Comparison of structured use of routine laboratory tests or near-patient assessment with clinical judgement in the management of bleeding after cardiac surgery


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Background. Using algorithms based on point of care coagulation tests can decrease blood loss and blood component transfusion after cardiac surgery. We wished to test the hypothesis that a management algorithm based on near-patient tests would reduce blood loss and blood component use after routine coronary artery surgery with cardiopulmonary bypass when compared with an algorithm based on routine laboratory assays or with clinical judgement.

Methods. Patients (n=102) undergoing elective coronary artery surgery with cardiac bypass were randomized into two groups. In the point of care group, the management algorithm was based on information provided by three devices, the Hepcon, thromboelastography and the PFA-100 platelet function analyser. Management in the laboratory test group depended on rapidly available laboratory clotting tests and transfusion of haemostatic blood components only if specific criteria were met. Blood loss and transfusion was compared between these two groups and with a retrospective case-control group (n=108), in which management of bleeding had been according to the clinician’s discretion.

Results. All three groups had similar median blood losses. The transfusion of packed red blood cells (PRBCs) and blood components was greater in the clinician discretion group (P<0.05) but there was no difference in the transfusion of PRBCs and blood components between the two algorithm-guided groups.

Conclusion. Following algorithms based on point of care tests or on structured clinical practice with standard laboratory tests does not decrease blood loss, but reduces the transfusion of PRBCs and blood components after routine cardiac surgery, when compared with clinician discretion. Cardiac surgery services should use transfusion guidelines based on laboratory-guided algorithms, and the possible benefits of point of care testing should be tested against this standard.


Keywords: assessment, near-patient tests; complications, bleeding diathesis; protocol, clinical

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excessive activation of fibrinolysis, depletion of coagulation factors and a reduction in platelet number and function.\textsuperscript{10–12} The causes of non-surgical bleeding in an individual patient can be multifactorial and difficult to identify. Standard haematology laboratory assays may not assess fibrinolysis and platelet dysfunction, the most important causes of non-surgical bleeding after CPB.\textsuperscript{13} A bleeding patient after CPB may therefore receive empirical treatment with protamine and blood components.\textsuperscript{13} Evidence for using blood components, such as fresh frozen plasma, platelets and cryoprecipitate, in this condition is limited and such treatment is of dubious efficacy.\textsuperscript{14} Excessive protamine administration may worsen bleeding.\textsuperscript{15}

The appropriate administration of pharmaceutical agents that affect haemostasis, including heparin, protamine, desmopressin (DDAVP) and anti-fibrinolytic agents, can decrease the blood loss associated with cardiac surgery.\textsuperscript{15–19} Treatment plans based on sequential perioperative near-patient haemostatic testing may be helpful. Studies have shown reduced use of blood components compared with clinician discretion,\textsuperscript{19–22} but these studies have not been compared with strict transfusion triggers and routine laboratory haematology testing.

We set out to compare prevention and management of bleeding after CPB in a group using point of care (POC) haemostatic assessment with a group managed using standard haematology laboratory tests (laboratory algorithm-guided (LAG)). In these two groups, transfusion of blood and components was based on the use of strict transfusion triggers. A third, retrospective group, managed by the same clinicians who had used clinical discretion, was also included.

We compared postoperative blood loss and the transfusion of packed red blood cells (PRBCs) and blood components in the POC, LAG and historical control groups. Another question was whether there were differences in the point of care test results between the LAG and POC groups in post hoc analysis.

**Methods**

Local ethics committee approval and written informed consent were obtained. Sequential patients for elective, first-time coronary artery bypass graft (CABG) surgery with CPB treated by the same surgical, intensivist and anaesthetic teams were invited to take part. Patients with preoperative abnormal clotting tests, including international normalized ratio (INR) >1.5, activated partial thromboplastin time (APTT) >1.5 or platelet count <150 × 10\textsuperscript{9} litre\textsuperscript{−1}, were excluded. The APTT ratio is the ratio between a patient’s APTT and a laboratory control APTT. Any medication affecting coagulation within 72 h of surgery, including warfarin, heparin, low molecular weight heparin, aspirin and clopidogrel, was also an exclusion criterion.

