Is Transfusion in Coronary Artery Surgery a Predictor or a Cause of Reduced Long-Term Survival?

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Abstract

Background

Transfusion is common after coronary bypass surgery. Transfused patients present with higher operative risk and an increased hazard ratio for curtailed long-term survival. There is debate as to whether transfusion itself may further exacerbate late mortality.

Methods

Long-term survival was studied in 2550 survivors following coronary revascularization in this retrospective, observational study. Kaplan-Meier survival curves were constructed to compare all transfused and non-transfused patients, as well as survival in propensity-matched transfused and non-transfused patients.

Results

Operative mortality was 1.05% (original cohort 2577). Maximum follow-up was 23 years (mean 11.8, median 12.4 years). 34.7% of patients received a transfusion (mean 2 units packed red blood cells). Baseline risk characteristics (age, female gender, small body habitus, risk stratification scoring, diabetes, hypertension and reduced stroke volume) operative parameters (urgency and no internal thoracic graft) as well as post-operative parameters (intensive care, hospital stay and ventilation time) and complications (haemorrhage, intra-aortic balloon, ventricular arrhythmias, prolonged inotropic support, atrial fibrillation, dialysis, doubling of creatinine and resternotomy) were higher in the transfused patients. The long-term survival of these patients was significantly reduced when compared with that of non-transfused patients (log rank test $p<0.001$). When analyzed as a sole risk factor, transfusion was associated with reduced long-term survival (log rank test $p<0.001$) but when analyzed collectively with other risk factors, transfusion failed to demonstrate a causative effect ($p=0.953$). When propensity matched groups were compared (612 transfused versus 1222 non-transfused patients) long-term survival was similar (log rank test $p=0.554$).

Conclusions

Transfusion was required in higher risk patients undergoing coronary revascularization. Long-term survival was curtailed in this group but this was due to preoperative risk and not directly to transfusion. Transfusion was a predictor but not a cause of reduced long-term survival.

Keywords: blood transfusion; coronary artery bypass surgery; long-term survival

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Introduction

Approximately a third of patients undergoing cardiac surgery require blood products, more than in any other category of planned major surgery.[1,2] Transfused patients present with higher risk and experience increased mortality, both in the short and long-term.[3,4,5] Transfusion may be necessary because of preoperative anaemia, blood loss, coagulopathy and haemodilution,[6,7] or because of haemodynamic instability,[1] the majority of patients receiving 2 units of blood.[7] Pre-existing anaemia is associated with other comorbidities and results in increased post-operative renal impairment as well as a higher stroke rate and mortality.[8] Prolonged intensive care stay exacerbates this situation leading to increased transfusion requirements.[9,10] Guidelines propose transfusion in unstable patients with a haemoglobin level below 7g/dL,[11] but clinical decisions often overrule this recommendation, particularly in older patients.[12] There is evidence that transfusion in low-risk patients results in higher long-term mortality, and this practice should be avoided whenever possible.[13] Retrospective

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data shows improvement in some patients after transfusion, whilst in others with certain comorbidities, the outcome is worse.[14] Moreover, the loose temporal relationship between transfusion and the onset of complications or death makes for an uncertain causative role,[15] particularly in the setting of poorer outcomes.[16,17]

Patients and methods

This retrospective, observational, cohort study was conducted using our dedicated coronary surgery database and included all consecutive patients undergoing solitary coronary artery bypass grafting utilizing cardiopulmonary bypass in a single-surgeon practice between 1st April 1995 and 31st December 2016. Data was collected prospectively and analyzed in December 2018 (observation time 2 to 23.5 years) and included patient demographics, operative urgency, risk scores, cardiac indices, surgery-, anaesthesia- and intensive care-related data, and in-hospital length of stay and complications (table 1). Transfusion-related data was recorded on anaesthesia and intensive care forms. All data were completed and validated at the point of the patient's discharge from hospital, and further systematically validated on a yearly basis. The primary endpoint was all-cause mortality during the follow-up period. Data pertaining to date of death was obtained from the National Statistics Office, using a unique personal identity number assigned to every patient. Patients, who died within 30 days, or while still in hospital after surgery, were excluded from the study.

