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Associations Between Clinical Factors and Postoperative Thrombosis in Pediatric Cardiac Surgery Patients: A Single-Center Retrospective Study

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IMPORTANCE: Postoperative thrombosis is a significant complication in pediatric cardiac surgery patients, contributing to morbidity and mortality. Identifying clinical factors associated with thrombosis can improve patient outcomes by guiding early detection and intervention.

OBJECTIVES: This study aimed to assess factors associated with postoperative thrombosis or thromboembolism in pediatric patients under 12 months old who underwent surgery for congenital heart disease (CHD). Design, Setting, and Participants: This retrospective cohort study analyzed electronic medical records from pediatric patients admitted to the Pediatric Cardiovascular Intensive Care Unit (PCICU) at the German Paediatric Heart Center, Bonn, between March 1, 2020, and March 1, 2021. A total of 197 children under 12 months old who underwent cardiac surgery were included in the analysis.

MAIN OUTCOMES AND MEASURES: Thrombosis was diagnosed postoperatively using imaging modalities such as ultrasound, echocardiography, and computed tomography. The primary outcome was the incidence of thrombosis and its association with clinical factors such as age, central venous catheter (CVC) duration, CRP levels, and D-dimer levels.

RESULTS: Among 197 patients, the incidence of thrombosis was 8.63%, predominantly venous (70.6%). Initial associations were observed between thrombosis and younger age, lower body weight, higher hematocrit, cyanosis, longer central venous catheter (CVC) use, and elevated C-reactive protein (CRP) and d-dimer levels. Receiver operating characteristic analysis indicated a higher risk in patients with d-dimer levels above 5.47 mg/L. The stepwise multiregression analysis identified longer CVC duration in situ ($\beta = 0.553$; $p < 0.001$), higher CRP levels ($\beta = 0.217$; $p = 0.022$), and younger age at admission ($\beta = -0.254$; $p = 0.006$) as significant predictors of thrombosis. Decision tree analysis identified CVC use longer than 12.5 days and CRP levels above 118.01 mg/L as the most critical risk factors.

CONCLUSIONS AND RELEVANCE: Postoperative thrombosis is a notable risk in pediatric CHD patients, particularly in neonates. Prolonged CVC use and elevated CRP levels are critical risk factors. Routine monitoring of D-dimer and CRP levels, along with timely sonographic screening, can aid early thrombosis detection and intervention. Further research is warranted to optimize thrombosis prevention strategies in this population.

KEYWORDS: associated factors; cardiac surgery; congenital heart disease; pediatric patients; thrombosis

Congenital heart disease (CHD) is diagnosed in up to 0.9% of live births (1). Advancements in the cardiothoracic surgery and pediatric cardiology in recent decades have led to significant enhancements in both

DOI: 10.1097/CCE.0000000000001170

RESEARCH IN CONTEXT

- Enhanced survival rates: Advancements in cardiothoracic surgery and pediatric cardiology have significantly improved both short- and long-term survival rates for individuals with congenital heart disease worldwide.
- Thrombosis and postoperative complications: In the early postoperative period, thrombosis is a major contributor to mortality and morbidity for pediatric patients undergoing cardiac surgery for congenital heart disease.
- Risk factors: We aimed to identify factors associated with thrombosis in children under 1 year old with congenital heart disease following cardiac surgery, within a pediatric cardiovascular ICU setting.

short- and long-term survival rates for individuals born with CHD on a global scale (2, 3). Thrombosis largely contributes to mortality and morbidity in the early postoperative period (4, 5). Considering Virchow's triad (6) in children with CHD, possible reasons for the development of venous thrombosis after cardiac surgery become apparent (7, 8): these include abnormalities in blood flow due to reduced cardiac output, arrhythmia, or turbulent blood flow caused by stenosis or insufficiencies in valves or vessels. Frequently required supplementation of blood components, postoperative inflammation, hemoconcentration due to high-dose diuretic therapy or systemic inflammatory response syndrome (SIRS), and changes in hemodynamics associated with the type of cardiac surgery may also contribute to the formation of thrombosis. Furthermore, prosthetic material, vascular injury, and central venous lines might increase the risk of thrombosis. The interplay between these parameters and their respective contributions to the development of postoperative thrombosis in children with CHD is subject to current research (5, 9). The incidence of thrombosis in children with CHD postoperatively ranges between 2.9% (4) and 49% (10). As described in the literature (10, 11), especially children younger than 1 year old are at an increased risk of thrombotic complications postoperatively. The aim of our study was to explore factors associated with thrombosis or thromboembolism in this population after cardiac surgery for CHD in the setting of a pediatric cardiovascular ICU (PCICU).

