Original Article

Utility of Sonoclot in Prediction of Postoperative Bleeding in Pediatric Patients Undergoing Cardiac Surgery for Congenital Cyanotic Heart Disease: A Prospective Observational Study

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Objectives: To assess the utility of Sonoclot in prediction of postoperative bleeding in pediatric patients undergoing cardiac surgery with cardiopulmonary bypass for congenital cyanotic heart disease.

Design: Prospective, observational study.

Setting: Single university hospital.

Participants: Eighty-seven pediatric patients undergoing cardiac surgery for congenital cyanotic heart disease.

Interventions: Laboratory coagulation parameters (prothrombin time, international normalization ratio, activated partial thromboplastin time, fibrinogen, D-dimer) as well as point-of-care Sonoclot glass bead activation time, clot rate, and platelet function (gbPF) were done before induction of anesthesia and following heparin reversal after termination of cardiopulmonary bypass (CPB) in all patients.

Measurements and Main Results: Postoperative blood loss was monitored by the amount of chest tube drainage. The primary outcome was to define Sonoclot parameters for prediction of postoperative bleeding. Secondary outcomes studied were amount of postoperative blood loss, transfusion requirement of various blood products, incidence of surgical re-exploration, duration of postoperative mechanical ventilation, intensive care unit and hospital stay. Among studied subjects, 37.9% (33 of 87 patients) were designated as bleeders while 62.1% (54 of 87 patients) were non-bleeders. Lower age, D-dimer, and gbPF test after termination of CPB following heparin neutralization were predictive for postoperative bleeders. Among these, post-protamine gbPF had the highest area under the curve (0.725), 95% confidence interval (0.619-0.831) for prediction of postoperative bleeders. Duration of mechanical ventilation (26.41 ± 36.44 vs 8.25 ± 6.36 h, respectively, p = 0.001), intensive care unit stay (7.36 ± 4.05 vs 4.96 ± 2.49, p = 0.001), and hospital stay (11.69 ± 4.82 vs 6.36 ± 3.48 p = 0.001) were higher in bleeders; however, incidence of re-exploration was comparable between both groups.

Conclusion: Postoperative bleeders may be predicted independently by post-CPB gbPF, postoperative D-dimer, and lower age of patients. Among these, post-CPB gbPF has maximum predictive value.

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Key Words: pediatric cyanotic heart disease; Sonoclot; laboratory tests; postoperative bleeding predictors

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PEDIATRIC CONGENITAL CYANOTIC heart disease patients undergoing cardiopulmonary bypass (CPB) cardiac surgery are at high risk of postoperative bleeding and allo- geneic blood transfusion.\(^1\) Besides surgical and CPB-induced alteration in coagulation cascade, these patients often have pre-existing coagulation factor deficiency and platelet dysfunction due to persistent chronic hypoxemia and low-cardiac-output syndrome.\(^2\) Perioperative transfusion of fresh frozen plasma (FFP), platelets, and cryoprecipitate are associated with multiple transfusion-related complications such as acute lung injury, acute kidney injury, and nosocomial infections, leading to significant morbidity and mortality.\(^3,4\) Early identification of patients who are likely to bleed may decrease overall blood loss and transfusion requirements by instituting early therapeutic intervention.

Laboratory tests for coagulation have an average turnaround time of 45-60 minutes. They reflect initial thrombin formation and do not consider the role of corpuscular elements of blood in coagulation or give information about clot stability and fibrinolysis.\(^5\) Point-of-care viscoelastic tests provide results in 5-to-10 minutes. These tests are cost-saving and more effective than standard laboratory tests.\(^6\) Thromboelastography (TEG) has shown higher specificity for postoperative bleeding as compared with standard coagulation tests.\(^7\) Sonoclot (Sienco, Inc, Boulder, CO) is another point-of-care test for the viscoelastic properties of blood that is more economical and easy to conduct.\(^8\) In the adult population, post-CPB deranged Sonoclot parameters have shown to correlate well with postoperative bleeding.\(^9\) However, its role in the prediction of postoperative bleeding in pediatric congenital cyanotic heart disease patients undergoing cardiac surgery has not been evaluated so far.