Patients were randomized into two groups of 51 patients where bleeding was managed and transfusion triggers were set either by an algorithm based on near-patient haemostatic testing or by an algorithm using routine laboratory haemostatic tests. A third, retrospective matched group of 108 patients who had undergone routine CABG surgery with the same clinical team over a 4-month period preceding the interventional study was included. They had received blood components on the basis of individual clinician’s discretion. This third group was included to reflect transfusion practice for routine CABG surgery at King’s College Hospital before this study. The study design is shown in Figure 1.

Anaesthesia was induced with an intravenous induction agent, typically thiopentone or propofol. Maintenance of anaesthesia was with a combination of isoflurane and propofol. A single dose of an intermediate-acting non-depolarizing muscle relaxant, vecuronium or rocuronium, was administered after induction of anaesthesia. Each patient was given fentanyl 500–1000 μg. Some patients received morphine (10–15 mg) for additional analgesia. During CPB, patients were cooled to 32°C.

**Details of haemostatic management**

Patients in the tested groups were given tranexamic acid 15 mg kg\textsuperscript{−1} before surgery. Most patients in the clinician discretion group received low-dose aprotinin (1 Mu load and 1 Mu in the cardiopulmonary bypass prime) or tranexamic acid (10–15 mg kg\textsuperscript{−1}) according to the discretion of the attending physician.

The LAG algorithm was developed after consulting the British Society for Haematology guidelines, the American Society of Anesthesiologists’ guidelines,\textsuperscript{23 24} and current available data on aprotinin and DDAVP.\textsuperscript{19 25} The management of the LAG group is shown in Figure 2. Aprotinin (2 Mu) and desmopressin (0.4 μg/kg) were given to patients who bled >100 ml h\textsuperscript{−1} within 24 h after surgery.\textsuperscript{19 25} After this, four units of fresh frozen plasma were administered if patients were still bleeding >100 ml h\textsuperscript{−1} and the INR or APTT ratio were more than
1.5 times the control value. A platelet pool was transfused if excessive bleeding persisted or the platelet count was less than 50,000 litre⁻¹. Laboratory clotting tests were requested only for patients who had increased bleeding.

At King’s College Hospital, results from urgent full blood count (FBC) and laboratory clotting tests are available 30–45 min after the specimens are delivered to the laboratory. Point of care haemostatic tests were run for these patients, but investigators were blinded to the results. These tests were run so that retrospective analysis could be done after completion of the study to determine whether knowledge of these results might have altered management in these patients. The transfusion trigger for red cell transfusion was a haemoglobin concentration less than 8 g dl⁻¹.

Fig 2 Management of laboratory algorithm guided (LAG) and point of care (POC) groups. ACT=activated clotting time; CPB=cardiopulmonary bypass; INR=international normalized ratio; APTT=activated thromboelastin time; FBC=full blood count; HDR=heparin dose response; TEG=thromboelastography; HPT=heparin protamine titration.

All patients in the clinician discretion group had undergone elective first-time CABS surgery and had been managed according to standard clinical practice at our institution. This entailed administering heparin to achieve an ACT > 480 s for the duration of CPB, reversing heparin with a protamine to heparin ratio of 1 mg per 100 units of total heparin administered and treating excessive post-operative bleeding according to the attending clinicians’ discretion, which typically included protamine 50 mg, and empirical transfusion of 4 units of fresh frozen plasma and a pool of platelets. They were not bound by any transfusion trigger for PRBCs.

Data on blood loss and blood component use were recorded. For 24 h after surgery, blood loss into chest tube drains and all fluids and blood components administered were recorded. This was done by staff in the special recovery unit, who were not aware of study group allocations.

Near-patient tests

**ACT**

The ACT+/Junior (Hemochron®; ITC, Edison, NJ, USA) is a modification of the standard ACT machine, which requires only two drops of blood and is operator-independent.

