Blood product utilisation for coronary artery bypass graft surgery at a public and a private hospital in Western Cape Province, South Africa

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Background. Numerous studies have documented variation in transfusion practice for coronary artery bypass graft (CABG) surgery, despite the widespread availability of clinical guidelines. Blood management systems seek to streamline utilisation, with key indicators being patient care and outcome as well as reduction of waste and cost.

Objectives. To facilitate this view, this study sought to audit blood product utilisation for CABG surgery at a private and a public sector hospital in Western Cape Province, South Africa.

Methods. A retrospective audit of 100 consecutive patients undergoing CABG surgery at a private and a public hospital during 2017 was performed. Blood product use was compared between the two hospitals, and the influence of confounding factors such as gender, weight, age, pre- and intraoperative medications, type and complexity of the procedure, and patient comorbidities was analysed.

Results. The proportion of patients receiving red cell concentrates (RCCs) at the public hospital was significantly higher than at the private hospital (92% v. 56%; p<0.001), which resulted in significantly higher postoperative haemoglobin concentrations (p<0.001). Although the increased proportion of RCC transfusion observed at the public hospital may have been influenced by decreased body mass (p<0.001), the patient population at the private hospital was older (p<0.05) and had higher rates of ischaemia (p<0.001), increased numbers of grafts (p<0.001) and higher preoperative use of aspirin (p<0.05).

Conclusions. This study demonstrated increased use of blood products at the public hospital, despite performing fewer grafts. Although this study had limitations, which included low patient numbers and the inclusion of only two hospitals, we concluded that there is a significant variation in the use of blood products despite the risks associated with blood transfusion. These findings could be used to employ systems that will lead to improved blood usage practices.

Although blood products are the favoured choice for replacing volume, replenishing coagulation factors and restoring tissue oxygenation, evidence suggests that the use of red cell concentrates (RCCs) in particular is often inappropriately high despite the potential risks and financial costs.1-3 Numerous studies have shown that patient outcome is in no way affected by whether a restrictive or liberal transfusion strategy is used.4-6 However, despite the availability of clinical guidelines, significant variation occurs in transfusion practice, although the underlying causes for these differences remain unclear.7-10

Substantial blood loss is common during coronary artery bypass graft (CABG) surgery, causing anaemia and placing stress on the heart because of an increase in cardiac output.11 The most rapid approach to combat anaemia remains blood transfusion,12-13 and therefore, despite increasing awareness and improved technology, the variation in blood product use in cardiac surgery remains significant.

This wide variation has been demonstrated in many studies. For example, an audit of 82 446 cardiac patients at 408 hospitals7 reported that the rates of blood transfusion for cardiac surgery ranged from 7.8% to 92% for RCCs, from 0% to 97% for fresh-frozen plasma (FFP) and from 0.4% to 90.4% for platelets. These differences remained despite adjustments for risk factors. Others have demonstrated similar findings, with transfusion rates ranging from 33% to 74%.14-15

In South Africa (SA), two studies, conducted on patients undergoing cardiac surgery at academic centres in Johannesburg and KwaZulu-Natal Province, demonstrated and confirmed the high rates of blood product use in patients undergoing cardiac surgery.11,12 Both these articles suggested the use of blood management guidelines to assist in prevention of unnecessary blood transfusion.

SA’s healthcare delivery is divided into two systems, with the private sector providing medical services to those with medical aid cover and other sources of funding, while public hospitals, funded by the government, provide a service to the majority of lower-income South Africans. The level and quality of service offered by these two tiers of healthcare differ significantly.16 Owing to these differences, it has been hypothesised that significant variation may exist between blood usage practices of clinicians performing CABG surgery in the private sector compared with those in the public sector.

Objectives

As few studies have been conducted in Western Cape Province, the objectives of this study were to examine transfusion practices at a
private and a public sector hospital, as well as the clinical features of
the patient populations.

Methods
Patient population and study design
This was a retrospective study of 100 consecutive patients equally
divided between a private hospital and a public hospital. Participants
were recruited during 2017 in the Western Cape, and unscheduled
patients undergoing multiple cardiac procedures including coronary
angioplasty and/or stent insertion, valve replacement and pacemaker
insertion were excluded from the analysis.