The authors hypothesized that Sonoclot will be able to predict postoperative bleeding at a predefined time, ie, at induction of anesthesia or after heparin reversal following termination of CPB in pediatric congenital cyanotic heart disease patients undergoing cardiac surgery. The primary outcome of this study was to define Sonoclot parameters for prediction of postoperative bleeding. Secondary outcomes included amount of postoperative blood loss, transfusion requirement of various blood products, incidence of surgical re-exploration, duration of postoperative mechanical ventilation, intensive care unit (ICU) stay, and hospital stay.

Methods

The study was conducted at the cardiothoracic center of a tertiary care hospital from January 2015 to June 2016. After obtaining institute ethics committee approval and written informed consent from parents, 87 patients aged between 6 months and 14 years, undergoing cardiac surgery using CPB for cyanotic congenital heart disease, were enrolled in this prospective observational study. Patients with preoperative deranged liver or renal function and those who received anticoagulant or antiplatelet drugs within one week of surgery were excluded.

Patients were premedicated with 0.5 mg/kg of oral midazolam in the preoperative holding area. Induction of anesthesia was performed using sevoflurane inhalation and intravenous fentanyl (2.5 µg/kg). Vecuronium (0.1mg/kg) was used to facilitate endotracheal intubation. Anesthesia was maintained using isoflurane inhalation, intravenous fentanyl (continuous infusion, 1 µg/kg/h, and intermittent boluses, 2 µg/kg, up to a total of 10-15 µg/kg during surgery), and vecuronium. Monitoring included electrocardiography, pulse oximetry, central venous pressure, invasive blood pressure, nasopharyngeal temperature, urine output, and intermittent arterial blood gas analysis. All children received intravenous dexamethasone, 0.3 mg/kg, and epsilon aminocaproic acid, 100 mg/kg, at induction of anesthesia followed by 10 mg/kg/h of continuous infusion until the end of surgery.

Heparin, 300 IU/kg, was used to achieve anticoagulation before onset of CPB. During CPB, activated clotting time (ACT) value > 480 seconds was maintained by using additional doses of heparin (100 IU/kg). The CPB circuit consisted of a roller pump (Sarns 8000; Terumo, Tokyo, Japan) and membrane oxygenator. The circuit was primed using Plasmalyte, 20% mannitol (1.5 mL/kg), heparin (5000 IU/L), and blood as needed to maintain hematocrit 30% during CPB. The prime volume was determined based on the type of oxygenator needed for the child’s body weight. For patients requiring pump flow up to 1.2 L/min, the neonatal oxygenator (Sorin, Lillypoot D901, Mirandola Modena, Italy) with priming volume of 220-300 mL was used; for flow between 1.2-2.5 L/min, the pediatric oxygenator (Sorin, Lillypoot D902, Mirandola Modena, Italy) with prime volume of 450-600 mL; and for flows above 2.5 L/min, the Diodeco Evoflow oxygenator (Sorin, Mirandola Modena, Italy) with prime volume of 1-1.2 L. Moderate hypothermia (28ºC-30ºC) and pump flow between 2.4-2.8 L/min/m² were maintained during CPB. Cold, intermittent potassium-based blood cardioplegia was used to achieve myocardial protection. Ultrafiltration was used during CPB to achieve zero balance in all patients. Termination of CPB was facilitated using appropriate doses of inotropes as deemed necessary by the attending anesthesiologist. After termination of CPB, heparin was neutralized with equivalent doses of protamine (1:1 ratio of total initial dose of heparin). If the ACT value remained more than 20% of baseline value, additional protamine, 1 mg/kg, was administered up to a maximum dose of 1.5 mg/100 IU of heparin and ACT value was checked again. In case of absence of clot in the surgical field and presence of obvious clinical bleeding despite normal ACT value, patients were transfused with FFP and platelet concentrate (10 mL/kg each) after obtaining blood samples for Sonoclot analysis and laboratory tests. The decision to transfuse blood and blood products was made by personnel not involved in the study (attending anesthesiologist in consultation with operating surgeon) depending upon amount of blood loss in the surgical field and hemoglobin drop in sequential arterial blood gas (transfusion trigger hemoglobin 10 gm% or 2 gm% decrease from baseline). All patients were shifted to the ICU for elective mechanical ventilation. Patients who received blood or blood products on the table due to clinically significant bleeding were classified as intraoperative bleeders.

