, we found that the risk associated with RBC transfusion was almost completely eliminated by introducing preoperative haemoglobin levels and renal function into the [10].

In most of the publications mentioned above only red blood cell (RBC) transfusion was studied, whereas in reality many patients also receive transfusions of plasma and platelets as well. From a clinical and statistical point of view, there is significant colinearity between these different types of transfusions, but from an immunological standpoint, these different blood components differ in many ways [11]. Few studies have been carried out on the effects of the transfusion of different blood components other than RBCs. Koch et al. reported platelet transfusion to have a beneficial effect [3, 12], while Ranucci et al. reported that platelet transfusion was associated with increased in-hospital mortality, and that plasma transfusion had a negative effect [3, 12].

The aim of the present study was to evaluate the effects of the transfusion of different blood components on long-term mortality. Our goal was to create a more robust model by including additional risk factors and all types of transfusions.

Methods

Study design

The study protocol was approved by the local ethics committee. The patients included in this study had undergone cardiac surgery at the Department of Thoracic Surgery at the University Hospital in Lund, Sweden, from January 1, 2002 to December 31, 2008. Data were collected from four principal sources. Clinical data were retrieved from the in-house clinical database, in which relevant clinical information is collected on perioperative care during the patients' hospital stay. The databases of the hospital's clinical chemistry laboratory and blood bank served as the second and third sources of data. Time of death was obtained from the Swedish tax authority in May 2009, defining the follow-up period of 0.5 to 7.5 years. When data were missing or extreme outliers were identified, patient records were read in a first attempt to complete the data.

Patient inclusion and exclusion

Data were gathered on all patients who had undergone coronary artery bypass grafting (CABG) as their sole cardiac procedure (n=5922). Patients who had undergone emergency surgery, defined as surgery within one hour of the decision to operate, were excluded (n=121), as were those who died during the first seven days following surgery (n=34), and those who had received 8 or more units of RBCs (n=506). Eight units was chosen since together with plasma, this represents more than half the blood volume in most adult patients, and indicates massive bleeding, in which case the transfusion was life-saving. A total of 5261 patients were finally included in the analysis.

Completeness and reliability of the data

Perioperative information are entered into the in-house clinical database by each surgeon (100% completion rate). Information on deaths was obtained from the Swedish tax authority, which lacks data only in exceptional cases such as emigration. The emigration rate for all Swedes in this age category is approximately 0,1% per year[14]. Preoperative creatinine values were missing from the chemistry laboratory data for 104 patients, and were imputed based on levels on the first postoperative day [10]. Preoperative haemoglobin concentrations were not available for 21 patients, and a standard mean value substitution method was employed.

The postoperative renal function of the patients was categorized using the RIFLE criteria (Risk-Injury-Failure-Loss-End Stage) based on the preoperative creatinine level and the maximum creatinine level during the hospital stay [15]. Renal function was also expressed as the estimated glomerular filtration rate (eGFR), and calculated according to the MDRD formula (Modification of Diet in Renal Disease) [16]:

$$\text{eGFR} = 32788 \times \text{Serum creatinine}^{1.154} \times \text{Age}^{-0.203} \times (0.742 \text{ if female})$$

where eGRF is expressed as (mL/min/1.73 m²), serum creatinine in µmol/L and age in years.

Surgery and postoperative care

Surgery was performed in a standardized manner. The use of aprotinin and tranexamic acid was left to the discretion of the individual surgeon. During the patient's stay in the intensive care unit (ICU), extra aprotinin, protamine, tranexamic acid, or desmopressin were administered based on coagulation analyses or clinical assessment. No pre-defined limits for RBC transfusion or reoperation for bleeding were used during the period, and indications for transfusion of blood products were determined by the physician in charge of the ICU or the ward after clinical judgement.

Selection of Outcome variables and Statistical Analysis

The variables used for survival analysis were based on frequently found predictors for decreased survival in recent survival studies focusing on renal function or RBC transfusion in cardiac surgery [1-4, 9, 17-19]. In addition, we included other potential risk factors and preoperative laboratory parameters that could reflect preoperative morbidity of importance for long-term survival. The following variables were entered as dichotomous variables: gender, diabetes, chronic obstructive pulmonary disease (COPD), history of cerebrovascular disease, peripheral vascular disease, left ventricular ejection fraction (LVEF) 30-50%, LVEF<30%, recent myocardial infarction, known pulmonary hypertension (systolic pressure>60 mmHg), acute coronary symptoms, previous CABG, previous percutaneous coronary intervention (PCI), use of cardiopulmonary bypass, intra-aortic balloon pump (IABP) before surgery, IABP after surgery, postoperative sepsis, postoperative stroke, postoperative atrial fibrillation,

perioperative myocardial infarction, and re-operation for bleeding or mediastinitis. Perfusion time, age, time on ventilator in the ICU and BMI were entered as continuous variables. Renal function (expressed as preoperative eGFR), haemoglobin, plasma C-reactive protein, plasma alanine aminotransferase, plasma leukocyte count and platelet count were entered as continuous variables. For the 195 patients who underwent off-pump surgery, the perfusion time used in the analysis was the mean value for the other 5066 patients. Transfusion of blood products was defined as a transfusion during surgery or during the post-operative stay, and was entered as a continuous variable representing units of blood products transfused.