**Hepcon**

The Hepcon HMS Hemostasis Management System® (Medtronic; Minneapolis, MN, USA) device has six channels. In each channel, a plastic rod is rapidly lifted and dropped by an oscillating metal bar. Fresh blood is automatically placed into each channel by a 3 ml syringe inserted into the machine. The time for blood to clot is displayed for each channel. Tests currently available include the ACT, heparin dose response (HDR) and heparin assay by heparin/protamine titration (HPT). The HDR is intended to identify the dose of heparin required to achieve adequate anticoagulation in individual patients. The HPT facilitates the maintenance of patient-specific heparin levels
Table 1 Patient characteristics (median (interquartile range)). There were no significant differences among groups in any characteristic. LAG=labouratory algorithm-guided; POC=point of care; CD=clinician discretion; INR=international normalized ratio

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>LAG group (n=51)</th>
<th>POC group (n=51)</th>
<th>CD group (n=108)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>62 (57–70)</td>
<td>66 (58–71)</td>
<td>67 (60–72)</td>
</tr>
<tr>
<td>Male: number (%)</td>
<td>39 (76)</td>
<td>41 (80)</td>
<td>85 (78)</td>
</tr>
<tr>
<td>Female: number (%)</td>
<td>12 (24)</td>
<td>10 (20)</td>
<td>24 (22)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>78 (72–88)</td>
<td>83 (76–95)</td>
<td>79 (70–87)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172 (167–175)</td>
<td>170 (165–176)</td>
<td>170 (165–176)</td>
</tr>
<tr>
<td>Preoperative prothrombin time</td>
<td>0.92 (0.8–0.93)</td>
<td>0.93 (0.9–0.94)</td>
<td>0.94 (0.9–0.95)</td>
</tr>
<tr>
<td>Preoperative APTT ratio</td>
<td>0.92 (0.87–0.96)</td>
<td>0.9 (0.86–0.95)</td>
<td>0.94 (0.9–0.97)</td>
</tr>
<tr>
<td>Cardiopulmonary bypass time (min)</td>
<td>76 (66–84)</td>
<td>81 (69–93)</td>
<td>81 (70–96)</td>
</tr>
</tbody>
</table>

Adherence to algorithms decreases after CABG transfusion

During CPB and calculates the optimal protamine dose to reverse heparin. This test also detects residual heparin effect after initial protamine administration. The PFA-100® (Dade Behring, Deerfield, IL, USA) platelet function analyser is an in vitro system that provides a measure of platelet function in citrated whole blood. It is superior to the bleeding time in demonstrating patients with platelet-endothelial bleeding disorders, such as von Willebrand’s disease. The PFA-100 assesses the time taken for a platelet plug to occlude a microscopic aperture within a membrane coated with platelet agonists, collagen and either epinephrine or adenosine 5′-diphosphate (ADP). A citrated blood sample of 800 μl is added to a reservoir well in a disposable cartridge. The instrument aspirates the blood sample under constant vacuum through a capillary and the microscopic aperture. The coated membrane, coupled with the high shear force that is generated, results in the attachment, activation and aggregation of platelets, which eventually form a stable platelet plug at the aperture. The time that is taken to occlude the membrane is known as the ‘closure time’.

Thromboelastography

Two dual-channel Thromboelastograph (TEG) Coagulation Analysers (Haemoscope; Niles, IL, USA) were used in parallel, connected to a notebook computer. The thromboelastographs underwent regular quality control and calibration. All thromboelastography measurements were performed with the machines prewarmed to 37°C. The thromboelastography values recorded included reaction time (R), α angle, maximal amplitude (MA) and lysis index at 30 min (LY30, percentage reduction of MA 30 min after the MA). R represents the time to initial clot formation, the α angle relates to the rate of clot extension, MA relates to clot strength and the lysis indices reflect the extent of fibrinolysis present.

Recombinant tissue factor was used as an activator for the thromboelastographs, as described in previous studies. Recombinant tissue factor (TF; Innovin®; Dade Behring, Milton Keynes, UK) was diluted to a concentration of 1:120. Thirty-seven microlitres of this solution was decanted into 1 ml plastic containers, which were stored at −20°C and warmed to room temperature before the thromboelastography test. One millilitre of fresh blood was added to the containers to yield an equivalent final TF concentration of 0.3 μl per ml of blood. Three hundred and sixty microlitres of this blood was decanted into a thromboelastograph cup and the thromboelastography was started exactly 4 min after the blood sample had been withdrawn from each patient. During CPB, heparinase-coated thromboelastograph cups were used to eliminate the anticoagulant properties of heparin.