Blood samples for laboratory tests (prothrombin time [PT] and activated partial thromboplastin time [aPTT], international Please cite this article as: Rajkumar V, et al. (2017), http://dx.doi.org/10.1053/j.jvca.2017.02.002
Patients with postoperative chest drainage more than 8 mL/kg drainage recorded at 4, 8, 12, and 24 hours of ICU stay. Using the method described by Kamada et al,13 ie, 

\[
\frac{a}{b}\times 100\% \text{ where } a \text{ is maximum clot strength and } b \text{ is the clot strength at 15 minutes after the "a" level.}
\]

Strength at 15 minutes after the induction of anesthesia and after termination of CPB following reversal of heparin but before transfusion of blood products and closure of the chest. For laboratory study, blood was collected in vacutainer citrate tubes containing 0.3 mL of sodium citrate. The quantity of sodium citrate was reduced for patients with hematocrit of more than 60%, using the formula: citrate volume required (mL) = \((100 - \text{hematocrit}) \times 2.7/(595 - \text{hematocrit})\). Sonoclot analysis included glass bead activation time (gbACT), clot rate (gbCR), and platelet function (gbPF). Diminishing rate of clot strength 15 minutes after maximum strength (DR15) that reflects clot retraction and lysis over a period of 15 minutes was used to assess fibrinolysis. DR15 value was calculated using the method described by Kamada et al,13 ie, 

\[
\frac{a-b}{a}\times 100\% \text{ where } a \text{ is maximum clot strength and } b \text{ is the clot strength at 15 minutes after the "a" level (Fig 1).}
\]

Postoperative blood loss was monitored by chest tube drainage recorded at 4, 8, 12, and 24 hours of ICU stay. Patients with postoperative chest drainage more than 8 mL/kg during the first 4 hours in the ICU were designated as bleeders.14 Type and amount of blood product transfusion in the ICU were decided by the ICU physician who was not involved in the study and blinded to the result of Sonoclot analysis. Patients were transfused with packed red blood cells (PRBC) to maintain hematocrit of 30%. Amount of postoperative PRBC, platelets and FFP transfused, need of surgical re-exploration, duration of mechanical ventilation, ICU stay, and hospital stay were noted.

Statistical Analysis

Statistical analysis was performed using SPSS software (IBM SPSS Statistics 21, Chicago, IL) for Windows. Sample size for the study was calculated based on the difference in the mean gbPF and SD between bleeders and non-bleeders in a previous study, which showed significantly deranged gbPF after termination of CPB among adult bleeders as compared with non-bleeders (1.5 ± 0.9 vs 2.6 ± 1.5, respectively).12 Considering at least similar derangement in cyanotic children (mean difference in gbPF between bleeders and non-bleeders 1.1 and SD of 1.4) with test power of 80% and an alpha error level of 0.05, a sample of 26 bleeders were needed for the study. The incidence of bleeders was about 33% in the previous study;15 therefore, to yield test power of 80% for comparison of bleeders and non-bleeders three times the number of bleeders, ie, 78 subjects, were needed. The authors enrolled 87 patients after taking into account a 10% loss of follow-up during the study.

For statistical analysis, patients were grouped dichotomously into “bleeders” and “non-bleeders” as per predefined criteria. All data were tested for normality using the Kolmogorov–Smirnov test. Values were expressed as mean ± standard deviation or median ± range, as appropriate. Continuous variables were compared using an independent t-test for parametric data and Mann–Whitney U test for non-parametric data. For categorical variables, comparisons were performed using chi-square test. To find variables that could predict bleeders, a univariate analysis was performed using laboratory parameters and Sonoclot parameters obtained at baseline and at the end of surgery after heparin neutralization. In the second step, those parameters associated significantly with bleeders were included in a multivariate regression analysis to predict factors independently associated with bleeders. In addition prediction for bleeding was tested using area under the receiver operating characteristic curve for bleeders. A p value < 0.05 was considered as statistically significant.