MATERIALS AND METHODS

This single-center retrospective cohort study included all pediatric patients younger than 1 year old with CHD who underwent cardiac surgery between March 1, 2020, and March 1, 2021, at the German Paediatric Heart Centre in Bonn.

The study protocol received approval for this retrospective cohort study from the University Hospital of Bonn Ethics Board (Approval Number 31, granted on May 10, 2021. The original title of the study submitted to the ethics committee: "Postoperative, retrospective case-control analysis of prothrombotic factors in neonates and infants with congenital heart disease in the setting of a pediatric cardiac intensive care unit"). Informed consent for data processing was obtained from all patients' parents or legal guardians immediately after admission to the University Hospital of Bonn; all research procedures followed the ethical standards of the University Hospital of Bonn and were consistent with the Helsinki Declaration of 1975.

Patients with venous or arterial thrombosis diagnosed post-surgery via ultrasound, echocardiogram, transesophageal echocardiogram, CT, or fluoroscopy were included in the thrombosis group. We excluded children older than 1 year, as well as patients who underwent an isolated closure of patent ductus arteriosus, placement or removal of an implantable pacemaker, surgeries such as rethoracotomy or secondary thoracic closure, and those with clear laboratory evidence of thrombophilia. Blood count and coagulation tests were conducted as part of our standard practice before heart surgery and at regular intervals postoperatively.

Retrospective data analysis from the electronic medical records (Dräger ICM 10; Drägerwerk AG & Co. KGaA, Lübeck, Germany) involved assessing and entering information on 41 different variables that could possibly be associated with thrombosis. These variables cover a wide range of factors, including demographic data, hemodynamic factors, coagulation markers, blood transfusions, clotting factor transfusions, inflammatory indicators, diuretic use, and other factors such as amiodarone, platelet count, the need for post-surgery prostaglandin E1, hematocrit and hemoglobin levels, the need for post-surgery hydrocortisone, duration of PCICU stay, maximum central

venous pressure, duration of central venous catheter (CVC) use, and the need for extracorporeal membrane oxygenation (ECMO) after cardiac surgery.

Bias due to errors or inconsistencies in the electronic medical records was addressed through accuracy checks of the data, including comparisons with redundant electronic or written records where available.

Surgical Characteristics, Perioperative Management of Bleeding, Prevention of Thrombosis, and Levosimendan Cycle

The German Paediatric Heart Centre in Bonn performed 426 heart surgeries on children under 18 years old during the study period, 278 of whom were under 1 year old. After considering the exclusion criteria, data from 197 patients were included in this study.

A CVC is routinely inserted before surgery in any child undergoing cardiac surgery: Newborns and small infants generally receive a 4.0–4.5-Fr. Three lumen CVC in the right jugular vein. If necessary, the left jugular vein or the femoral veins are used. Based on clinical requirements, insertion may occur earlier to stabilize the child before the operation. Replacement of the catheter may be necessary during postoperative care due to occlusion, infection, or displacement.