Ethical and legal considerations
Confidentiality was maintained by ensuring that patient and clinical
staff details at each hospital were anonymised. For the purposes of
the audit, unique study numbers were created for each institution.
These numbers were P1 - 50 for the private hospital and T1 - 50 for
the public hospital, and were linked with the data collection form.
As the data collection was retrospective and anonymised, a waiver of
consent was sought and granted. Ethics approval was obtained from
the Cape Peninsula University of Technology’s Ethics Committee (ref.
no. CPUT/HW-REC2016/H32), and approval to collect the data was
granted by the management of the relevant hospitals.

Data collection
A data collection form detailing the required information was
devised. At the private hospital, data were collected and recorded
onto the information sheet by the hospital staff, while at the public
hospital, the records of 50 consecutive cardiac surgery patients were
made available to the investigator, who recorded the information
onto the collection form. Data were cross-checked with the Western
Cape Blood Service records. All information was transcribed onto
the data collection form for data capture and analysis. Transfusion
episodes were recorded from the time surgery commenced and
concluded at 24 hours post surgery.

The data form included information on the following
patient parameters: gender, weight, age, details of preoperative
anticoagulants including aspirin, clopidogrel and warfarin, and
comorbidities including hypertension, diabetes mellitus, ischaemic
heart disease, renal dysfunction and congestive heart failure, as well
as cerebrovascular disease or stroke.

Additional information gathered included the details of the
procedure itself, the number of grafts performed, whether the
operation was on or off pump, and intraoperative use of the
anticoagulant heparin and its reversal with protamine. Further
information on any blood conservation techniques, such as the use
of cell salvage equipment and antifibrinolytics such as aprotinin and
transaminic acid, was also recorded.

Information on pre- and postoperative laboratory test results
was documented and included serum creatinine levels, international
normalised ratio (INR) and activated partial thromboplastin time
(aPTT), as well as haemoglobin (Hb) values and platelet counts.
Finally, details on the numbers and type of blood products used were
recorded.

Statistical analysis
All data were transcribed onto a predesigned Excel worksheet
(version 15.0.4420.1017, 2013; Microsoft, USA) with standardised
input methods. The use of a double-entry method ensured capture
accuracy, while data duplication was limited by the use of unique
study numbers. The data were then uploaded to an SPSS version 22
statistical package (IBM, USA) for analysis. Information obtained
in this way included frequency and contingency tables as well as a
descriptive analysis for numerical variables using the median and the
interquartile range (IQR).

Where deemed suitable, summary statistics were portrayed as
medians and IQRs. Performance indicators included the number
of patients transfused as well as the number of units transfused
er per hospital. The χ² test was used to identify significant differences
between two or more groups pertaining to categorical variables or
to determine the significant association between two categorical
variables. The independent-samples median test was used to compare
the medians of counts between two groups. The independent-
samples Mann-Whitney U-test was used to test for differences
between two groups of numerical variables, and p-values were given
to test the null hypothesis, thereby testing the validity of a claim made
about a population. These p-values given for information purposes
were compared against a significance value of <0.05.

Multivariate analysis
The assumption of normality, which is required for classic linear
models, is violated when working with ordinal variables. The
dependent variables (RCCs, FFP and platelets) are all ordinal
variables. However, owing to scarcity of data, FFP and platelets
were transformed to binary variables, indicating whether the blood
product was given or not. The variable RCCs was also transformed
onto an ordinal variable with fewer categories for the same reason.

Therefore, a generalised linear model of the family of linear models
that includes analysis of variance as well as regression models was
utilised to determine which factors or measurements influenced
blood usage in the hospitals.¹⁴,¹⁵

The three components making up the generalised linear model are
a random component, a systematic component and a link function.¹⁶

The assumption of normality is relaxed in the generalised linear
model. The distribution of the dependent values can be from any
of the class of exponential distributions. The type of data of the
dependent variable informs the choice of the link function. In this
study, the selected link function for the ordinal dependent variables
was the cumulative logit link function, and for the binary variables it
was the logit link function. The analysis, in each of the three cases,
was repeated until a model that fitted the data well, as indicated by
the goodness-of-fit statistics, emerged.