Results

A total of 106 patients were screened for enrollment in the study; 15 patients were aged < 6 months while the initial surgical plan changed to shunt procedure in 4 patients. Of those, 87 patients fulfilled the inclusion criteria and completed the study. Among the studied subjects, 37.9% (33 of 87) turned out to be bleeders and the remaining 62.1% (54 of 87) were designated as non-bleeders. Of the 33 bleeders, 5 patients received blood products during the intraoperative period for clinically significant bleeding and were designated as intraoperative bleeders. Patients in the bleeder group were younger than non-bleeders (p < 0.001) (Table 1). Other demographic characteristics like sex ratio, duration of CPB, duration of aortic cross-clamp, and preoperative diagnosis, except for higher incidence of tetralogy of Fallot among non-bleeders, were comparable between the two groups (Table 1). Bleeders had higher amounts of chest tube drainage at all measured time points, ie, 4, 8, 12, and 24 hours after surgery (p < 0.001) (Fig 2). Preoperative laboratory tests for coagulation were comparable between the two groups except for higher D-dimer values among bleeders (p = 0.04) (Table 2). After termination of CPB, bleeders had a significantly higher aPTT (p = 0.014) and D-dimer (p = 0.008) as compared with non-bleeders (Table 2). Preoperative Sonoclot analysis parameters were comparable between the two groups except for lower of gbCR
Values among bleeders were significantly higher than non-bleeders (p = 0.009). After termination of CPB, gbCR (p = 0.015), gbPF (p < 0.001), and DR15 (p = 0.026) became significantly lower among bleeders than non-bleeders (Table 3).

Univariate analysis showed that lower age (p = 0.001) and body surface area (p = 0.001), preoperative gbCR (p = 0.011) and postoperative PT (p = 0.047), aPTT (p = 0.029), D-dimer (p = 0.016), gbCR (p = 0.01), gbPF (p = 0.001), and DR15 (p = 0.012) were significantly associated with bleeding. The area under the curve (AUC) for the prediction of postoperative bleeding was highest in post-gbPF (0.725), 95% confidence interval (CI, 0.619-0.831) followed by post-gbCR (0.666), 95% CI (0.550-0.782); pre-gbCR (AUC 0.663, 95% CI 0.545-0.781); post-DR15 (0.659), 95% CI (0.534-0.783); post-D-dimer (0.654), 95% CI (0.553-0.775) and aPTT post-AUC (0.640), 95% CI (0.518-0.762), respectively (Figs 3 and 4).

Multivariate regression analysis showed that only postoperative gbPF, postoperative D-dimer, and lower age were associated significantly with bleeding (Table 5). Among these post-CPB, gbPF had higher AUC than the D-dimer, suggesting its better predictive value for postoperative bleeding. Durations of mechanical ventilation (p = 0.001), ICU stay (p = 0.001), and hospital stay (p = 0.001) were higher among bleeders as compared to non-bleeders (Table 4).

Discussion

The present study found 37.9% of bleeders among pediatric congenital cyanotic patients. The postoperative bleeding was predicted independently by post-CPB gbPF, post-CPB
Williams et al.2 showed that age and size of patients were significantly higher incidence of bleeding as compared to acyanotic patients. The incidence of bleeding was even higher in cyanotics, patients aged 1-6 months. The age, height, and weight were found to be significant predictors for bleeding. Williams et al.2 showed that age and size of patients were inversely related to postoperative bleeding and magnitude of transfusion. Those aged < 1 month had the highest risk of bleeding and received maximum transfusion. Miller et al.17 showed that children < 8 kg had significantly higher chest tube drainage. Andrew et al.18 proposed the concept of developmental hemostasis and recommended the use of pediatric-specific reference range of coagulation tests for those aged < 1 year. The authors’ study results reaffirmed these findings. A higher mean weight among bleeders in this study in comparison with previous studies may have been because the authors excluded children < 6 months of age. This was done because these children often require prolonged CPB and greater degree of hypothermia during intracardiac repair.