Patients were risk-stratified by Parsonnet score (from 1995) as well as by additive (after 2000) and logistic EuroSCORE (after 2006). All complications were recorded in real time and classified according to organ-system. Data collection included incidence of perioperative myocardial infarction, arrhythmia, intra-aortic balloon counter-pulsation and permanent pacemaker use, transient ischaemic attack, stroke, temporary renal impairment, dialysis, gastrointestinal haemorrhage or perforation and resternotomy for tamponade or haemorrhage. Ventilation time, blood volume loss and transfusion, and inotropic support were also recorded.

Packed red blood cells, fresh frozen plasma and platelet transfusions were prescribed by the attending surgeon and anaesthetist. Indications were based on haemodynamic data, blood loss, haemoglobin and haematocrit levels and comorbid conditions. Thromboelastometry-guided therapy supplemented routine activated clotting time, international normalized ratio and activated partial thromboplastin time, platelet counts and fibrinogen levels where indicated. A lower target haemoglobin level was accepted in younger patients. The decision to transfuse was also guided by the clinical picture.

Antiplatelet drugs were stopped 5 days before routine surgery when logistically feasible, but aspirin and/or heparin were administered until surgery in acute coronary syndrome, and in urgent or emergency cases. All patients underwent cardiopulmonary bypass with surface-modified tubing and membrane oxygenator at normothermia and myocardial protection was with antegrade cold blood cardioplegia. Tranexamic acid was used routinely whereas aprotinin was only administered rarely and for excess blood loss.

Table 1. Risk indicators in transfused and non-transfused patients

parameter	transfused n%/m(SD) n:886	not transfused n%/m(SD) n:1664	p value
age	64.89 (8.84)	61.39 (8.72)	<0.001
female gender	296 (33.4%)	204 (12.3%)	<0.001
height	1.60 (0.10)	1.63 (0.09)	<0.001
weight	74.40 (13.16)	79.36 (13.22)	<0.001
body surface area	1.77 (0.19)	1.85 (0.18)	<0.001
body mass index	29.15 (4.41)	29.68 (4.24)	0.005
Parsonnet score	7.96 (5.79)	5.35 (4.66)	<0.001
additive EuroSCORE	3.38 (2.23)	2.30 (1.93)	<0.001
logistic EuroSCORE	3.37 (4.01)	2.33 (1.95)	<0.001
diabetes	260 (29.3%)	353 (21.2%)	<0.001
hypertension	428 (48.3%)	621 (37.3%)	<0.001
ejection fraction	71.23 (13.49)	72.15 (12.96)	0.146
stroke volume	87.38 (28.60)	93.55 (28.71)	<0.001
urgent	236 (26.6%)	354 (21.3%)	0.002
emergency	20 (2.3%)	12 (0.7%)	0.001
single coronary bypass	16 (1.8%)	38 (2.3%)	0.425
double coronary bypass	203 (22.9%)	361 (21.7%)	0.481
triple coronary bypass	400 (45.1%)	788 (47.4%)	0.287
quadruple coronary bypass	234 (26.4%)	401 (24.1%)	0.199
quintuple coronary bypass	32 (3.6%)	76 (4.6%)	0.254
no internal thoracic graft	32 (3.6%)	31 (1.9%)	0.007
ischaemic time	29.89 (9.44)	30.20 (8.71)	0.424
bypass time	57.74 (16.53)	56.69 (16.01)	0.126
intensive care (dy)	1.06 (0.38)	1.02 (0.42)	0.023
high dependency (dy)	1.70 (4.37)	0.84 (2.15)	<0.001
ward (dy)	3.16 (2.60)	2.80 (2.18)	<0.001
ventilation (hr)	9.23 (7.94)	7.43 (5.79)	<0.001
ventilation >24hr	20 (2.3%)	14 (0.8%)	0.003
haemorrhage (ml)	620.8 (347.9)	491.7 (169.6)	<0.001
intra-aortic balloon	46 (5.2%)	17 (1.0%)	<0.001
permanent pacemaker	3 (0.3%)	3 (0.2%)	0.432
ventricular arrhythmia	19 (2.1%)	18 (1.1%)	0.033
inotropic support >24hr	309 (34.9%)	269 (16.2%)	<0.001
atrial fibrillation	159 (17.9%)	237 (14.2%)	0.014
atrial flutter	10 (1.1%)	20 (1.2%)	0.870
dialysis	22 (2.5%)	2 (0.1%)	<0.001
doubling of creatinine	53 (6.0%)	18 (1.1%)	<0.001
gastric haemorrhage	3 (0.3%)	5 (0.3%)	0.870
stroke	7 (0.8%)	12 (0.7%)	0.847
transient ischaemic attack	8 (0.9%)	8 (0.5%)	0.199
resternotomy	8 (0.9%)	5 (0.3%)	0.042