The Cox proportional hazard model was used to determine which factors affected long-term survival, and the Wald test was used to determine the strength of the relation. For missing data, mean substitution was used. A backward stepwise elimination procedure was used starting with the above mentioned variables. Variables with $p < 0.05$ were retained in the model together with transfusion of blood products regardless of their level of significance. Variables with $p > 0.05$ were removed in order of strength as defined by level of significance. After all non-significant variables had been removed, they were entered one at the time to confirm that they were not relevant to the model. To check the linearity of the risk associated with plasma transfusion, plasma was categorized in four different categories and four new variables were created (no plasma transfusion, 1-2, 3-4, 5-6, or more than 6 units of plasma transfused) and entered into the model instead of plasma as continuous variable. The interaction between different types of transfusion was evaluated by creating 8 variables (RBC transfusion yes/no, plasma transfusion yes/no, and platelet transfusion yes/no). These variables were then entered in the final model, and the continuous variables for units of blood products were removed from the model. Student's t-test was used for group comparisons, where numbers were large and the distributions not strongly skewed; otherwise the Wilcoxon–Mann–Whitney test was performed. Unless otherwise stated, the results are presented as the mean \pm 1 standard deviation. The R-project software (version 2.13.0) with the survival package was used to test the proportional hazards assumption for a Cox regression model fit. All other statistical calculations were performed using Statistica, version 8 (StatSoft inc, Tulsa, OK, USA).

Results

Study population

Patients were followed for between 152 and 2706 days (mean 1423 days). During follow-up there were 503 deaths. Among the patients, 2618 (49.8%) received RBC transfusion, 1533 (29.1%) received plasma transfusion and 418 (7.9%) received platelets (Figure 1). Patient characteristics are described in Table 1.

Analysis of patients receiving plasma transfusions

Patients who received plasma showed more preoperative comorbidity (Table 1) and more postoperative complications (Table 2) than patients not receiving plasma. The patients given plasma received on average 4.2 ± 4.0 units of plasma, and 80.7% also received an average of 3.0 ± 2.1 units of RBCs.

Cox analysis

Stepwise elimination of non-significant variables in the Cox proportional hazards ratio analysis left 16 variables in the model: age (per year), COPD, diabetes, history of cerebrovascular disease, peripheral vascular disease, female gender, previous myocardial infarction, LVEF <30%, previous CABG, perfusion time (per min), permanent stroke, preoperative haemoglobin (per g/L), preoperative eGFR (per ml/min/1.73 m²), transfusion of RBC (per unit), transfusion of plasma (per unit) and transfusion of platelets (per unit). Transfusion of the three different blood products was forced to remain in the model. RBC transfusion gave a hazard ratio (HR) of 1.007 (95% CI 0.96-1.06, p=0.775), transfusion of plasma gave a HR of 1.060 (95% CI 1.04-1.09, p<0.001) and transfusion of platelets gave a HR of 0.817 (95% CI 0.70-0.96, p=0.011) for each unit transfused (Table 3).

When plasma was entered in the analysis as a categorical variable, the HR for 1-2 plasma transfusions became 1.18 (95% CI 0.91-1.54, p=0.212), the HR for 3-4 plasma transfusions became 1.28 (95% CI 0.95-1.75, p=0.107), the HR for 5-6 plasma transfusions became 1.142 (95% CI 0.70-1.87, p=0.599), and the HR for 7 or more plasma transfusions became 1.710 (95% CI 1.21-2.42, p=0.003, Figure 2).

The result of the interaction analysis only revealed one significant interaction, and it was the group that received RBC and plasma transfusion, but not platelet transfusion, with a HR of

6.51 (95% CI 1.02-41.7, $p=0.048$). The group that received only RBC transfusion had a HR of 1.15 (95% CI 0.90-1.48, $p=0.266$). None of the other groups were significant (table 4).

Discussion

Two principal findings were made in this study. First, we found an association between plasma transfusion and increased long-term mortality. Secondly, we found no association between RBC transfusion and long-term survival. These findings challenge the current view on transfusion after cardiac surgery.

The finding that there was no significant correlation between RBC transfusion and long-term survival is in contrast to the results of the majority of studies published to date. Previous studies have reported hazards ratio for long-term mortality between 1.03 and 2.4, depending on the study design and whether transfusion was entered as a dichotomous variable or continuous variable [1, 2, 4, 6-8, 10, 20, 21]. In a previous study on the same cohort, we found a hazard ratio of 1.10 when using a model similar to that in other studies, but when we included preoperative eGFR and haemoglobin levels the hazard ratio decreased to 1.05 and was no longer significant [10]. By increasing the number of potential risk factors and including all types of transfusion, the present study revealed a hazard ratio of 1.007 for RBC transfusion with a confidence interval of 0.96-1.06, thereby further diminishing any risk associated with RBC transfusion. From a statistical point of view, it appears that RBC transfusion and plasma transfusion interact strongly. When including plasma transfusion in the model, the risk associated with RBC transfusion was further decreased, since our model revealed that the associated risk from RBC transfusion actually belonged to plasma transfusion. In an editorial, Engoren commented on our previous article and concluded that just showing that transfusion of RBC is not dangerous may not be enough [10, 22]. Instead, we should try to find improved outcome of transfusion in these patients. The findings of this study, takes at least, one step in that direction.