D-dimer, and lower age of the patients. Among these, post-CPB gbPF had maximum predictive value.

Pediatric cyanotic heart disease patients are at higher risk of postoperative bleeding due to associated coagulation abnormalities and high hematocrit.5,6 Savan et al.16 found 24% of bleeders following post-CPB cardiac surgery in pediatric congenital heart disease patients. Cyanotic patients had significantly higher incidence of bleeding as compared to acyanotic patients. The incidence of bleeding was even higher in cyanotics, patients aged 1-6 months. The age, height, and weight were found to be significant predictors for bleeding. Williams et al.2 showed that age and size of patients were inversely related to postoperative bleeding and magnitude of transfusion. Those aged < 1 month had the highest risk of bleeding and received maximum transfusion. Miller et al.17 showed that children < 8 kg had significantly higher chest tube drainage. Andrew et al.18 proposed the concept of developmental hemostasis and recommended the use of pediatric-specific reference range of coagulation tests for those aged < 1 year. The authors’ study results reaffirmed these findings. A higher mean weight among bleeders in this study in comparison with previous studies may have been because the authors excluded children < 6 months of age. This was done because these children often require prolonged CPB and greater degree of hypothermia during intracardiac repair.

The rising cost of healthcare and increased workload on hospitals necessitates early identification of patients likely to bleed and/or require blood product transfusion to prevent significant blood loss and its consequences. Laboratory tests for coagulation have inherent problems of laboratory investigation involving storage, transportation of the sample to the laboratory, and logistics to receive laboratory results. Moreover, these tests do not evaluate coagulation properties of whole blood and do not consider platelets and their interaction with vascular endothelium, which is very important for clot formation and strength.

The point-of-care viscoelastic blood test Sonoclot analyzer contains a hollow open-ended disposable plastic probe mounted on an ultrasonic transducer. The probe vibrates vertically while immersed to a fixed depth in a cuvette containing a sample of whole blood. The blood exerts a viscous drag on the probe that increases as the blood sample clots and fibrin strands form on the probe tip, and between the probe and the wall of the cuvette. This increasing impedance in vibration of the probe is detected by the electronic circuits driving the probe, which ultimately is converted into an output signal on a paper chart recorder in the form of a Sonoclot signature. The device allows the assessment of the patient’s coagulation status by using different cuvettes with different

### Table 2
Pre- and Postoperative Laboratory Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bleeders (n = 33) (Mean ± SD)</th>
<th>Non-bleeders (n = 54) (Mean ± SD)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin (gm%)</td>
<td>17.27 ± 3.87</td>
<td>17.56 ± 3.46</td>
<td>0.720</td>
</tr>
<tr>
<td>S\textsubscript{O}2 (%)</td>
<td>82.33 ± 8.24</td>
<td>83.72 ± 6.87</td>
<td>0.399</td>
</tr>
<tr>
<td>Total leucocyte count/mm\textsuperscript{3}</td>
<td>7.876 ± 2.389</td>
<td>8.146 ± 2.526</td>
<td>0.622</td>
</tr>
<tr>
<td>Platelets (lakh/mm\textsuperscript{3})</td>
<td>2 ± 1.1</td>
<td>2.3 ± 0.8</td>
<td>0.276</td>
</tr>
<tr>
<td>Prothrombin time (s)</td>
<td>14.97 ± 1.61</td>
<td>14.83 ± 1.15</td>
<td>0.664</td>
</tr>
<tr>
<td>aPTT (s)</td>
<td>38.09 ± 17.88</td>
<td>34.26 ± 7.13</td>
<td>0.163</td>
</tr>
<tr>
<td>Fibrinogen (g/L)</td>
<td>2.38 ± 0.54</td>
<td>2.42 ± 0.62</td>
<td>0.748</td>
</tr>
<tr>
<td>D-dimer (ng/mL)</td>
<td>112 ± 63.56</td>
<td>90.89 ± 30.30</td>
<td>0.040</td>
</tr>
</tbody>
</table>