Statistics

For comparison between three groups, with the incorporation of Bonferroni correction, results would be deemed significant with P < 0.025. With 43 patients in each of the three groups, the study would be powered (80%) to detect a 15% difference among groups in postoperative blood loss after routine cardiac surgery at King’s College Hospital with a P value of 0.01. This power calculation was based on a mean 24-h postoperative blood loss of 1000 ml with a standard deviation of 200 ml. With 50 patients in each of the algorithm groups and 100 patients in the clinician discretion group, the study would be powered (80%) to detect a decrease from 15% to 0% in the proportion of patients receiving fresh frozen plasma or platelets among the groups (P=0.01). Fifteen per cent is the current proportion of patients receiving fresh frozen plasma and platelets after routine CABG surgery at King’s College Hospital and elsewhere in the UK. With 50 patients in each of the algorithm groups, and 100 patients in the clinician discretion group, the study was powered (80%) to detect a decrease in the proportion of patients receiving PRBCs from 90% to 70% among the groups (P=0.008). Ninety per cent is the current proportion of patients receiving PRBCs after routine CABG surgery at King’s College Hospital and elsewhere in the UK. We allocated patients into the groups with sealed envelopes. Investigators were not blinded to group allocation. Those measuring and documenting post-
operative bleeding were blinded to group allocation. Distribution of continuous data was assessed with the Shapiro–Wilks test of normality. Results were generally not normally distributed and non-parametric statistical tests were therefore used. Kruskal–Wallis one-way ANOVA was used for comparisons among continuous variables. Results are expressed as medians (interquartile ranges). The \( \chi^2 \)-test was applied to categorical data, such as the number of patients receiving PRBC, platelet and fresh frozen plasma transfusions.

\( P < 0.025 \) was regarded as significant for comparisons among the three groups. The Mann–Whitney \( U \)-test was used for comparisons between the POC and LAG groups. The Wilcoxon signed ranks test was used for paired comparisons within groups. \( P < 0.05 \) was regarded as significant. Multivariate stepwise regression analysis was done to determine whether any point of care or laboratory coagulation test parameters predicted postoperative blood loss.

Results

Complete data were collected on all patients enrolled in the study and no participant was excluded from the analysis. Patient characteristics are shown in Table 1. Perioperative fluid administration (including during CPB) was similar in most patients and is shown in Table 2. The main results from the study are summarized in Tables 2 and 3.

The median blood loss was not significantly different among the groups (Table 2). Patients in the clinician discretion group received significantly more (\( P < 0.025 \)) transfusions of blood components (packed red cells, fresh frozen plasma and pooled platelets) compared with those in the LAG and POC groups. There were no significant differences in this regard between the LAG and POC groups. A summary of numbers of units transfused to each group is as follows. The clinician discretion group (\( n = 108 \)) received 285 units of PRBCs, 14 units of platelets and 65 units of fresh frozen plasma. The LAG group (\( n = 51 \)) received 93 units of PRBCs, 2 units of platelets and 0 units of fresh frozen plasma. The POC group (\( n = 51 \)) received 99 units of PRBCs, 3 units of platelets and 6 units of fresh frozen plasma. The volume of PRBCs transfused to each group was as follows: LAG group: median = 495 ml (interquartile range (IQR) = 0 to 612); POC group: median = 500 ml (IQR = 0 to 678 ml); clinician discretion group: median = 512 ml (IQR = 286 to 962 ml); \( P = 0.03 \) (Kruskal–Wallis ANOVA).

The results of the near-patient tests are shown in Table 4. There were no differences between the LAG and POC groups in the point of care test results. Postoperative blood loss with normal and abnormal point of care test results for