The results of the present study indicate that plasma transfusion in cardiac surgery is associated with decreased long-term survival, and that this risk is found in patients receiving many plasma transfusions. Similar findings that plasma transfusion is associated with worse outcome have been reported in a few studies on patient populations mostly receiving massive transfusions. A study based on the trauma-associated severe haemorrhage (TASH) score [23], which was used to objectively determine which patients would benefit or exhibit increased complications as a result of a high plasma:RBC ratio after severe trauma, demonstrated that the outcome was indeed dependent on the TASH score, where a high plasma:RBC ratio was

associated with adverse outcome. [24]. However, in a recent meta-analysis, plasma transfusion was associated with a reduction in the risk of death and multi-organ failure in patients undergoing massive transfusions. The results were based on studies judged to have “very-low-quality” evidence [13]. Plasma transfusion also significantly reduced the risk of multi-organ failure, but increased the risk of acute lung injury [13]. In patients undergoing cardiac surgery without the need for massive transfusions, plasma transfusion was found to markedly increase short-term mortality [12, 25]. Our finding that plasma transfusion is associated with decreased long-term survival seems to be in agreement with the reports of other authors on short-term outcome. However, no one has yet been able to ascertain whether it is the plasma per se or the need for plasma transfusion that carries the risk. Significant risk were only found in patients receiving 7 or more units of plasma, and in these patients the high rate of plasma transfusion might be explained by a comorbidity and not a bleeding. Therefore, we should be careful in drawing any far-reaching conclusions from this finding.

Platelet transfusion was found to be associated with decreased mortality, although previous studies have reported conflicting results [3, 12, 26]. The clinical indication for platelet transfusion intra- and postoperatively in cardiac surgery is mainly bleeding, and platelets are often administered together with plasma and/or RBC transfusion, which makes the situation more complex. It was recently reported that fresh frozen plasma and platelet transfusion carry a higher risk of short-term mortality than transfusions of packed red blood cells [12]. Morphological, biochemical and functional changes occur in platelets during storage [27]. However, platelet storage time was not found to be associated with adverse short-term outcomes, decreased long-term survival, or infections after cardiac surgery [28]. Our finding, that platelet transfusion may be associated with better outcome, is difficult to explain based on the information available from our studies and those of others, and could be a coincidental finding of little clinical relevance. However, one explanation could be that platelet transfusion is a surrogate marker for reduced or impaired platelet function, which may be pharmacologically induced or naturally low. The assumption that the need for platelet transfusion is related to lower platelet function, and consequently associated with a lower incidence of future thromboembolic events, thereby increasing the chances of longer life, is with the present knowledge theoretical. In addition, we did not have access to information on preoperative antiplatelet therapy, further precluding any potential relation from being revealed.

This study has some limitations. First of all, a larger sample size would have been preferable to more accurately determine the relationship between transfusion and outcome. Secondly, some concern has been expressed about the storage time of RBCs and plasma and the effect on outcome after cardiac surgery. For example, van Straten et al. have shown that a longer plasma storage time is a risk factor for early but not late mortality in CABG patients [29], while Koch found that the age of RBCs affected long-term survival negatively [30]. Unfortunately, we did not have access to the age of the blood products given. Thirdly, we did not distinguish between fresh frozen plasma, fresh plasma or leukocyte-depleted blood products in this study. The use of leukocyte-depleted blood products has been routine for several years in patients undergoing cardiac surgery at our clinic, but we cannot guarantee that some patients were given non leukocyte-depleted transfusions. It could also be argued that by excluding patients receiving 8 or more units of RBCs, we excluded the patients exposed to the largest transfusions, thereby missing relevant information. We therefore included the patients receiving more than 8 units in a post hoc analysis, and while the hazard ratio for RBC transfusion remained virtually the same (1.005, 95% CI 0.98-1.03), the value for plasma decreased from 1.060 (95% CI 1.04-1.09) to 1.028 (95% CI 1.02-1.04). However, we still believe that in this study it is not relevant to analyse the potential risks of transfusion in patients requiring a transfusion to survive. The aim of the present study was to investigate the long-term effects of blood product transfusion in cardiac surgery patients, and we therefore excluded patients who died within 7 days of surgery. In a post-hoc analysis, the patients who died during the first week were included, and it did not change the results regarding transfusion and outcome. Moreover, patients dying during the first week are a heterogeneous group, often representing outliers in several ways, and may jeopardize the proportional hazard assumption. The relevant clinical question is whether a different transfusion regimen could have prevented any of the patients from dying within 7 days, and changed the outcome of the analysis. This is a limitation in retrospective studies such as this. To shed some light on the issue, a separate analysis should be performed on this subgroup. On the other hand, one strength of the study is the completeness of the database, where important variables have a more than 99,5% completion rate.