### Table 3
Sonoclot Analysis Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bleeders (n = 33) (Mean ± SD)</th>
<th>Non-bleeders (n = 54) (Mean ± SD)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT</td>
<td>148.15 ± 35.29</td>
<td>151.67 ± 35.75</td>
<td>0.656</td>
</tr>
<tr>
<td>gbACT</td>
<td>164.82 ± 84.66</td>
<td>148.52 ± 58.91</td>
<td>0.293</td>
</tr>
<tr>
<td>gbCR</td>
<td>9.13 ± 6.69</td>
<td>14.84 ± 10.99</td>
<td>0.009*</td>
</tr>
<tr>
<td>gbPF</td>
<td>1.89 ± 1.39</td>
<td>2.23 ± 1.47</td>
<td>0.280</td>
</tr>
<tr>
<td>DR15</td>
<td>36.16 ± 12.10</td>
<td>38.47 ± 11.56</td>
<td>0.377</td>
</tr>
<tr>
<td>Post CPB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT</td>
<td>138.45 ± 19.51</td>
<td>135.93 ± 19.35</td>
<td>0.557</td>
</tr>
<tr>
<td>gbACT</td>
<td>212.94 ± 147.91</td>
<td>167.93 ± 95.61</td>
<td>0.088</td>
</tr>
<tr>
<td>gbCR</td>
<td>10.39 ± 8.76</td>
<td>15.92 ± 10.84</td>
<td>0.015*</td>
</tr>
<tr>
<td>gbPF</td>
<td>1.15 ± 0.85</td>
<td>2.12 ± 1.31</td>
<td>0.000*</td>
</tr>
<tr>
<td>DR15</td>
<td>33.63 ± 15.87</td>
<td>40.75 ± 13.13</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Abbreviations: ACT, activated clotting time; CPB, cardiopulmonary bypass; SD, standard deviation; Sp\textsubscript{O}2, oxygen saturation. *p < 0.05 is considered significant.

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Table 4
Postoperative Blood Product Transfusion and Outcome

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Bleeders (n = 33) (Mean ± SD)</th>
<th>Non-bleeders (n = 54) (Mean ± SD)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRBC (mL/kg)</td>
<td>13.49 ± 10.97</td>
<td>9.03 ± 3.25</td>
<td>0.247</td>
</tr>
<tr>
<td>Fresh frozen plasma (mL/kg)</td>
<td>14.66 ± 7.60</td>
<td>11.37 ± 6.26</td>
<td>0.148</td>
</tr>
<tr>
<td>Platelet concentrate (mL/kg)</td>
<td>7.66 ± 3.10</td>
<td>5.00 ± 2.85</td>
<td>0.003*</td>
</tr>
<tr>
<td>PRBC (% transfused)</td>
<td>54</td>
<td>16</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Fresh frozen plasma (% transfused)</td>
<td>75.76</td>
<td>31.48</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Platelet concentrate (% transfused)</td>
<td>81.81</td>
<td>40.74</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Re-exploration n (%)</td>
<td>0 (0)</td>
<td>1 (1.9)</td>
<td>0.432</td>
</tr>
<tr>
<td>Mechanical ventilation (h)</td>
<td>26.41 ± 36.44</td>
<td>8.25 ± 6.36</td>
<td>0.001*</td>
</tr>
<tr>
<td>ICU stay (d)</td>
<td>7.36 ± 4.05</td>
<td>4.96 ± 2.49</td>
<td>0.001*</td>
</tr>
<tr>
<td>Hospital stay (d)</td>
<td>11.69 ± 4.82</td>
<td>8.63 ± 3.48</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

Abbreviation: ICU, intensive care unit; PRBC, packed red blood cells; SD, standard deviation.
*p < 0.05 statistically significant.
coagulation activators/inhibitors such as celite, kaolin, and glass beads.¹⁹ Sonoclot result is depicted quantitatively as the activated clotting time (Son ACT), CR, and PF. The Son ACT is the time from the activation of the sample until the beginning of fibrin formation as defined by first upward deflection in the Sonoclot signature. The CR is the maximum slope of the Sonoclot signature during initial fibrin polymerization and clot development (R1). This is indicative of rate of conversion of fibrinogen to fibrin and the fibrinogen levels. The secondary slope (R2) reflects further fibrinogenesis, fibrin polymerization, and platelet-fibrin interaction.¹¹ The PF is denoted by amalgamation of time to peak and the peak amplitude into one parameter, which is graded 0–5, where 0 denotes no platelet function and 5 denotes strong platelet function.