<table>
<thead>
<tr>
<th>Variable</th>
<th>LAG group (( n = 51 ))</th>
<th>POC group (( n = 51 ))</th>
<th>CD group (( n = 108 ))</th>
<th>( P (\chi^2 \text{ test}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postoperative 24 h blood loss (ml)</td>
<td>850 (688–1095)</td>
<td>755 (606–975)</td>
<td>810 (550–1295)</td>
<td>0.01</td>
</tr>
<tr>
<td>Postoperative haemoglobin (g dl(^{-1}))</td>
<td>9.3 (8.5–9.7)</td>
<td>9.3 (8.4–10.3)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Postoperative 24 h haemoglobin (g dl(^{-1}))</td>
<td>9.9 (9–10.8)</td>
<td>10.1 (9–10.9)</td>
<td>10.1 (9.6–10.8)</td>
<td>N/A</td>
</tr>
<tr>
<td>Postoperative platelet count (( \times 10^9 ) litre(^{-1}))</td>
<td>140 (111–168)</td>
<td>131 (110–165)</td>
<td>149 (123–187)</td>
<td>N/A</td>
</tr>
<tr>
<td>Postoperative 24 h platelet count (( \times 10^9 ) litre(^{-1}))</td>
<td>159 (135–200)</td>
<td>149 (123–187)</td>
<td>144 (121–174)</td>
<td>0.003</td>
</tr>
<tr>
<td>Heparin loading dose ( \times 100 ) (units)</td>
<td>310 (280–360)</td>
<td>250 (205–313)</td>
<td>230* (200–250)</td>
<td>N/A</td>
</tr>
<tr>
<td>Total heparin dose ( \times 100 ) (units)</td>
<td>480 (420–560)</td>
<td>505 (421–553)</td>
<td>330* (300–350)</td>
<td>N/A</td>
</tr>
<tr>
<td>Total protamine dose (mg)</td>
<td>240 (210–280)</td>
<td>353 ² (292–403)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Intra-operative crystalloid (ml)</td>
<td>2000 (1550–2000)</td>
<td>2000 (1100–2000)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Intra-operative colloid (ml)</td>
<td>1000 (1000–1500)</td>
<td>1000 (1000–1250)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Postoperative 24 h crystalloid (ml)</td>
<td>2892 (2580–3244)</td>
<td>2845 (2478–3215)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Postoperative 24 h colloid (ml)</td>
<td>2500 (2000–2980)</td>
<td>2000 (2000–2500)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Postoperative 24 h urine (ml)</td>
<td>2792 (2297–3350)</td>
<td>2740 (2356–3259)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Time to extubation after surgery (min)</td>
<td>255 (180–355)</td>
<td>262 (181–370)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blood component</th>
<th>LAG group (( n = 51 ))</th>
<th>POC group (( n = 51 ))</th>
<th>CD group (( n = 108 ))</th>
<th>( P (\chi^2 \text{ test}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packed red blood cells</td>
<td>35 (69)</td>
<td>34 (68)</td>
<td>92 (85)</td>
<td>0.01</td>
</tr>
<tr>
<td>Fresh frozen plasma</td>
<td>0</td>
<td>2 (4)</td>
<td>16 (15)</td>
<td>0.003</td>
</tr>
<tr>
<td>Platelets</td>
<td>1 (2)</td>
<td>2 (4)</td>
<td>14 (13)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*Table 2 Results. For each value, the median and interquartile range are presented. The usual intraoperative colloid was 6% hydroxyethyl starch in normal saline (308 mosmol litre\(^{-1}\), molecular weight 200 kDa, degree of substitution 0.5). The usual postoperative colloid was modified fluid gelatin. The usual crystalloid fluid was Ringer’s lactate. \( * P < 0.025 \) (Kruskal–Wallis ANOVA); \( \text{² } P < 0.05 \) (Mann–Whitney \( U \)-test). LAG=labatory algorithm-guided; POC=point of care; CD=clinician discretion; N/A=not available.
Adherence to algorithms decreases after CABG transfusion

Table 4 Baseline and immediate postoperative point of care test results in the algorithm groups (median (interquartile range)). There were no significant differences between the POC and LAG groups. *P<0.05 compared with baseline value (Wilcoxon signed ranks test). Normal values for the POC tests are as follows: platelet function analyser ADP closure time <120 s; epinephrine closure time <170 s; tissue factor thromboelastograph R time <10 min and MA >50 mm; activated clotting time <120 s. POC=point of care; LAG=labatory algorithm-guided.