The results of this study emphasize the fundamental differences between different blood products by showing that long-term outcome differs depending on type of transfusion given. Reliable and accurate data on the long-term risks of transfusions are paramount in making

valid transfusion recommendations, and our findings may serve as a step in that direction, as long as firmer evidence in form of randomized trials are lacking.

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Disclosures

Henrik Bjursten has a vested interest in ErySaveAB. Lars Algotsson lectures for Orion PharmaAB and Abbott Scandinavia AB. The other authors have no conflicts of interest to report.

Legends

Figure 1

Venn diagram of the covariance of transfusion of different blood products in the study population: number and percentage (of entire population of 5261 patients) receiving products.

Figure 2

Unadjusted Kaplan-Meier curves divided into patients receiving different amount of plasma (0 = no plasma transfusion, 1-2, 3-4, 5-6 refers to corresponding units of plasma given, >6 refers to 7 or more units transfused).

Table 1. Perioperative characteristics of the study population.

Variable	n	All	Plasma transfusion		p
			No n=3728	Yes n=1533	
Age (y)	5261	67 (9.7)	66.4 (9.6)	68.4 (9.6)	<0.0001
Female gender	5261	1155 (22%)	798 (21.4%)	357 (23.3%)	0.1340
Body mass index	5256	27.2 (4)	27.3 (4)	26.8 (3.9)	<0.0001
Diabetes	5261	1180 (22.4%)	868 (23.3%)	312 (20.4%)	0.0206
History of cerebrovascular disease	5261	460 (8.7%)	300 (8%)	160 (10.4%)	0.0053
COPD	5261	483 (9.2%)	326 (8.7%)	157 (10.2%)	0.0876
Peripheral vascular disease	5261	741 (14.1%)	497 (13.3%)	244 (15.9%)	0.0143
Neurological dysfunction	5261	88 (1.7%)	63 (1.7%)	25 (1.6%)	0.8793
Previous vascular surgery	5261	113 (2.1%)	52 (1.4%)	61 (4%)	<0.0001
Critical preoperative state	5261	160 (3%)	54 (1.4%)	106 (6.9%)	<0.0001
Pulmonary hypertension	5261	24 (0.5%)	6 (0.2%)	18 (1.2%)	<0.0001
LVEF 30-50%	5261	1435 (27.3%)	933 (25%)	502 (32.7%)	<0.0001
LVEF <30%	5261	309 (5.9%)	150 (4%)	159 (10.4%)	<0.0001
Recent myocardial infarction	5261	2261 (43%)	1478 (39.6%)	783 (51.1%)	<0.0001
Previous CABG	5261	98 (1.9%)	46 (1.2%)	52 (3.4%)	<0.0001
Previous PCI	5261	636 (12.1%)	448 (12%)	188 (12.3%)	0.8033
Euroscore - additive	5261	4.6 (3.1)	4.2 (2.9)	5.6 (3.5)	<0.0001
NYHA	I	5261	1294 (24.6%)	292 (19%)	<0.0001
	II	5261	1764 (33.5%)	459 (29.9%)	0.0004
	III	5261	1620 (30.8%)	526 (34.3%)	0.0004
	IV	5261	582 (11.1%)	255 (16.6%)	<0.0001
CCS	I	5261	203 (3.9%)	43 (2.8%)	0.0109
	II	5261	1786 (33.9%)	429 (28%)	<0.0001
	III	5261	2265 (43.1%)	635 (41.4%)	0.1256
	IV	5261	1003 (19.1%)	424 (27.7%)	<0.0001
Urgency	Elective (>1 week)	5261	3403 (64.7%)	865 (56.4%)	<0.0001
	Prioritized (<1 week)	5261	1509 (28.7%)	483 (31.5%)	0.0037
	Urgent (<24 hours)	5261	349 (6.6%)	185 (12.1%)	<0.0001
	Emergency (<1 hour)	5261	0 (0%)	0 (0%)	<0.0001
Use of CPB	5261	5066 (96.3%)	3589 (96.3%)	1477 (96.3%)	0.8951
Perfusion time (min)	5066	79.5 (24.8)	76.9 (23.1)	85.7 (27.5)	<0.0001
Crossclamping time (min)	5066	47.4 (16.7)	46.5 (16.4)	49.7 (17.2)	<0.0001
IABP before surgery	5261	131 (2.5%)	41 (1.1%)	90 (5.9%)	<0.0001
IABP after surgery	5261	117 (2.2%)	38 (1%)	79 (5.2%)	<0.0001
Preop haemoglobin (g/L)	5241	133.2 (15.5)	133.7 (15.3)	131.9 (15.9)	0.0002
Preop creatinine (μmol/L)	5260	86.5 (36.1)	85.1 (34.7)	90 (39.2)	<0.0001
Preop eGFR (mL/min/1.73 m ²)	5260	84.3 (23.6)	85.4 (22.8)	81.4 (25.2)	<0.0001
Preop platelets (10 ⁹ /L)	4841	238.5 (67.2)	240.6 (66.5)	233.5 (68.9)	0.0008
Preop ALAT (μkat/L)	4855	1.02 (5.9)	1.03 (6)	0.98 (5.4)	0.7603
Preop leukocytes (10 ⁹ /L)	4838	7.7 (4)	7.5 (2.6)	8.1 (6.2)	<0.0001
Preop CRP (mg/L)	4787	9.3 (21.3)	8.1 (18.7)	12.4 (26.3)	<0.0001
30-day mortality	5261	20 (0.4%)	10 (0.3%)	10 (0.7%)	0.0397