The Son ACT value corresponds to the conventional ACT measurement and is used to guide heparin therapy.²⁰ In contrast, the analogous value R (reaction time) in TEG and as CT (clot time) in rotation thromboelastometry reflects a more developed and later stage of initial clot formation. Tanaka et al found that R values of TEG were 1.5-fold (native more developed and later stage of initial clot formation.

Table 5
Prediction of Bleeders on Multivariate Logistic Regression Analysis

<table>
<thead>
<tr>
<th>Parameters</th>
<th>p value</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.001¹</td>
<td>1.337 (1.16-1.54)</td>
</tr>
<tr>
<td>gbPF post-CPB</td>
<td>0.010</td>
<td>1.98 (1.18-3.38)</td>
</tr>
<tr>
<td>D-dimer post-CPB</td>
<td>0.029²</td>
<td>1.81 (1.06-3.08)</td>
</tr>
</tbody>
</table>

Abbreviations: CPB, cardiopulmonary bypass; gbPF, glass bead platelet function. *p < 0.05 is considered significant.

but neither preoperative Sonoclot parameters nor laboratory tests of coagulation was predictive for postoperative bleeders. Chaudhary et al¹⁵ demonstrated that the Sonoclot CR value was significantly lower in the cyanotic (19.31 ± 10.68 U/min) than acyanotic pediatric congenital heart disease patients (24.88 ± 9.23 U/min; p = 0.009). Platelet function was deranged in 31% of patients (cyanotic, 59%; acyanotic, 8%; p < 0.001). They suggested that baseline Sonoclot parameters in conjunction with post-bypass parameters for an individual patient may help in the formulation of specific blood component transfusion guidelines. The authors’ study also had a similar finding. Although post-CPB gbPF, post-CPB D-dimer, and patient’s age were predictors for postoperative bleeders, receiver operating characteristic curve plotted to evaluate sensitivity and specificity showed that post-CPB gbPF had maximal AUC (0.725), 95% CI (0.619-0.831), sensitivity 74.07%, specificity 63.64% with positive predictive value 55.52%, and negative predictive value 80.02%, suggesting it was the best predictor of bleeders among all studied tests parameters.

Postoperative bleeding requiring blood product transfusion is associated with prolongation of ICU and hospital lengths of stay, and increased morbidity and mortality in both adult and pediatric patients.⁵,⁶,²⁵⁻²⁹ As expected, transfusion requirements were more frequent and higher among bleeders. The total amounts of platelets transfused were high among bleeder, but the amount of PRBC and FFP transfused were comparable between both groups. This may have been because of higher preoperative hematocrit in studied subjects. Bleeders required significantly longer duration of mechanical ventilation, ICU stay, and hospital length of stay.

The authors’ study had a few limitations. First, the patient population was heterogeneous, with a wide range of age from 6 months to 14 years and a wide spectrum of diagnoses. However, size of the patients and degree of cyanosis (or the surrogate hematocrit) are the prime factors for postoperative bleeding rather than the specific cardiac diagnosis. The authors excluded infants aged < 6 months to decrease the degree of heterogeneity, while hematocrit levels were comparable between both groups. Second, it was a single-center study involving multiple surgeons so generalization of data may be limited. The amount of PRBC administered into the pump prime and thereafter during CPB to maintain adequate hematocrit was not recorded; however, the authors maintained the same target hematocrit for each subject. Last, because it was a prospective observational study, the possibility of bias could not be ruled out.

The authors concluded that postoperative bleeders may be predicted independently by post-CPB gbPF, postoperative D-dimer, and younger age of patients. Among these, post-CPB gbPF had maximum predictive value.

References


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