Results
Study population
The study population reviewed was 50 consecutive patients
undergoing CAGB surgery from each hospital. The only significant
differences observed between the baseline characteristics of the
patients (Table 1) were age, which was significantly higher at the
private hospital (p<0.05), the number of grafts performed (p<0.001)
and levels of ischaemia (p<0.001), which were both higher at the
private hospital, and body weight, which was significantly lower at
the public hospital (p<0.05).

RCC analysis
Seventy-four percent of the total patients received RCCs within
24 hours of the procedure: 28 of these were from the private hospital
and 46 from the public hospital. The remaining patients, 22 from the
private hospital and 4 from the public hospital, did not receive any
RCC transfusion.

Subsequently, a significant difference in RCC transfusion rates
between the private hospital and the public hospital was noted (56%
v. 92%; $\chi^2=16.84, df=1, p<0.001$), as seen by the use of 166 RCC units at the public hospital compared with only 99 at the private hospital. Although there was no significant difference between preoperative Hb concentrations (14.0 g/dL at the private hospital compared with the public hospital’s 13.8 g/dL), as shown by the independent-samples Mann-Whitney U-test ($p>0.05$), the postoperative Hb results were significantly different (11.2 g/dL v. 14.1 g/dL; $p<0.001$)

**FFP and platelets**

There was a significant difference in the use of FFP between the two hospitals (exact $\chi^2=13.457, df=4, p<0.01$), with 37 units used at the public hospital compared with 4 at the private hospital. The two groups had similar median INR results (Mann-Whitney U-test $p>0.05$) and aPTTs, with both falling within the normal reference range.

Pre- and postoperative platelet counts from both institutions support the relatively low use of platelets, as only 13 units of pooled platelets were used at the private hospital and 11 at the public hospital (exact $\chi^2=1.444, df=4, p>0.05$). The median (IQR) preoperative platelet count at the public hospital was 263.5 (111) × 10⁹/L and at the private hospital 233 (111) × 10⁹/L, while the median (IQR) postoperative platelet count at the private hospital was 189 (63) × 10⁹/L and that at the public hospital 222.5 (138) × 10⁹/L, both well above the recommended reference range for transfusion.

**Variables influencing RCC use**

Before transformation to an ordinal variable, eight variables emerged as having a significant influence on blood use by the hospitals (Table 2). The most significant factor in the use of RCCs was the type of hospital ($p<0.001$), followed by age ($p<0.01$), number of grafts

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**Table 1. Demographics and baseline characteristics**

|                          | All patients | P     | T     | $p$-value |
|--------------------------|--------------|-------|-------|-----------|
| Total, N                 | 100          | 50    | 50    |           |
| Age (years), median (IQR)| 61 (16)      | 63 (15)| 57 (12)| <0.05*    |
| Weight (kg), median (IQR)| 82.5 (29.8)  | 86 (33)| 78 (19.5)| <0.05*    |
| Hb (g/dL), median (IQR)  |              |       |       |           |
| Pre operation            | 14.05 (1.8)  | 14.5 (2.1)| 13.8 (1.75)| 0.140     |
| Post operation           | 11.95 (3.075)| 11.1 (2.5)| 12.9 (2.9)| <0.001*   |
| Female gender, n (%)     | 16 (16)      | 6 (12) | 10 (20)| 0.275     |
| Comorbidities, n         |              |       |       |           |
| Hypertension             | 71           | 33    | 38    | 0.271     |
| Diabetes mellitus        | 33           | 13    | 20    | 0.137     |
| Renal dysfunction        | 5            | 2     | 3     | 1.00 (exact $p$-value) |
| Ischaemic heart disease  | 53           | 43    | 10    | <0.001*   |
| Congestive heart failure | 2            | 2     | 0     | 0.495 (exact $p$-value) |
| Cerebrovascular disease/stroke | 9            | 4     | 5     | 1.00 (exact $p$-value) |
| Number of grafts, $n$ patients |       |       |       |           |
| 1 - 2                    | 30           | 9     | 21    |           |
| 3                        | 42           | 17    | 25    |           |
| 4 - 6                    | 28           | 24    | 4     |           |
| Preoperative medication, n|              |       |       |           |
| Warfarin                 | 6            | 2     | 4     | 0.678 (exact $p$-value) |
| Aspirin                  | 67           | 38    | 29    | 0.556     |
| Clopidogrel              | 13           | 5     | 8     | 0.372     |
| Previous coronary surgery, n|       |       |       | 0.585     |
| None                     | 84           | 41    | 43    |           |
| CABG/coronary angioplasty/valve replacement/pacemaker | 16 | 9 | 7 |           |