Data are presented as the mean (standard deviation) for continuous variables, or number (percent) for dichotomous variables, together with a comparison between patients receiving plasma and patients not receiving plasma. COPD = chronic obstructive pulmonary disease, LVEF = left ventricular ejection fraction, CABG = coronary artery bypass grafting, PCI = percutaneous coronary intervention, NYHA = New York Heart Association, CCS = Canadian Cardiovascular Society. CPB = cardiopulmonary bypass, IABP = intra-aortic balloon pump, eGFR = estimated glomerular filtration rate, ALAT = alanine transaminase, CRP = C-reactive protein

Table 2. Postoperative outcome

Variable	n	Plasma transfusion			p
		All n=5261	No n=3728	Yes n=1533	
Hours in the ICU	5157	22 (19-24)*	22 (18-23)*	23 (20-44)*	<0.0001
Time on ventilator (min)	5161	360 (255-540)*	330 (240-450)*	502 (350-840)*	<0.0001
Postop heart failure	4672	154 (3.3%)	34 (1%)	120 (9.1%)	<0.0001
Postop myocardial infarction	4672	70 (1.5%)	27 (0.8%)	43 (3.3%)	<0.0001
Postop sepsis	4672	38 (0.8%)	11 (0.3%)	27 (2%)	<0.0001
Postop permanent stroke	4672	23 (0.5%)	13 (0%)	10 (1%)	0.104
Postop transient cerebral ischaemia	4672	28 (0.6%)	17 (0.5%)	11 (0.8%)	0.194
Postop atrial fibrillation	4672	1139 (24.4%)	754 (22.5%)	385 (29.2%)	<0.0001
Re-operation for bleeding	5258	123 (2.3%)	0 (0.1)	0.1 (0.3)	<0.0001
Postoperative mediastinitis	5258	56 (1.1%)	33 (1%)	23 (2%)	0.049
Haemoglobin at discharge (g/L)	5190	103 (11.2)	102.8 (11.4)	103.2 (11)	0.247
RIFLE - Risk at discharge	5228	500 (9.6%)	320 (9%)	180 (12%)	<0.0001
RIFLE - Injury at discharge	5228	117 (2.2%)	74 (2%)	43 (3%)	0.07
RIFLE - Failure at discharge	5228	95 (1.8%)	50 (1%)	45 (3%)	<0.0001
Units of RBC transfused	5261	1.6 (1.9)	0.96 (1.4)	2.98 (2.1)	<0.0001
No. receiving RBCs	5261	2618 (49.8%)	1381 (37%)	1237 (80.7%)	<0.0001
Units of plasma transfused	5261	1.2 (2.9)	0 (0)	4.2 (4)	<0.0001
No. receiving plasma	5261	1533 (29.1%)	0 (0%)	1533 (100%)	<0.0001
Units of platelets transfused	5261	0.2 (0.7)	0.1 (0.3)	0.5 (1)	<0.0001
No. receiving platelets	5261	418 (7.9%)	93 (2.5%)	325 (21.2%)	<0.0001

Legend: Postoperative outcome of the study population presented as the mean (standard deviation) for continuous variables or number (percent) for dichotomous variables, together with a comparison between patients receiving red blood cells and those not receiving red blood cells.

* Outcome variables that are strongly skewed are presented as the median and the range between first and third quartiles. RIFLE=Risk-Injury-Failure-Loss-End Stage, RBCs = red blood cells.

Table 3. Cox Proportional hazard model

	HR	95% C.I.	Wald	p
Age (y)	1.051	1.04-1.06	68.5	<0.001
COPD	1.669	1.33-2.10	19.5	<0.001
Diabetes	1.518	1.25-1.84	18.3	<0.001
History of cerebrovascular disease	1.296	1.01-1.67	4.1	0.044
Peripheral vascular disease	1.651	1.34-2.03	22.5	<0.001
Female gender	0.623	0.50-0.78	17.6	<0.001
Previous myocardial infarction	1.315	1.09-1.58	8.4	0.004
LVEF <30%	2.178	1.69-2.81	36.1	<0.001
Previous CABG	1.686	1.06-2.69	4.8	0.029
Perfusion time (min)	1.005	1.00-1.01	6.2	0.013
Permanent stroke	2.810	1.25-6.31	6.3	0.012
Preoperative Haemoglobin (g/L)	0.985	0.98-0.99	21.4	<0.001
Preoperative eGFR (mL/min/1.73 m ²)	0.990	0.99-0.99	20.3	<0.001
RBC transfusion	1.007	0.96-1.06	0.1	0.775
Plasma transfusion	1.060	1.04-1.09	23.1	<0.001
Platelet transfusion	0.817	0.70-0.96	6.4	0.011