<table>
<thead>
<tr>
<th>POC device</th>
<th>Test</th>
<th>LAG group</th>
<th>POC group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platelet function analyser</td>
<td>ADP cartridge baseline closure time (s)</td>
<td>88 (74–101)</td>
<td>91 (76–105)</td>
</tr>
<tr>
<td>Platelet function analyser</td>
<td>ADP cartridge postoperative closure time (s)</td>
<td>89 (78–108)</td>
<td>91 (76–111)</td>
</tr>
<tr>
<td>Platelet function analyser</td>
<td>Epinephrine cartridge baseline closure time (s)</td>
<td>133 (120–165)</td>
<td>128 (111–160)</td>
</tr>
<tr>
<td>Platelet function analyser</td>
<td>Epinephrine cartridge postoperative closure (s)</td>
<td>177* (126–300)</td>
<td>225* (161–300)</td>
</tr>
<tr>
<td>Thromboelastography</td>
<td>Baseline R value (min)</td>
<td>4.5 (3.5–6.1)</td>
<td>5.7 (4.4–7.1)</td>
</tr>
<tr>
<td>Thromboelastography</td>
<td>Postoperative R value (min)</td>
<td>8.2* (5.8–13)</td>
<td>7.5* (6–11.5)</td>
</tr>
<tr>
<td>Thromboelastography</td>
<td>Baseline MA value (mm)</td>
<td>65 (61.5–69)</td>
<td>65 (61.6–68.5)</td>
</tr>
<tr>
<td>Thromboelastography</td>
<td>Postoperative MA value (mm)</td>
<td>51.5* (46.5–56.5)</td>
<td>56* (50–60)</td>
</tr>
<tr>
<td>Activated clotting time</td>
<td>Baseline ACT (s)</td>
<td>104 (97–111)</td>
<td>109 (101–113)</td>
</tr>
<tr>
<td>Activated clotting time</td>
<td>Postoperative (s)</td>
<td>114* (108–118)</td>
<td>116* (107–124)</td>
</tr>
</tbody>
</table>

Table 5 Postoperative blood loss (median (interquartile range)) in the combined algorithm (LAG and POC) groups. Blood loss is presented for normal and abnormal point of care test results. *Blood loss significantly increased with abnormal test result (P<0.03, Mann–Whitney U-test). PFA=platelet function analyser.

<table>
<thead>
<tr>
<th>Postoperative test</th>
<th>Blood loss (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFA: ADP closure &lt;120 s</td>
<td>775 (608–969)</td>
</tr>
<tr>
<td>PFA: ADP closure &gt;120 s</td>
<td>838 (753–925)</td>
</tr>
<tr>
<td>PFA: epinephrine closure &lt;170 s</td>
<td>788 (650–944)</td>
</tr>
<tr>
<td>PFA: epinephrine closure &gt;170 s</td>
<td>800 (600–975)</td>
</tr>
<tr>
<td>Thromboelastography R time &lt;10 min</td>
<td>775 (625–906)</td>
</tr>
<tr>
<td>Thromboelastography R time &gt;10 min</td>
<td>850 (656–1101)</td>
</tr>
<tr>
<td>Thromboelastography MA &gt;50 mm</td>
<td>750 (598–925)</td>
</tr>
<tr>
<td>Thromboelastography MA &lt;50 mm</td>
<td>850* (731–1146)</td>
</tr>
<tr>
<td>Thromboelastography lysis 30 &lt;2.5%</td>
<td>788 (608–950)</td>
</tr>
<tr>
<td>Thromboelastography lysis 30 ≥2.5%</td>
<td>813 (708–1105)</td>
</tr>
<tr>
<td>Junior ACT &lt;120 s</td>
<td>923 (810–1036)</td>
</tr>
<tr>
<td>Junior ACT &gt;120 s</td>
<td>797 (624–966)</td>
</tr>
</tbody>
</table>

Discussion

It is interesting that an algorithm using treatment based on standard laboratory haemostatic testing was as effective as an algorithm based on point of care testing. It is also notable that there was no difference in the point of care test results when analysed retrospectively between the POC and LAG groups. Previous studies assessing point of care testing in association with cardiac surgery have concluded that these tests reduce blood component use. These studies, however, may have been limited by their use of clinician discretion in the control groups.

An important finding of this study is that when transfusion of blood components after cardiac surgery depends on the clinician’s discretion, unnecessary transfusion resulted. This can be confidently asserted because while blood loss was not significantly different in all three groups, transfusion was greater in the clinician discretion group.

There is worldwide concern over the inappropriate use of blood components in view of their costs and numerous complications, which include immunosuppression, alloimmunization and risks of transfusion-transmitted infection, in addition to haemolytic and non-haemolytic transfusion reactions. The unknown risks of transmission of variant Creutzfeldt–Jacob disease by blood transfusion are of particular concern in the UK and accentuate the need for the appropriate use of blood components. Clinicians responsible for prescribing blood products need to be able to justify every transfusion. The health service circular Better Blood Transfusion has highlighted the clinical governance issues and the need to research and review the treatment with blood components. Thus, the use of clinical algorithms to rationalize the use of blood components is of increasing interest to clinical risk management teams.