In cases of clinically significant bleeding during the perioperative period, our center employs standard procedures to restore hemostatic function. This includes the prompt administration of fibrinogen concentrate (0.4–1.0 g). If bleeding persists, prothrombin complex concentrate (PPSB) containing factors II, VII, IX, and X is administered at doses of 250–500 international units (IU), and platelets are transfused at a dose of 15–20 mL per kg of body weight, regardless of the actual platelet count, until adequate hemostasis is achieved. Hypocalcemia is routinely treated with tailored substitution based on point of care test results. In cases of volume depletion and intraoperative bleeding, fresh frozen plasma (FFP) is administered regardless of the amount of coagulation factors. Postoperatively, we perform a single factor analysis to determine if FFP is needed. At a dose of 5 mg/kg/hr, tranexamic acid is regularly administered via continuous infusion for up to 6 hours post-surgery. The postoperative thromboprophylaxis strategy involves the continuous infusion of unfractionated heparin (UFH) at 100 IU/kg/d.

For high-risk subpopulations with aortopulmonary shunts or implanted stents, the dose of UFH is adjusted to achieve a target activated partial thromboplastin time (aPTT) between 60 and 80 seconds within 24 hours postoperatively.

For the group of children with cyanotic heart disease, the transfusion threshold for packed erythrocyte concentrate is a hemoglobin level of less than 14 g/dL. Children with persistent impaired cardiac function received levosimendan at a dose of 0.2 μg/kg/min for 48 hours, referred to as a "levosimendan cycle" in the following text.

Identification of Thrombosis

Systematic screening for venous thromboembolic events was conducted in cases of CVC occlusion, rapid elevation of D-dimers (threshold > 3 mg/L), or when there was a reasonable suspicion of thrombosis (such as abdominal or cervical venous congestion, elevated central venous pressure, or chylothorax). D-dimers were sequentially measured directly upon admission to the PCICU and daily until discharge. The timing of D-dimer measurement was adjusted to occur earlier, after 8–12 hours, if a significant increase in levels was detected. Some thrombi were discovered incidentally during routine daily ultrasound examinations (neonatal brain ultrasound, echocardiography, vascular sonography), in the heart catheter laboratory (fluoroscopy), or incidentally during chest MRI or CT scans.

Treatment of Thrombosis

In the case of a CVC-related thrombus, a new CVC was inserted, and the affected CVC was removed.

Neonates and infants with thrombosis or thromboembolism outside of the brain were treated with enoxaparin at an initial dose of 3 mg/kg/d via continuous drip infusion. We then adjusted enoxaparin to achieve a target anti-Xa range of 0.4–0.6 U/mL.

Statistical Analysis

After data extraction, the patients were divided into two groups: those with thrombosis and those without. Data from both groups were compared and analyzed. We presented continuous variables as medians and 5th–95th percentiles. Means between two groups were compared using an independent sample *t* test. For the correlation analysis, the Pearson correlation coefficient was calculated.

The chi-square test of independence was used to determine if there was a significant relationship between two nominal variables. Two-sided *p* values of less than 0.05 were considered statistically significant.

A receiver operating characteristic (ROC) curve was used to identify the threshold value for D-dimer in diagnosing thrombus. To determine the cutoff point with the most favorable balance between sensitivity and specificity, the Youden's index was computed for each data point on the curve.

To evaluate thrombosis risk factors, we performed a stepwise multiregression analysis. The stepwise method was applied, with criteria for entry set at p value of less than 0.05 and for removal set at p value of greater than 0.10. Goodness-of-fit was assessed using R^2 values, F statistics, and p values. Multicollinearity among predictors was checked using the variance inflation factor (VIF) and a correlation matrix. All VIF values below 1.5 indicated no significant multicollinearity concerns.

Additionally, a decision tree analysis was conducted using the classification and regression tree method to explore the factors associated with thrombosis. The variables used in the decision tree included duration of CVC placement, maximum C-reactive protein (CRP) levels, and age at admission. The model was evaluated based on its accuracy, sensitivity, and specificity.

All statistical tests were conducted at a significance level of 0.05.

Statistical analyses were conducted using IBM SPSS, Version 27 (IBM Corp, Armonk, NY) and GraphPad Prism 8.0 (GraphPad Software, LLC, San Diego, CA).