Statistical Methods

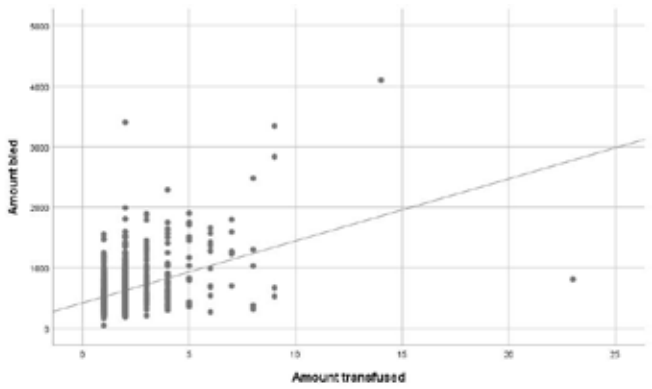
Kaplan-Meier survival curves were constructed to compare all transfused and non-transfused patients, as well as survival in propensity matched transfused and non-transfused patients. Risk indicators in the two groups were compared using the chi-squared test for categorical variables and the Student's t-test for continuous variables. Cox regression analysis was used to calculate hazard ratios for curtailed long-term survival.

Results

A total of 2550 patients (886 transfused, 1664 not transfused) were included after elimination of 27 patients who died perioperatively (mortality 1.05%). Risk indicators were significantly higher in the transfused patients. These included age, female gender, small body habitus, Parsonnet score, additive EuroSCORE and logistic EuroSCORE, diabetes, hypertension, lower stroke volume, operative urgency, no internal thoracic graft, intensive care, hospital stay and ventilation time, haemorrhage, intra-aortic balloon, ventricular arrhythmias, prolonged inotropic support, atrial fibrillation, dialysis, doubling of creatinine and resternotomy (table 1).

The transfused patients experienced more post-operative haemorrhage (620.8±347.9ml versus 491.7±169.6ml, $p<0.001$) and a higher incidence of excessive haemorrhage (9.9% versus 1.0% >1L $p<0.001$, 2.7% versus 0.06% >1.5L, $p<0.001$). Of the transfused patients, 45.5% received 1 unit, 34.6% 2 units, 15.1% 3-4 units, 2.9% 5-6 units and 1.9% over 6 units. There was a significant positive correlation between the haemorrhage volume and the amount transfused (figure 1).

The hazard ratio for each parameter was calculated by Cox Regression analysis (table 2). All explanatory variables with p values less than the 0.05 level of significance were significant predictors of survival duration. When the explanatory variables were analyzed individually, twenty-four variables were found to be significant predictors of survival duration; however when the variables were analyzed collectively these predictors (except Parsonnet score



Correlation between amount transfused and haemorrhage volume	
Pearson correlation	0.433
p value	0.000
sample size	886

Figure 1 Correlation between haemorrhage volume and amount transfused

Table 2. Cox-Regression analysis relating survival duration to each predictor individually