Legend: Results of Cox proportional hazard analysis. HR = hazard ratio, COPD = chronic obstructive pulmonary disease, CABG = coronary artery bypass grafting, eGFR = estimated glomerular filtration rate, RBC = red blood cell,

Table 4. Interaction analysis

	n	HR	95% C.I.	Wald	p
RBC yes/PLA yes/TRC yes	304	0.95	0.61-1.47	0.06	0.812
RBC yes/PLA yes/TRC no	933	1.52	1.20-1.95	11.6	<0.001
RBC yes/PLA no/TRC yes	63	1.19	0.48-2.93	0.14	0.705
RBC yes/PLA no/TRC no	1318	1.15	0.89-1.48	1.23	0.266
RBC no/PLA yes/TRC yes	21	1.98	0.49-8.01	0.91	0.339
RBC no/PLA no/TRC yes	30	0.81	0.1-5.80	0.04	0.831
RBC no/PLA yes/TRC no	275	1.22	0.83-1.79	0.32	0.320

Interaction between different types of transfusion (RBC=Red Blood Cells, PLA=Plasma, TRC=Platelets) when the variables were added to the final Cox model. Number of patients in each group is also presented.

Figure 1

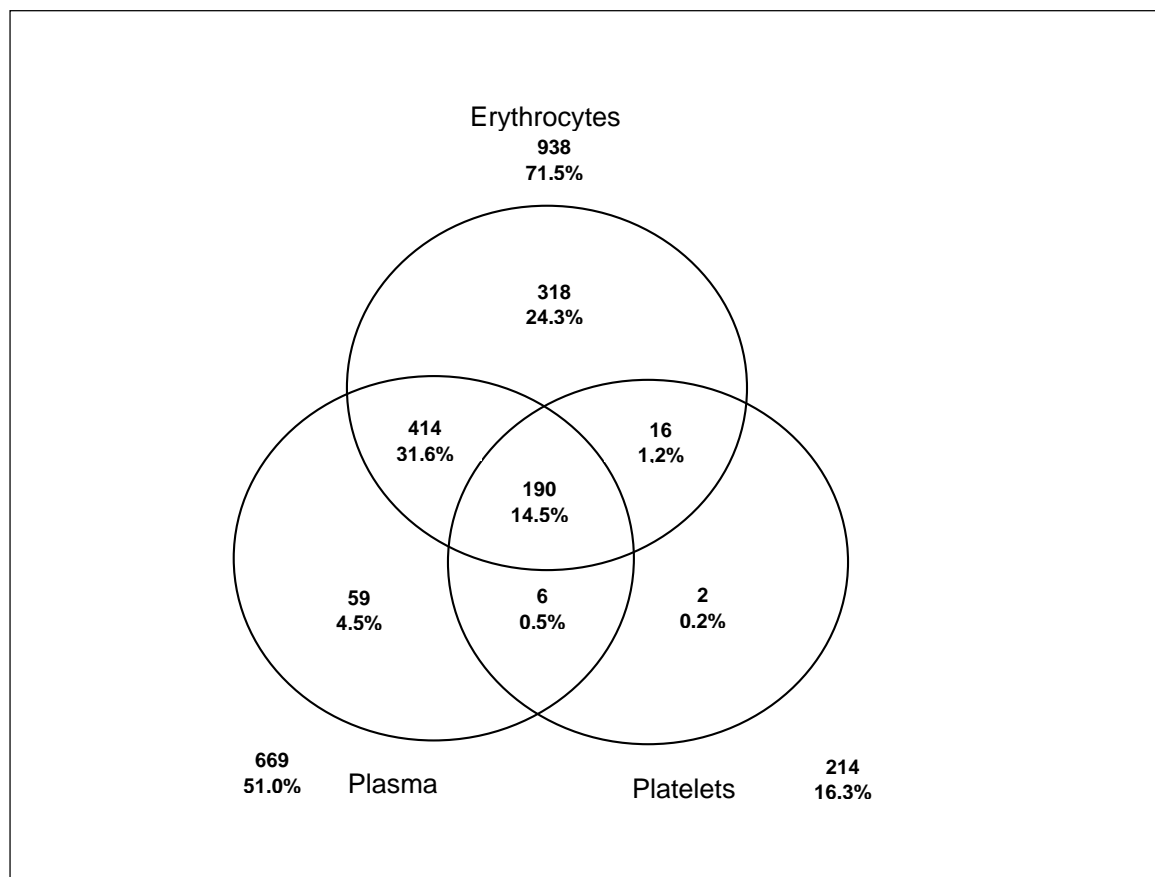
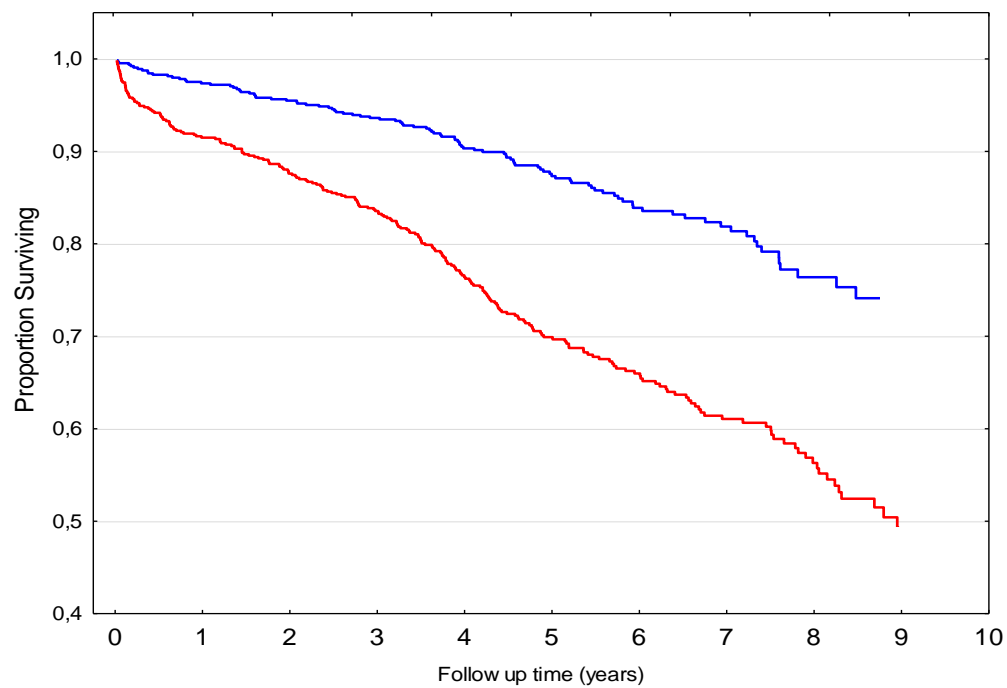