RESULTS

We analyzed data from 197 patients younger than 12 months at the time of heart surgery. Thrombosis was diagnosed during the PCICU stay of 18 patients, and thrombophilia testing was conducted in 11 of them (64.7%). The testing included laboratory assays such as antithrombin, protein C, protein S, activated protein C resistance, factor V Leiden, prothrombin gene mutation, antiphospholipid antibodies, and lupus anticoagulant. One male patient with thrombosis was found to be heterozygous for factor V Leiden, leading to his exclusion from the study. Among the remaining 17 patients (8.7%), 12 (70.6%) had venous thromboses, 4 (23.5%) had arterial thromboses, and one (5.9%) had both types. Of the 12 patients with venous thrombosis, 3 (25%) had isolated thrombosis limited to the CVC. Among the 17 patients with thrombosis, 10 (58.8%) were cyanotic and 7 (41.2%) had single-ventricle physiology.

In the stepwise multiregression analysis, the duration of CVC in situ, maximum CRP levels, and age at admission were identified as significant predictors of postoperative thrombosis.

Model 1 showed that the longer duration of CVC in situ was significantly associated with thrombosis (R^2 = 0.306; $F(1, 86) = 37.849$; $p < 0.001$). The standardized coefficient for the longer duration of CVC in situ was $\beta = 0.553$ ($p < 0.001$).

Model 2 added maximum CRP levels as a significant predictor, increasing R^2 to 0.348 ($F(1, 85) = 5.459$; p = 0.022), with CRP levels showing a standardized coefficient of $\beta = 0.217$ ($p = 0.022$).

Model 3 included age at admission, further improving the model fit ($R^2 = 0.404$; $F(1, 84) = 8.022$; p = 0.006). Age at admission showed a negative association with thrombosis, with a standardized coefficient of $\beta = -0.254$ ($p = 0.006$).

Multicollinearity was not a concern, as all VIF values were below 1.5.

The decision tree analysis revealed that CVC duration and maximum CRP levels were strongly associated with thrombosis. Patients with a CVC duration exceeding 12.5 days and a CRP level above 118.01 mg/L were at the highest risk of developing thrombosis. The decision tree model had an overall accuracy of 93.9%, with a sensitivity of 58.8% and a specificity of 97.2%.

Tables and Figures

Based on the demographic information in **Table 1**, thrombosis was more prevalent in younger children (median 25 vs. 154 d; $p = 0.05$) and those with a lower body weight (3.80 vs. 5.30 kg; $p = 0.009$). Thrombosis typically occurred around a median of 4 days after surgery (mean, 5 d; interquartile range, 5.5; range, 0–16 d) and was more frequent in children with a longer duration of CVC in situ (19 vs. 4 d; $p = 0.002$).

Considering hemodynamic factors, thrombosis was more commonly observed in children with a higher number of levosimendan cycles (0.75 vs. 0.14 cycles; p = 0.011) and in those with cyanosis (oxygen saturation < 86%) at discharge (58.8 vs. 26.1%; $p = 0.004$). The Pearson correlation between cyanosis and mean hematocrit was positive and statistically significant ($r = 0.43$; $p < 0.001$).

Regarding coagulation factors, maximal D-dimer levels were higher in the group of children with thrombosis (12.56 vs. 2.69 mg/L; $p < 0.001$), as were

TABLE 1.
Effect of Demographic, Hemodynamic, Coagulation, and Other Factors on Thrombosis