P = private hospital; T = public hospital; IQR = interquartile range; Hb = haemoglobin; CABG = coronary artery bypass graft.

*Statistically significant ($p<0.05$).

**Table 2. Generalised linear model result for RCCs*”

| Independent variables (factors and covariates) | Wald $\chi^2$ | df | $p$-value |
|-----------------------------------------------|---------------|----|-----------|
| Cerebrovascular disease or stroke             | 2.977         | 1  | 0.084     |
| Hospital                                      | 18.330        | 1  | 0.000     |
| Aspirin                                       | 5.781         | 1  | 0.016     |
| Previous cardiac surgery                      | 11.191        | 4  | 0.024     |
| Number of grafts                              | 16.374        | 5  | 0.006     |
| Clopidogrel                                   | 3.162         | 1  | 0.075     |
| Age                                           | 9.052         | 1  | 0.003     |
| Weight                                        | 5.906         | 1  | 0.015     |

RCCs = red cell concentrates

*Dependent variable: RCCs. Likelihood ratio $\chi^2=54.69, df=15, p<0.001$. 

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Variables affecting FFP use
Owing to very small frequencies in some categories, FFP was transformed into a binary variable indicating whether FFP was transfused or not. The cross-tabulation in Table 5 shows a significant difference in the number of times FFP was transfused between the two types of hospital ($\chi^2=35.86, df=5, p<0.0001$).

The results of the generalised linear model showed that the only significant factor in the number of times FFP was transfused was the hospital type ($p<0.002$) (Table 6).

### Table 3. Frequency table of RCCs v. hospital type

| Hospital | Units of RCCs | $\chi^2$ | df | $p$-value |
|----------|--------------|--------|----|-----------|
| P, n patients | 22 14 3 11 50 | 10.077 | 1 | 0.002 |
| T, n patients | 4 18 21 7 50 | 3.571 | 1 | 0.059 |
| Total, N patients | 26 32 24 18 100 | 4.884 | 1 | 0.027 |

RCCs = red cell concentrates; P = private hospital; T = public hospital.

### Table 4. Generalised linear model result for RCCs*

| Source | Wald $\chi^2$ | df | $p$-value |
|--------|--------------|----|-----------|
| Hospital | 10.077 | 1 | 0.002 |
| Warfarin | 3.571 | 1 | 0.059 |
| Aspirin | 4.884 | 1 | 0.027 |
| Number of grafts | 13.878 | 5 | 0.016 |
| Weight | 6.150 | 1 | 0.013 |
| Age | 11.257 | 1 | 0.001 |

*RCCs = red cell concentrates.*

### Table 5. Number of times FFP transfused by hospital

| Hospital | No FFP transfused | FFP transfused | Total |
|----------|-------------------|----------------|-------|
| P, n patients | 48 2 | 50 | |
| T, n patients | 34 16 | 50 | |
| Total, N patients | 82 18 | 100 | |

FFP = fresh-frozen plasma; P = private hospital; T = public hospital.

### Table 6. Generalised linear model result for FFP*

| Source | Wald $\chi^2$ | df | $p$-value |
|--------|--------------|----|-----------|
| Intercept | 25.230 | 1 | <0.001 |
| Hospital | 9.591 | 1 | 0.002 |

*FFP = fresh-frozen plasma.*

Variables influencing the transfusion of platelets
Owing to a similar scarcity in cells, the platelet variable was transformed to a binary variable, indicating whether the patient received platelets or not, and the results demonstrated no significant difference between the two types of hospital in the number of times platelets were transfused ($\chi^2=0.22, df=1, p>0.5$) (Table 7).