parameter	n%/m(SD)	Hazard Ratio	(95%) CI of HR	p value
transfused	886 (34.7%)	1.728	(1.483 – 2.013)	<0.001
age	62.61 (8.917)	1.081	(1.071 – 1.091)	<0.001
female gender	500 (19.6%)	1.187	(0.991 – 1.422)	0.062
height	1.620 (0.091)	0.085	(0.035 – 0.203)	<0.001
weight	77.59 (13.41)	0.988	(0.982 – 0.995)	<0.001
body surface area	1.822 (0.188)	0.327	(0.207 – 0.514)	<0.001
body mass index	29.49 (4.305)	1.002	(0.983 – 1.022)	0.836
Parsonnet score	6.258 (5.226)	1.111	(1.098 – 1.124)	<0.001
additive EuroSCORE	2.674 (2.104)	1.263	(1.226 – 1.301)	<0.001
logistic EuroSCORE	2.711 (2.923)	1.094	(1.053 – 1.137)	<0.001
diabetes	613 (24.0%)	1.555	(1.289 – 1.874)	<0.001
hypertension	1049 (41.1%)	1.087	(0.912 – 1.295)	0.354
ejection fraction	71.81 (13.17)	0.991	(0.984 – 0.998)	0.008
stroke volume	91.25 (28.81)	0.997	(0.993 – 1.000)	0.047
urgent	590 (23.1%)	1.226	(1.026 – 1.466)	0.025
emergency	32 (1.3%)	0.914	(0.455 – 1.835)	0.800
single coronary bypass	54 (2.1%)	0.785	(0.432 – 1.424)	0.426
double coronary bypass	564 (22.1%)	1.300	(1.088 – 1.553)	0.004
triple coronary bypass	1188 (46.6%)	0.981	(0.842 – 1.142)	0.800
quadruple coronary bypass	635 (24.9%)	0.844	(0.708 – 1.006)	0.058
quintuple coronary bypass	108 (4.2%)	0.928	(0.647 – 1.331)	0.685
no internal thoracic graft	63 (2.5%)	1.393	(0.860 – 2.255)	0.178
ischaemic time	30.09 (8.966)	0.994	(0.985 – 1.002)	0.143
bypass time	57.05 (16.20)	0.998	(0.993 – 1.002)	0.293
intensive care (dy)	1.036 (0.409)	1.491	(1.315 – 1.690)	<0.001
high dependency (dy)	1.154 (3.184)	1.060	(1.047 – 1.074)	<0.001
ward (dy)	2.925 (2.337)	1.077	(1.057 – 1.097)	<0.001
ventilation (hr)	8.052 (6.668)	1.020	(1.013 – 1.028)	<0.001
ventilation >24hr	34 (1.3%)	1.508	(0.808 – 2.818)	0.197
haemorrhage (ml)	536.6 (254.1)	1.000	(1.000 – 1.000)	0.899
intra-aortic balloon	63 (2.5%)	1.617	(1.036 – 2.523)	0.034
permanent pacemaker	6 (0.2%)	7.156	(3.202 – 15.99)	<0.001
ventricular arrhythmia	37 (1.5%)	1.754	(0.991 – 3.105)	0.054
inotropic support >24hr	578 (22.7%)	2.213	(1.880 – 2.604)	<0.001
atrial fibrillation	396 (15.5%)	1.409	(1.148 – 1.729)	0.001
atrial flutter	30 (1.2%)	1.352	(0.724 – 2.524)	0.344
dialysis	24 (0.9%)	4.000	(2.136 – 7.491)	<0.001
doubling of creatinine	71 (2.8%)	3.324	(2.350 – 4.703)	<0.001
gastric haemorrhage	8 (0.3%)	1.285	(0.321 – 5.152)	0.723
stroke	19 (0.7%)	1.147	(0.476 – 2.764)	0.761
transient ischaemic attack	16 (0.6%)	5.109	(2.882 – 9.058)	<0.001
resternotomy	13 (0.5%)	1.638	(0.613 – 4.378)	0.325

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and double coronary bypass) were not significant since their *p* values exceeded the level of significance of 0.05. Using a forward procedure, three predictors were found to be significant (table 3). The parsimonious survival model, that analyzed all the explanatory variables collectively and retained the significant predictors, identified Parsonnet score as the strongest predictor of survival duration, followed by doubling of creatinine and double coronary bypass.

When analyzed as a sole risk factor, transfusion was associated with reduced long-term survival (log rank test $p<0.001$) but when analyzed collectively with other risk factors, transfusion failed to demonstrate a causative effect ($p=0.953$).

The survival probability of transfused patients was significantly worse ($p<0.001$), (figure 2). This difference was present from the early postoperative phase and increased with time (44% versus 62% 19-year survival).

274 patients (30.9%) were deleted from the transfused group (886-274=612) and 442 patients (26.6%) from the non-transfused group (1664-442=1222) in order to achieve propensity matching for 18 important risk factors. The deleted patients (table 5) included high-risk patients from the transfused group and low-risk patients from the not-transfused group, with the former having 24 risk factors that were significantly worse than the latter. The resultant propensity-matched groups were comparable for age, gender, height, additive EuroSCORE and logistic EuroSCORE, ejection fraction and stroke volume, urgency, no internal thoracic graft, ischaemic time, permanent pacemaker, ventricular arrhythmia, atrial fibrillation and flutter, gastric haemorrhage, stroke, transient ischemic attack and resternotomy (table 4). The survival probability (figure 3) and the cumulative hazard (figure 4) of the propensity-matched transfused and non-transfused patients were similar ($p=0.554$).