Variables	No Thrombosis (n_{Total} = 180)		Thrombosis (n_{Total} = 17)		*p*
Demographic data		$n_{evaluated}$		$n_{evaluated}$	
Sex, female (%)	73 (40.6)	180	6 (35.3)	17	0.672
Age at admission (d)	154 (0–364)	180	25 (1–294)	17	0.050
Age at surgery (d)	155 (2–364)	180	26 (3–295)	17	0.060
Body weight (kg)	5.3 (2.3–9.9)	180	3.80 (2.1–8.7)	17	0.009
Hemodynamic					
Number of levosimendan cycles	0.14 (0–4)	180	0.75 (0–2)	17	0.011
Cyanosis at discharge (%)	47 (26.1)	180	10 (58.8)	17	0.004
Duration of central venous catheter use (d)	4 (1–37)	157	19 (13–107)	16	0.002
Coagulation-related factors					
Maximal D-dimer level (mg/L)	2.69 (0.2–32.3)	100	12.56 (3.1–32.42)	16	< 0.001
Anti-factor Xa level (international units/mL)	0.2 (0.02–0.78)	25	0.5 (0.09–0.68)	17	0.024
Others					
Maximum level of C-reactive protein (mg/L)	63.59 (1.18–359.62)	177	126.44 (23.74–347.86)	17	0.009
Overall intake of furosemide (hr)	82 (0–1762)	175	314 (160–2410)	17	0.005
Maximum hematocrit level (%)	46.3 (29–66)	180	54.3 (47–65)	16	< 0.001
Hematocrit (%)	39.9 (23–60)	179	44.7 (27–52)	17	0.045
Maximum hemoglobin level (g/dL)	15.1 (9.8–22.6)	180	18.5 (15.9–22.1)	17	< 0.001
Hemoglobin level (g/dL)	12.7 (7.8–18.1)	170	13.6 (10.1–15.7)	17	0.388
Length of pediatric cardiovascular ICU stay (hr)	100 (16–1768)	179	379 (236–2573)	17	0.003

Data are presented as the number of patients (%) or median (interquartile range).

anti-factor Xa level (0.5 vs. 0.2 IU/mL; $p = 0.024$) reflecting the use of enoxaparin in treating thrombosis. Maximum and median hematocrit levels were also higher in thrombosis patients (54.3% vs. 46.3; $p < 0.001$ and 44.7 vs. 39.9%; $p = 0.045$) (**Fig. 1**). Maximum hemoglobin values correlated with thrombosis (18.5 vs. 15.1 g/dL; $p < 0.001$), although median hemoglobin values did not ($p = 0.388$) (**Fig. 2**).

For inflammatory markers, maximum CRP levels were higher in the thrombosis group (126.44 vs. 63.59 mg/L; $p = 0.009$).

Thrombosis was also associated with the total duration of furosemide use (314 vs. 82 hr; $p = 0.005$), the infusion of prostaglandin E1 after surgery (52.9% vs. 7.2%; $p < 0.001$), and the length of PCICU stay (379 vs. 100 hr; $p = 0.003$). A correlation analysis showed a positive relationship between mean hematocrit levels and overall furosemide intake ($r = 0.22$; $p = 0.02$).

Thrombosis did not correlate with laboratory markers like N-terminal pro-B-type natriuretic peptide, aPTT, interleukin-6, procalcitonin, fibrinogen, or platelet count, nor with hemodynamic markers like central venous pressure, maximum daily urine output per body weight, or the need for ECMO therapy (**eTable 1**, http://links.lww.com/CCX/B426).

Postoperative treatments, including catecholamines, ethacrynic acid, amiodarone, hydrocortisone, or perioperative administration of procoagulatory factors like fibrinogen concentrate, PPSB, or platelets, were not associated with thrombosis (eTable 1, http://links.lww.com/CCX/B426).

The ROC analysis for the diagnostic value of D-dimers is shown in **Figure 3**. Patients with maximal D-dimer levels above 5.47 mg/L had a significantly higher risk of thrombosis (area under the curve, 0.83; 95% CI, 0.75–0.92; $p < 0.001$). For this D-dimer cutoff, sensitivity was 94%, specificity was 65%, the Youden index was 0.588, the positive predictive value was 0.3, and the negative predictive value was 0.99.