The generalised linear model showed that two variables influenced the transfusion of the number of platelets, which excluded the type of hospital, confirming the $\chi^2$ result (Table 8).

### Table 7. Number of times platelets transfused by hospital

| Hospital | No platelets transfused | Platelets transfused | Total |
|----------|-------------------------|----------------------|-------|
| P, n patients | 37 | 13 | 50 |
| T, n patients | 39 | 11 | 50 |
| Total, N patients | 76 | 24 | 100 |

P = private hospital; T = public hospital.

### Table 8. Generalised linear model result for platelets*

| Source | Wald $\chi^2$ | df | $p$-value |
|--------|--------------|----|-----------|
| Gender | 4.037 | 1 | 0.047 |
| Clopidogrel | 3.938 | 1 | 0.047 |

*Dependent variable: Platelets. Model: Gender, Clopidogrel. Likelihood ratio $\chi^2=35.86, p<0.001$.

### Table 9. Summary of factors influencing the use of RCCs, FFP and platelets

| RCCs | FFP | Platelets |
|------|-----|-----------|
| Age | ✓ | ✓ |
| Hospital | ✓ | ✓ |
| Weight | ✓ | ✓ |
| Number of grafts | ✓ | ✓ |
| Aspirin | ✓ | ✓ |
| Warfarin | ✓ | ✓ |
| Gender | ✓ | ✓ |
| Clopidogrel | ✓ | ✓ |

RCCs = red cell concentrates; FFP = fresh-frozen plasma; P = private hospital; T = public hospital.

In multivariate analyses, age, body mass, the number of grafts and use of aspirin and warfarin influenced the decision to administer RCCs. However, despite the private sector hospital having significantly older patients ($p<0.05$) and performing significantly more grafts per hospital, confirming the $\chi^2$ result (Table 8).
Interestingly, although aspirin is also used to inhibit the function of platelets, and is widely used at both hospitals, it did not influence the decision to utilise platelet products.

Although a previous history of coronary interventions has been linked with an increase in blood product use,\textsuperscript{[29]} the present study was unable to demonstrate any significant difference owing to the low percentage of patients with a previous history. Additional analysis of the use of cardiopulmonary bypass machines was not relevant, as both hospitals made sole use of on-pump methods.

The use of intraoperative anticoagulants has also been shown to lead to increased blood use.\textsuperscript{[16]} Owing to the widespread use of heparin in this study and its half-dose reversal with protamine, we were not able to make any significant comparison between the two hospitals. Additionally, analysis of the antifibrinolytic medications aprotinin and tranexamic acid was irrelevant, because these products were not used by either hospital.

The efficacy of cell salvage, the process whereby blood loss during surgery is minimised by reusing it, has been well documented.\textsuperscript{[21]} Owing to the universal use of this procedure by both hospitals, a comparison of its effect on blood utilisation was not possible.

**Study limitations**

The results of this study are valuable in understanding blood use in an SA context, although the results may have some limitations. The audit was restricted to only two institutions in the Cape region, and is therefore not entirely representative of the Western Cape. For this reason, any general conclusions about blood usage practices in the public and private sector cannot be made and require the inclusion of more hospitals and centres. In addition, the study only focused on patients undergoing CAGB surgery and excluded other forms of bypass and cardiac surgery, which are also large consumers of blood products. Although every effort was made to include all relevant information, the availability of a blood bank in the private hospital and the age and type of bypass equipment were omitted. As many private hospitals do not have blood banks on site, and are likely to have newer and more efficient equipment than public hospitals, these factors could have influenced the final results.

**Conclusions**

Despite the above limitations, the results of this study suggest that there is significant variation in the transfusion of RCCs and FFP between the two hospitals. The factors influencing this, as identified by multivariate analysis, include age, gender, body mass, the number of grafts performed per surgery, and the use of anticoagulant therapy. As blood transfusion remains a risk and is associated with worse outcomes in cardiac surgery,\textsuperscript{[10]} it is recommended that further investigation, including more hospitals, be conducted, and that regional blood management systems be established to standardise blood product use.

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