Discussion

Patients who died perioperatively were excluded from this study because common causes of hospital death such as cardiogenic shock and sepsis could overshadow the influence of transfusion as a contributory factor.[18]

Transfusion of 1 to 2 units of packed red blood cells has been shown to increase perioperative morbidity [19] and mortality,[7] as well as mortality in the medium term.[20] There is evidence to suggest that preventing a low haemoglobin immediately after bypass, and its attendant renal complications, may be preferable to correcting it with a transfusion. However it is difficult to determine whether the anaemia or the transfusion is the cause of increased early morbidity.[21]

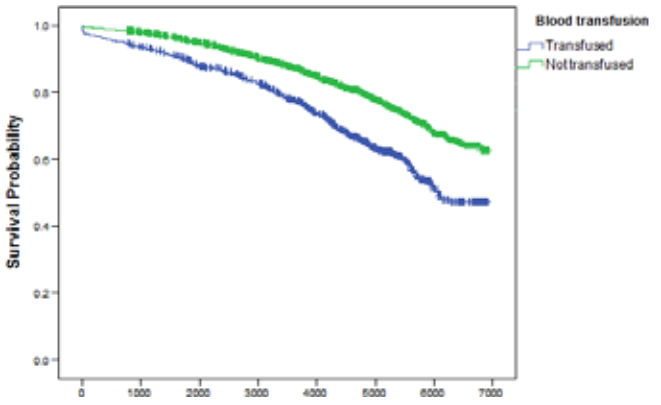
When haemorrhage results in severe anaemia with organ dysfunction due to reduced oxygen-carrying capacity, transfusion can correct the situation. Transfusion has been postulated to be detrimental by way of its depleted 2,3 Diphosphoglycerate, shifting the oxygen dissociation curve leftwards and reducing oxygen delivery. Transfusion also raises cytokine levels, increasing the already high inflammatory state after cardiopulmonary bypass. [22,23]

Table 3. Parsimonious survival model using a forward procedure

parameter	Wald	df	p value	Hazard Ratio	95% lower limit	95% upper limit
Parsonnet score	65.760	1	0.000	1.149	1.111	1.189
doubling of creatinine	10.333	1	0.001	3.705	1.667	8.232
double coronary bypass	4.487	1	0.037	1.730	1.042	2.870

Table 4. Risk indicators in propensity-matched transfused and non-transfused patients

parameter	transfused n%/m(SD) n:612	not transfused n%/m(SD) n:1222	p value
age	62.85 (8.56)	62.89 (8.95)	0.924
female gender	89 (14.5%)	179 (14.6%)	0.995
height	1.62 (0.09)	1.63 (0.09)	0.397
additive EuroSCORE	2.71 (1.92)	2.70 (1.86)	0.973
logistic EuroSCORE	2.56 (2.81)	2.67 (1.93)	0.621
ejection fraction	70.92 (13.20)	71.88 (13.22)	0.201
stroke volume	89.57 (29.30)	91.83 (28.08)	0.166
urgent	142 (23.2%)	292 (23.7%)	0.798
no internal thoracic graft	22 (3.6%)	26 (2.1%)	0.060
ischaemic time	30.65 (9.76)	30.10 (8.58)	0.220
permanent pacemaker	1 (0.2%)	2 (0.2%)	0.997
ventricular arrhythmia	14 (2.3%)	14 (1.1%)	0.545
atrial fibrillation	96 (15.7%)	192 (15.6%)	0.966
atrial flutter	9 (1.5%)	14 (1.1%)	0.870
gastric haemorrhage	3 (0.5%)	4 (0.3%)	0.588
stroke	5 (0.8%)	9 (0.7%)	0.843
transient ischaemic attack	4 (0.7%)	8 (0.7%)	0.994
resternotomy	6 (1.0%)	4 (0.3%)	0.071