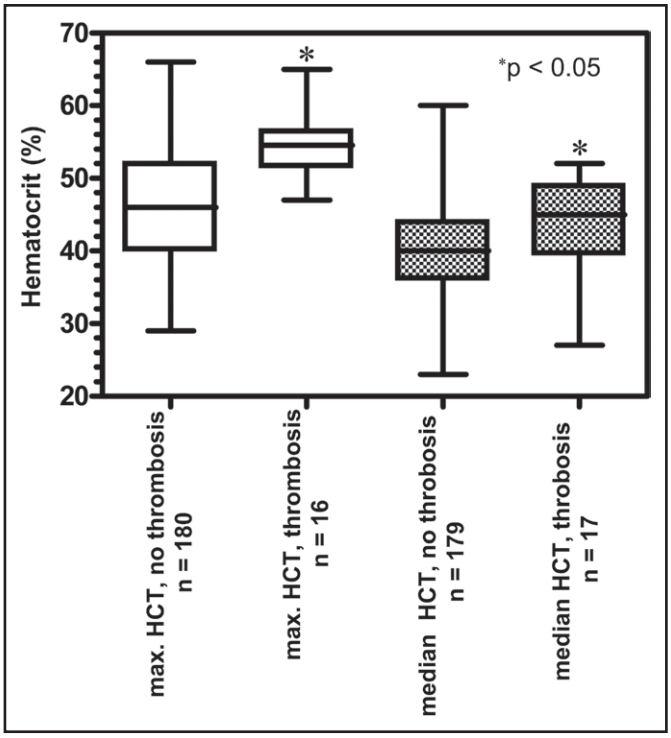

Figure 1. Relationship between maximum and median hematocrit (HCT) levels on the occurrence of thrombosis.

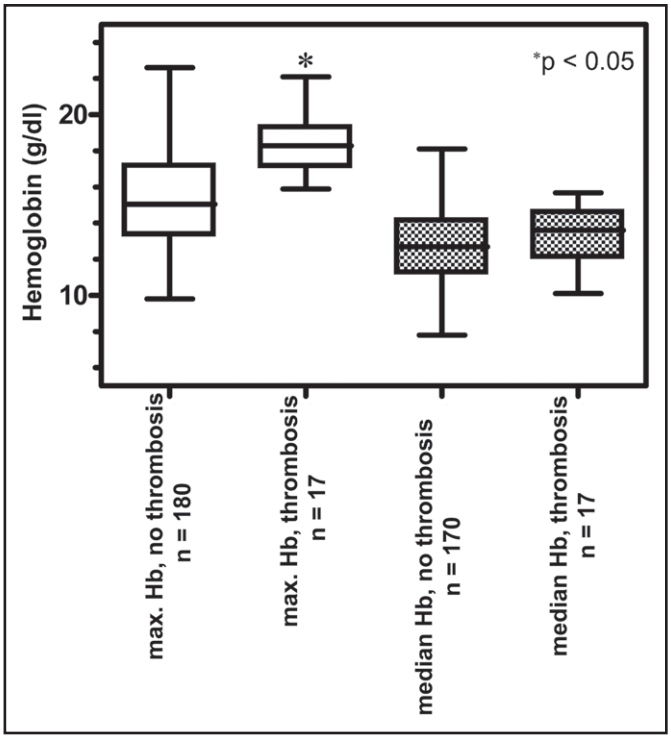

Figure 2. Relationship between maximum and median hemoglobin (Hb) levels on the occurrence of thrombosis.

DISCUSSION

The overall incidence of thrombosis in our study was 8.6%, predominantly venous (70.6%). This rate aligns with other studies reporting incidences between 2.9% (4) and 49% (10), highlighting variability due to different methodologies and patient demographics. Our study likely underestimates the true incidence due to the absence of a systematic screening protocol.

Thrombi were detected at a median of 4 days post-surgery, which is earlier than in some other studies (7, 9, 11). This early detection is likely due to proactive D-dimer monitoring, which serves as an indicator of coagulation and fibrinolytic activity (12).