A limit of this study design is the use of both prospective and retrospective data. However, blood loss was not significantly different in all three groups and was comparable with blood loss reported in other studies. Similarly, the proportion of patients who received PRBC transfusions in the clinician discretion group (85%) was similar to proportions reported elsewhere (82–92%).
One important concern about the study is that the point of care algorithm may be suboptimal. Point of care haemostatic testing is a developing field and better use of this technology may be possible. Specific near-patient tests were selected for the following reasons. Thromboelastography has been used in several algorithms where it has decreased postoperative bleeding and transfusion. Thromboelastography, unlike standard haematology laboratory tests, provides information about platelet function and fibrinolysis. The PFA-100 is comparable with platelet aggregometry in detecting platelet dysfunction. Unlike thromboelastography, the PFA-100 is sensitive enough to detect the effects of aspirin on platelet function. Routine use of the Hepcon has been associated with decreased postoperative bleeding. Heparin is individualized for patients with either heparin sensitivity or heparin resistance, both of which occur commonly. Similarly, protamine dose is calculated by the blood heparin concentration at the end of CPB.

The finding that platelet pools and fresh frozen plasma were seldom indicated after routine CABG with CPB is consistent with previous studies, which have not demonstrated benefit from empirical administration of either fresh frozen plasma or platelets after cardiac surgery. At our institution and according to several publications, the administration of blood products after routine cardiac surgery has been a common practice (between 10 and 20% of patients). In a recent study showing a reduction in PRBC transfusion with cell salvage techniques for routine CABG surgery, the transfusion rates for fresh frozen plasma (16%) and platelets (16%) were surprisingly high. If some of the treatment is unwarranted, this exposes patients to unnecessary risk. For example, fresh frozen plasma and platelets have been implicated in causing transfusion-related acute lung injury, which is one of the most common causes of morbidity and mortality after transfusion.

Strict adherence to an evidence-based algorithm coupled with either laboratory tests of coagulation or point of care tests decreased PRBC and blood component transfusion after routine CABG surgery with CPB compared with a historical control group where transfusion was according to clinician discretion. Our study does not support routine point of care tests, with the proviso that clinicians follow an algorithm based on laboratory results, which are rapidly available. These results may not be applicable to patients who are at high risk of bleeding. The high negative predictive value for postoperative bleeding of the information provided by thromboelastography and the PFA-100 may be particularly valuable. Although no point of care results predicted bleeding, it is interesting that in our low-risk cohort of patients there was a significant difference in the thromboelastograph MA between those who bled excessively and those who did not. Waiting over an hour for laboratory coagulation results may be unacceptable in certain situations and may also increase hospital costs if time to extubation and time spent in intensive care units is increased. POC diagnostic tests provide immediate information and may also decrease costs.

Blood is a scarce resource, and the introduction of variant Creutzfeldt-Jakob disease testing could potentially even further decrease the donor pool, with estimates that up to 50% of active donors could be lost. In the north of England approximately 4.1% of all PRBCs produced are used perioperatively for CABG surgery. The National Blood Service for England issues approximately 2.2 million units of blood a year. If, instead of using their own discretion to judge the need for blood and blood components, clinicians based these decisions on an effective algorithm, there would be potential to decrease national blood and blood component transfusions. Based on the findings of this study, the introduction of a transfusion algorithm for CABG surgery in England alone could save 9000 units of blood a year if the transfusion rate was decreased by 10%. In this era of clinical governance it appears unacceptable to allow clinician discretion alone to determine PRBC and blood component transfusion. Cardiac surgery services should institute transfusion guidelines based on strict transfusion triggers and laboratory-guided algorithms, and the possible benefits of point of care testing should be assessed against this standard.

Contributors
MSA and BJH had the original idea. MSA and BJH designed the study and obtained funding. MSA, ELA, JDF, JP and JBD recruited participants, performed the POC tests and collected data. MSA and GJD carried out data analysis. MSA, BJH and GJD prepared the manuscript, which was reviewed by all authors. MSA and BJH are the guarantors.

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