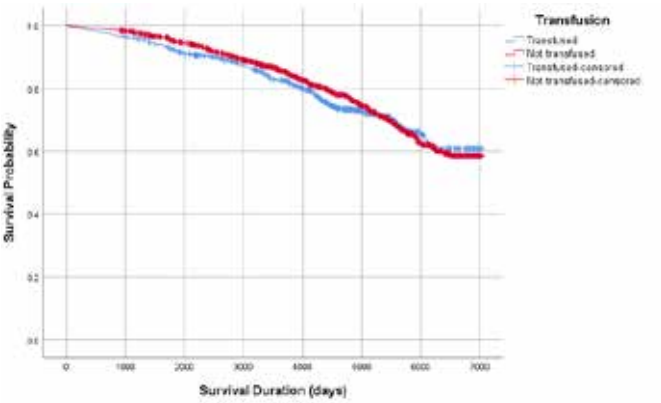


Overall Comparisons			
	Chi-Square	df	p value
Log Rank (Mantel-Cox)	60.677	1	<0.001

Figure 2 Kaplan-Meier survival curves in transfused and non-transfused patients

Table 5. Risk indicators in transfused and non-transfused deleted patients

parameter	transfused n%/m(SD) n:274	not transfused n%/m(SD) n:442	p value
age	68.9 (7.917)	57.10 (6.543)	<0.001
female	194 (70.8%)	25 (5.7%)	<0.001
height	1.54 (0.092)	1.66 (0.079)	<0.001
weight	69.88 (11.277)	81.48 (13.094)	<0.001
body surface area	1.68 (0.160)	1.89 (0.176)	<0.001
body mass index	29.41 (4.549)	29.615 (4.042)	0.554
Parsonnet score	10.85 (6.135)	3.85 (3.576)	<0.001
additive EuroSCORE	4.61 (2.264)	1.15 (1.663)	<0.001
logistic EuroSCORE	5.71 (5.883)	1.66 (2.123)	<0.001
diabetes	73 (26.6%)	98 (22.2%)	0.173
hypertension	126 (46.0%)	162 (36.7%)	0.013
ejection fraction	71.59 (14.139)	73.14 (11.794)	0.190
stroke volume	83.98 (27.017)	98.25 (29.385)	<0.001
urgent	91 (33.2%)	68 (15.4%)	<0.001
emergency	11 (4.0%)	5 (1.1%)	0.011
single coronary bypass	5 (1.8%)	11 (2.5%)	0.559
double coronary bypass	70 (25.5%)	92 (20.8%)	0.141
triple coronary bypass	139 (50.7%)	196 (44.3%)	0.096
quadruple coronary bypass	57 (20.8%)	118 (26.7%)	0.074
quintuple coronary bypass	2 (0.7%)	25 (5.7%)	0.001
no internal thoracic graft	10 (3.6%)	6 (1.4%)	0.044
ischaemic time	28.20 (8.476)	30.51 (8.916)	0.001
bypass time	54.78 (15.257)	57.18 (16.445)	0.054
intensive care (dy)	1.04 (0.294)	1.00 (0.067)	0.024
high dependency (dy)	1.47 (2.162)	0.67 (1.106)	<0.001
ward (dy)	3.45 (2.809)	2.60 (1.296)	<0.001
ventilation (hr)	8.80 (5.406)	6.81 (3.267)	<0.001
haemorrhage (ml)	542.26 (331.383)	500.64 (160.124)	0.053
intra-aortic balloon	16 (5.8%)	4 (0.9%)	<0.001
permanent pacemaker	2 (0.7%)	1 (0.2%)	0.311
ventricular arrhythmia	4 (1.5%)	4 (0.9%)	0.492
inotropic support >24hr	93 (33.9%)	55 (12.4%)	<0.001
atrial fibrillation	63 (23.0%)	46 (10.4%)	<0.001
atrial flutter	3 (1.1%)	5 (1.1%)	0.964
ventilation >24hr	4 (1.5%)	1 (0.2%)	0.054
dialysis	7 (2.6%)	0 (0.0%)	0.001
doubling of creatinine	15 (5.5%)	3 (0.7%)	<0.001
gastric haemorrhage	0 (0.0%)	1 (0.2%)	0.431
stroke	1 (0.4%)	3 (0.7%)	0.584
transient ischaemic attack	4 (1.5%)	0 (0.0%)	0.011
resternotomy	2 (0.7%)	1 (0.2%)	0.311



Overall Comparisons			
	Chi-Square	df	p value
Log Rank (Mantel-Cox)	0.350	1	0.554