Thrombosis after cardiac surgery is an often-overlooked problem (4). Even small findings can be relevant, as they may represent the early stages of a growing thrombus or residual findings after embolism. D-dimer determination is commonly used in diagnosing pulmonary embolism in adults (13), but only limited data exist for its role in pediatric CHD. Our study is one of the first to report on D-dimer levels in patients under 12 months with CHD post-surgery. Using D-dimer as a screening method is likely to result in many false positives and the detection of clinically

AT THE BEDSIDE

- Incidence of thrombosis: Our study found that 8.6% of pediatric patients younger than 12 months undergoing cardiac surgery for congenital heart disease experienced thrombosis, predominantly venous. This adds valuable real-world data.
- Thrombus detection timing: Thrombi are typically identified around 4 days post-surgery, emphasizing the need for routine monitoring for early detection and management of thrombotic events.
- Who should be screened? Pediatric intensivists should be aware of the increased risk of thrombosis in children following congenital heart surgery, particularly in those with prolonged central venous catheter use, elevated C-reactive protein levels, elevated D-dimer levels, and younger age. Recognizing these factors can help improve the detection and prevention of postoperative thrombosis in this vulnerable population.

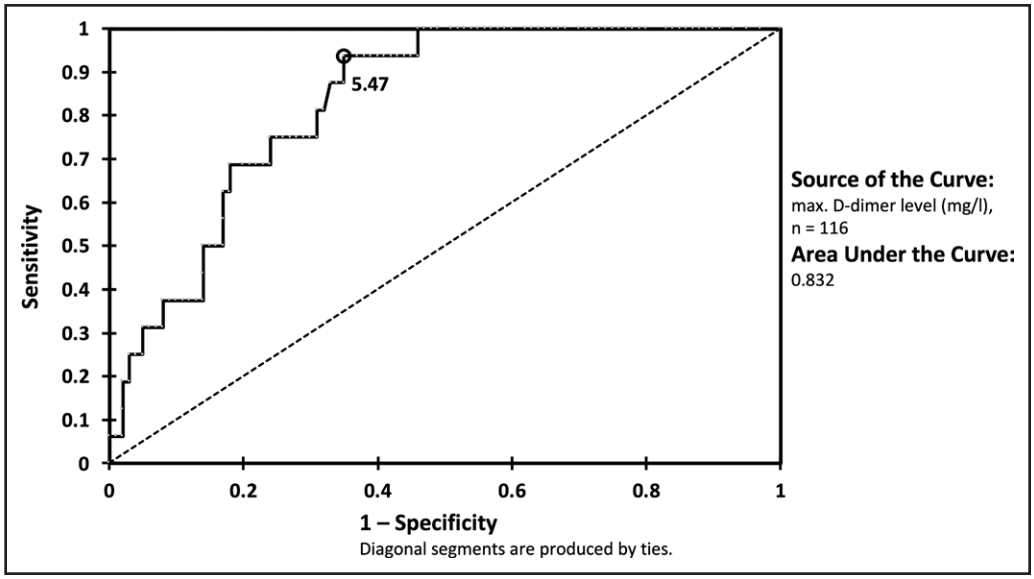

Figure 3. Receiver operating characteristic curve for thrombus diagnosis by D-dimer evaluation.

irrelevant findings. However, recommending sonography for significant D-dimer elevations remains reasonable due to its noninvasive nature and the risks associated with undetected thrombosis.

We identified that maximum CRP levels and prolonged use of CVC in situ are critical predictors of thrombosis, highlighting inflammation's role in thrombus formation. Elevated CRP levels indicate an inflammatory response that exacerbates endothelial damage, promoting a pro-thrombotic state. This is consistent with literature suggesting CRPs role in promoting coagulation by enhancing tissue factor expression and platelet aggregation (14). Our decision tree analysis further confirmed that CRP levels above 118.01 mg/L and CVC placement duration exceeding 12.5 days are key predictive factors for thrombosis.

CRP elevation post-cardiac surgery is common due to inflammation or SIRS, which complicates distinguishing between surgery-related inflammation and infection (15, 16). Jaworski et al (15) reported that CRP levels can peak at 132.3 mg/L on the second day after surgery with extracorporeal circulation (ECC). SIRS, triggered by ECC, causes the release of inflammatory mediators, increased capillary permeability, and fluid overload, ultimately leading to organ dysfunction (17). Typically, forced diuresis manages fluid overload. However, prolonged furosemide use may lead to hemoconcentration and stasis, increasing the risk of thrombosis (6). Our data showed that extended furosemide therapy correlated with higher hematocrit levels and thrombosis risk, highlighting the need to balance diuretic therapy to avoid hemoconcentration.