Figure 2



References

1. Engoren MC, Habib RH, Zacharias A, Schwann TA, Riordan CJ, Durham SJ, (2002) Effect of blood transfusion on long-term survival after cardiac operation. *Ann Thorac Surg* 74: 1180-1186
2. Koch CG, Li L, Duncan AI, Mihaljevic T, Cosgrove DM, Loop FD, Starr NJ, Blackstone EH, (2006) Morbidity and mortality risk associated with red blood cell and blood-component transfusion in isolated coronary artery bypass grafting. *Crit Care Med* 34: 1608-1616
3. Koch CG, Li L, Duncan AI, Mihaljevic T, Loop FD, Starr NJ, Blackstone EH, (2006) Transfusion in coronary artery bypass grafting is associated with reduced long-term survival. *Ann Thorac Surg* 81: 1650-1657
4. Kuduvalli M, Oo AY, Newall N, Grayson AD, Jackson M, Desmond MJ, Fabri BM, Rashid A, (2005) Effect of peri-operative red blood cell transfusion on 30-day and 1-year mortality following coronary artery bypass surgery. *Eur J Cardiothorac Surg* 27: 592-598
5. Spiess BD, (2004) Transfusion of blood products affects outcome in cardiac surgery. *Semin Cardiothorac Vasc Anesth* 8: 267-281
6. Murphy GJ, Reeves BC, Rogers CA, Rizvi SI, Culliford L, Angelini GD, (2007) Increased mortality, postoperative morbidity, and cost after red blood cell transfusion in patients having cardiac surgery. *Circulation* 116: 2544-2552
7. Surgenor SD, Kramer RS, Olmstead EM, Ross CS, Sellke FW, Likosky DS, Marrin CA, Helm RE, Jr., Leavitt BJ, Morton JR, Charlesworth DC, Clough RA, Hernandez F, Frumiento C, Benak A, DioData C, O'Connor GT, (2009) The association of perioperative red blood cell transfusions and decreased long-term survival after cardiac surgery. *Anesth Analg* 108: 1741-1746
8. van Straten AH, Soliman Hamad MA, van Zundert AA, Martens EJ, ter Woort JF, de Wolf AM, Scharnhorst V, (2011) Effect of duration of red blood cell storage on early and late mortality after coronary artery bypass grafting. *J Thorac Cardiovasc Surg* 141: 231-237
9. Engoren M, Arslanian-Engoren C, (2009) Long-term survival in the intensive care unit after erythrocyte blood transfusion. *Am J Crit Care* 18: 124-131; quiz 132
10. Dardashti A, Ederoth P, Algotsson L, Bronden B, Luhrs C, Bjursten H, (2011) Blood transfusion after cardiac surgery: is it the patient or the transfusion that carries the risk? *Acta Anaesthesiol Scand* 55: 952-61
11. (2005) Immunology of Leucocytes, Platelets and Plasma Components Mollison's Blood Transfusion in Clinical Medicine. Blackwell Science Ltd, pp. 546-610
12. Ranucci M, Pazzaglia A, Bianchini C, Bozzetti G, Isgro G, (2008) Body size, gender, and transfusions as determinants of outcome after coronary operations. *Ann Thorac Surg* 85: 481-486
13. Murad MH, Stubbs JR, Gandhi MJ, Wang AT, Paul A, Erwin PJ, Montori VM, Roback JD, (2012) The effect of plasma transfusion on morbidity and mortality: a systematic review and meta-analysis. *Transfusion* 50: 1370-1383
14. Statistiska centralbyrån. www.scb.se
15. Venkataraman R, Kellum JA, (2007) Defining acute renal failure: the RIFLE criteria. *J Intensive Care Med* 22: 187-193
16. Foot CL, Chinthamuneedi M, Fraser JF, Smith SE, Fayers T, Tesar P, Mullany DV, (2009) The association between preoperative eGFR and outcomes in cardiac surgical patients. *Crit Care Resusc* 11: 184-190