Figure 3 Survival probability of the propensity-matched transfused and non-transfused patients

Previous studies have shown little [24] or no [25] effect of transfusion on long-term survival whereas a study, by Jakobsen et al, demonstrated a strong correlation between transfusion in low-risk patients (EuroSCORE 0-4) and reduced long-term survival. [26] A possible mechanism proposed is immune modulation following a transfusion.[27] 54.7% of our transfused patients and 75.7% of our non-transfused patients were in a comparable risk category but our results are at variance with this study, which had a maximum follow-up of 12 years and also included patients undergoing valve replacement. Moreover, in our propensity-matched groups the additive EuroSCORE was equivalent at a mean of 2.7 and long-term survival was similar.

Urgent and emergency operations were significantly more frequent (p=0.002 and p=0.001 respectively) in the transfused group. These patients received aspirin and/or Heparin immediately prior to surgery, making them more likely to bleed excessively postoperatively, and to require transfusion. This risk factor was present equally in the propensity-matched groups.

The strong correlation between the amount of blood transfused and the postoperative haemorrhage volume suggests that the clinical decision to transfuse was justified. Reassessment of the clinical situation after the first unit resulted in a lesser amount transfused (80.1% received 1-2 units).

Although total postoperative stay was higher in transfused patients (mean 5.92 versus 4.66) this still represented a short hospital stay, taking into consideration the higher mean age (64.9 versus 61.4) and the fact that all patients were discharged to their home. In these patients transfusion may have helped expedite their recovery and mitigate an even longer hospital stay.

There is still no consensus regarding transfusion in critically ill patients undergoing coronary artery surgery. Practices vary widely in different centres, but transfusions tend to be more frequent in elderly, female patients receiving anti-platelet medications.[28] A life-saving transfusion must be weighed up against possible infection, lung-injury, circulatory overload, and possible adverse long-term outcomes.[29] Withholding transfusion when the

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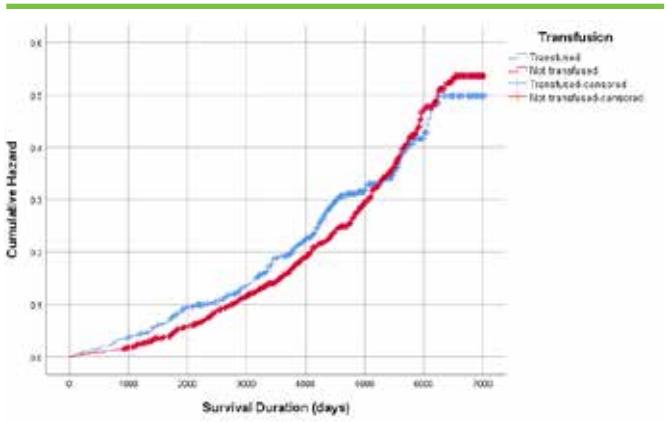

Overall Comparisons			
	Chi-Square	df	p value
Log Rank (Mantel-Cox)	0.350	1	0.554

Figure 4 Cumulative Hazard of the propensity-matched transfused and non-transfused patients

haematocrit is above 24% has not been shown to increase early morbidity and mortality.[30] A lack of clear evidence on the benefits of transfusion should promote a restrictive transfusion policy.

Limitations

The retrospective nature of this observational study necessarily limits the proof of a causal relationship between transfusion and poorer outcomes, especially in the long-term.

Although transfusion was not a predictor of long-term survival, other confounders that were either not measured, or that were not matched by propensity scoring, may have influenced survival. The severity of the clinical presentation with high-risk patients and urgent operations is more likely to affect outcomes or to overshadow the role of transfusion.

Propensity score analysis was employed to reduce bias in this observational study, as randomization into two treatment groups was not possible. Propensity matching was only achieved for 18 out of 41 risk variables as further matching would have significantly reduced the size of both groups, rendering them unrepresentative of the original cohorts.

Conclusion

Blood transfusion can save lives when used appropriately. This study shows that long-term survival was curtailed in transfused patients but this was due to preoperative risk and not directly to transfusion, which was a significant predictor but not a cause of reduced long-term survival. Controversy still exists regarding the causal nature of transfusion and long-term outcomes and it would be prudent to use blood products with greater vigilance. Further research is required to clarify the problem.

Declarations of interest

The authors declare no conflict of interest.

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