We also observed a strong association between younger age and thrombosis formation, likely explained by developmental hemostasis (18), where neonates have lower levels of natural anticoagulants, increasing the procoagulant state (19–21). Additionally, conditions such as secondary erythrocytosis in cyanotic CHD raise the risk of thrombosis due to high blood viscosity and blood stasis (22, 23). Our findings suggest a correlation between maximum hemoglobin levels and thrombosis, possibly reflecting frequent RBC transfusions in cyanotic patients or those with impaired cardiac function requiring high-dose catecholamines.

The decision tree analysis identified prolonged CVC use (> 12.5 d) as a critical risk factor for thrombosis, emphasizing the severity of illness and its correlation with thrombosis. Reducing the duration of CVC placement in situ when clinically possible, and switching to peripheral venous access as soon as patients stabilize, may help mitigate the risk of thrombosis. The use of levosimendan cycles in patients who developed thrombosis could indicate a more complicated clinical course with severely impaired cardiac function.

Low-molecular-weight heparin (LMWH) may be more effective than low-dose UFH in preventing CVC-related thrombosis, highlighting the need for early thromboprophylaxis in high-risk patients (24, 25). Future research should focus on optimizing prophylactic treatments, understanding the impact of hyperviscosity, and evaluating the effect of thrombosis on the length of hospital stay.

CONCLUSIONS

This study identified several significant factors associated with thrombosis in pediatric patients undergoing

cardiac surgery for CHD. Our stepwise multiregression analysis highlighted prolonged CVC use, elevated CRP levels, and younger age as key predictors of thrombosis, underscoring the importance of close monitoring.

Virchow's triad provides a useful framework for understanding thrombosis in this cohort, including hypercoagulability due to elevated hematocrit and maximum hemoglobin levels, stasis from reduced cardiac function, and endothelial damage from surgery. Our findings emphasize the role of D-dimer and CRP monitoring post-surgery in detecting thrombosis early. Elevated D-dimer levels higher than 5.47 mg/L should prompt immediate sonographic screening, and high CRP levels (> 118.01 mg/L) further signal the risk of thrombus formation. Incorporating these biomarkers into routine postoperative care for pediatric CHD patients could enable earlier detection and intervention, reducing complications.

Additionally, our data suggest that prolonged furosemide use may contribute to thrombosis through hemoconcentration, and that efforts should be made to balance diuretic therapy to reduce this risk. We also identified a significant association between thrombosis and cyanosis, likely due to hyperviscosity from transfusions or erythrocytosis.

Minimizing CVC placement duration where possible, and early thromboprophylaxis using LMWH, may help reduce thrombosis risk. These insights highlight the need for targeted thromboprophylaxis and careful perioperative management. Future research should explore strategies to optimize prophylactic treatments and evaluate the impact of thrombosis on hospital length of stay in this population.

LIMITATIONS

This retrospective study, relying on electronic medical records, introduces potential bias due to missing variables and is better suited to highlight correlations than establish causality. Additionally, thrombosis screening was inconsistent, likely leading to an underestimation of the true incidence.

The use of both D-dimer levels and CRP as diagnostic tools has limitations due to their low specificity in postoperative settings, often resulting in false positives linked to conditions unrelated to thrombosis, such as inflammation or surgical recovery. Thus, D-dimer results should be interpreted alongside imaging, like ultrasound, to avoid misdiagnosis. Furthermore, the ROC analysis reflects diagnostic uncertainty due to this lower specificity, highlighting the need for more precise diagnostic thresholds in pediatric populations.

Last, the small sample size affects the statistical power of our findings. Larger studies are needed to validate these results and to further explore thrombosis risk factors in this vulnerable population.

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (http://journals.lww.com/ccejournal).

This work was supported by the Open Access Publication Fund of the University of Bonn. The data integration center of the University Hospital Bonn was funded by the Federal Ministry of Education and Research (grant number: 01ZZ1803Q).

The authors have disclosed that they do not have any potential conflicts of interest.

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