17. Brown JR, Cochran RP, MacKenzie TA, Furnary AP, Kunzelman KS, Ross CS, Langner CW, Charlesworth DC, Leavitt BJ, Dacey LJ, Helm RE, Braxton JH, Clough RA, Dunton RF, O'Connor GT, (2008) Long-term survival after cardiac surgery is predicted by estimated glomerular filtration rate. *Ann Thorac Surg* 86: 4-11
18. Hobson CE, Yavas S, Segal MS, Schold JD, Tribble CG, Layon AJ, Bihorac A, (2009) Acute kidney injury is associated with increased long-term mortality after cardiothoracic surgery. *Circulation* 119: 2444-2453
19. Hillis GS, Croal BL, Buchan KG, El-Shafei H, Gibson G, Jeffrey RR, Millar CG, Prescott GJ, Cuthbertson BH, (2006) Renal function and outcome from coronary artery bypass grafting: impact on mortality after a 2.3-year follow-up. *Circulation* 113: 1056-1062
20. Engoren M, Habib RH, Hadaway J, Zacharias A, Schwann TA, Riordan CJ, Durham SJ, Shah A, (2009) The effect on long-term survival of erythrocyte transfusion given for cardiac valve operations. *Ann Thorac Surg* 88: 95-100, 100 e101-103
21. Koch CG, Khandwala F, Li L, Estafanous FG, Loop FD, Blackstone EH, (2006) Persistent effect of red cell transfusion on health-related quality of life after cardiac surgery. *Ann Thorac Surg* 82: 13-20
22. Engoren M, (2011) Transfusion: is merely not bad good enough? *Acta anaesthesiologica Scandinavica* 55: 907-909
23. Maegele M, Lefering R, Wafaisade A, Theodorou P, Wutzler S, Fischer P, Bouillon B, Paffrath T, (2011) Revalidation and update of the TASH-Score: a scoring system to predict the probability for massive transfusion as a surrogate for life-threatening haemorrhage after severe injury. *Vox Sang* 100: 231-238
24. Borgman MA, Spinella PC, Holcomb JB, Blackburne LH, Wade CE, Lefering R, Bouillon B, Maegele M, The effect of FFP:RBC ratio on morbidity and mortality in trauma patients based on transfusion prediction score. *Vox Sang*
25. Bilgin YM, van de Watering LM, Versteegh MI, van Oers MH, Vamvakas EC, Brand A, (2011) Postoperative complications associated with transfusion of platelets and plasma in cardiac surgery. *Transfusion* 51: 2603-2610
26. Karkouti K, Wijeyesundera DN, Yau TM, Callum JL, Meineri M, Wasowicz M, McCluskey SA, Beattie WS, (2006) Platelet transfusions are not associated with increased morbidity or mortality in cardiac surgery. *Can J Anaesth* 53: 279-287
27. Devine DV, Serrano K, (2010) The platelet storage lesion. *Clin Lab Med* 30: 475-487
28. Welsby IJ, Lockhart E, Phillips-Bute B, Campbell ML, Mathew JP, Newman MF, Peterson E, Milano CA, (2010) Storage age of transfused platelets and outcomes after cardiac surgery. *Transfusion* 50: 2311-2317
29. van Straten AH, Soliman Hamad MA, Martens EJ, Tan ME, de Wolf AM, Scharnhorst V, van Zundert AA, (2010) Effect of storage time of transfused plasma on early and late mortality after coronary artery bypass grafting. *J Thorac Cardiovasc Surg* 141: 238-243 e231-232
30. Koch CG, Li L, Sessler DI, Figueroa P, Hoeltge GA, Mihaljevic T, Blackstone EH, (2008) Duration of Red-Cell Storage and Complications after Cardiac Surgery. *New England Journal of Medicine* 358: 1229-1239