Submitted: 03 March, 2024 Accepted: 06 June, 2024 Published: 08 November, 2024 DOI:10.22514/sv.2024.143

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ORIGINAL RESEARCH

Thrombus prevalence and risk factors in critically ill pediatric patients

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Abstract

We aimed to ascertain the prevalence of venous and arterial thrombus, potential thrombosis-inducing factors, and underlying medical conditions in critically ill pediatric patients admitted to our pediatric intensive care unit. We included patients who were admitted to our tertiary pediatric intensive care unit for 24 hours between June 2016 and June 2021 and had venous or arterial thrombosis confirmed by Doppler ultrasonography. Thirty patients with confirmed thrombosis who underwent Doppler ultrasonography and thirty patients without thrombosis, matched based on age and gender, were included in the control group. The female gender accounted for 63.3% of the patients in the thrombosis group. There was no significant gender difference between the thrombosis group and the control group. Age (in months), height, weight, and body mass index measurements were similar in both groups. The most common reason for hospitalization in the thrombosis group was post-operative care (n = 7; 23.3%). Thrombosis typically occurred after a mean of 6.9 $\pm$ 4.9 days of hospitalization. Coagulation parameters, Protein C, Protein S, homocysteine levels, pediatric mortality index (PIM), pediatric risk of mortality (PRISM-2), and Braden Q scores evaluating pressure ulcersdid not differ significantly between the two groups. Eleven patients in the thrombosis group were screened for the prothrombin *20210A* mutation, with all results being normal; eleven patients in the patient group were tested for Factor V Leiden mutation, and nine patients in the control group had no mutation. The thrombosis group had a significantly lower rate of mechanical ventilation and hemodialysis. Factors such as trauma, infection, heart failure, malignancy, history of chemotherapy, immobilization, presence of central catheter, history of surgical intervention, family history, and nephrotic syndrome were not significantly associated with thrombosis development. Central venous and arterial catheterization was identified as the most crucial acquired risk factor for thrombosis.

Keywords

Arterial; Pediatric intensive care; Thrombosis; Venous

1. Introduction

Although the frequency of thromboembolic events in children is less common compared to adults, it is on the rise as a complication of modern healthcare. In the general pediatric population, the incidence of venous thromboembolism (VTE) ranges from 0.14–0.21 per 10,000 children annually [1, 2]. The occurrence of VTE in hospitalized children is approximately between 0.2% and 1% [3]. A prospective study revealed that the majority of VTE cases (85%) occurred in a hospital setting, with almost all patients (98%) having at least one underlying risk factor, with a third of cases being related to central venous catheters (CVCs) [1]. There is limited data on arterial thrombotic events in children.

Many inherited and acquired risk factors can lead to thrombotic events. Indwelling catheterization, hyperviscosity syndrome, surgery, trauma, autoimmune disorders, renal diseases, congenital heart diseases, malignant diseases, chemotherapy, liver disease, thalassemia and sickle cell disease are predisposing factors associated with thrombotic events in childhood. The use of a central venous catheter (CVC) is the most significant acquired risk factor for thrombosis in children of all ages [4–6]. CVCs are necessary for children with chronic illnesses, particularly critically ill patients who require parenteral nutrition, dialysis, chemotherapy, blood transfusion or antimicrobial therapy.

While there are established guidelines for deep vein thrombosis (DVT) prevention in adult patients, research in this area for pediatric patients is limited [7, 8]. In our study, we aim to determine the frequency of venous and arterial thrombosis, potential causes of thrombosis, and underlying conditions in critically ill pediatric patients admitted to the

pediatric intensive care unit. We anticipate that the findings of this study will provide valuable insights for future research on venous and arterial thrombosis in critically ill pediatric patients.

2. Materials and methods

Our study was designed as a retrospective and cross-sectional study. Patients admitted to our tertiary pediatric intensive care unit for more than 24 hours between June 2016 and June 2021, with venous or arterial thrombosis identified through Doppler ultrasonography, were enrolled. The medical records of 5091 patients hospitalized at the Pediatric Intensive Care Unit of Çukurova University Faculty of Medicine Hospital during this period were reviewed by accessing the hospital information management system. Among them, 1168 patients were excluded due to hospitalization duration of less than 24 hours. Doppler ultrasonography was conducted on 76 remaining patients based on clinical suspicion, revealing thrombosis in 30 cases. Out of these 76 patients, 46 individuals without thrombosis and 30 patients matching the age and gender criteria of the patient group were selected as the control group (Fig. 1).

Demographic characteristics (age, gender, height and weight), Tanner staging, laboratory parameters such as activated partial thromboplastin time test (aPTT), prothrombin time (PT), International Normalized Ratio (INR), fibrinogen, platelets, protein C level, protein S level, homocysteine level, factor V Leiden mutation, prothrombin *20210A* mutation (F5 Leiden, and Prothrombin *20210A* mutation were analyzed using real-time polymerase chain reaction (PCR) method), pediatric mortality index (PIM), pediatric mortality risk classification (PRISM-2) and Braden Q scale scores were assessed. The Braden Q is a risk assessment tool for VTE. Patients were retrospectively screened for thrombosis risk factors including infection, trauma, malignancy, chemotherapy, surgery, central venous and arterial catheter, mechanical ventilation, hemodialysis, extracorporeal membrane oxygenation, family history and previous deep vein thrombosis.

The statistical analysis of the data was conducted using the IBM SPSS Statistics 25.0 (IBM Corp., Chicago, IL, USA) Categorical measurements were presented as numerical values and percentages, while continuous measurements were described in terms of mean, standard deviation, median and range. presented as numerical values and percentages, while continuous measurements were described in terms of mean, standard deviation, median and range. For the comparison of

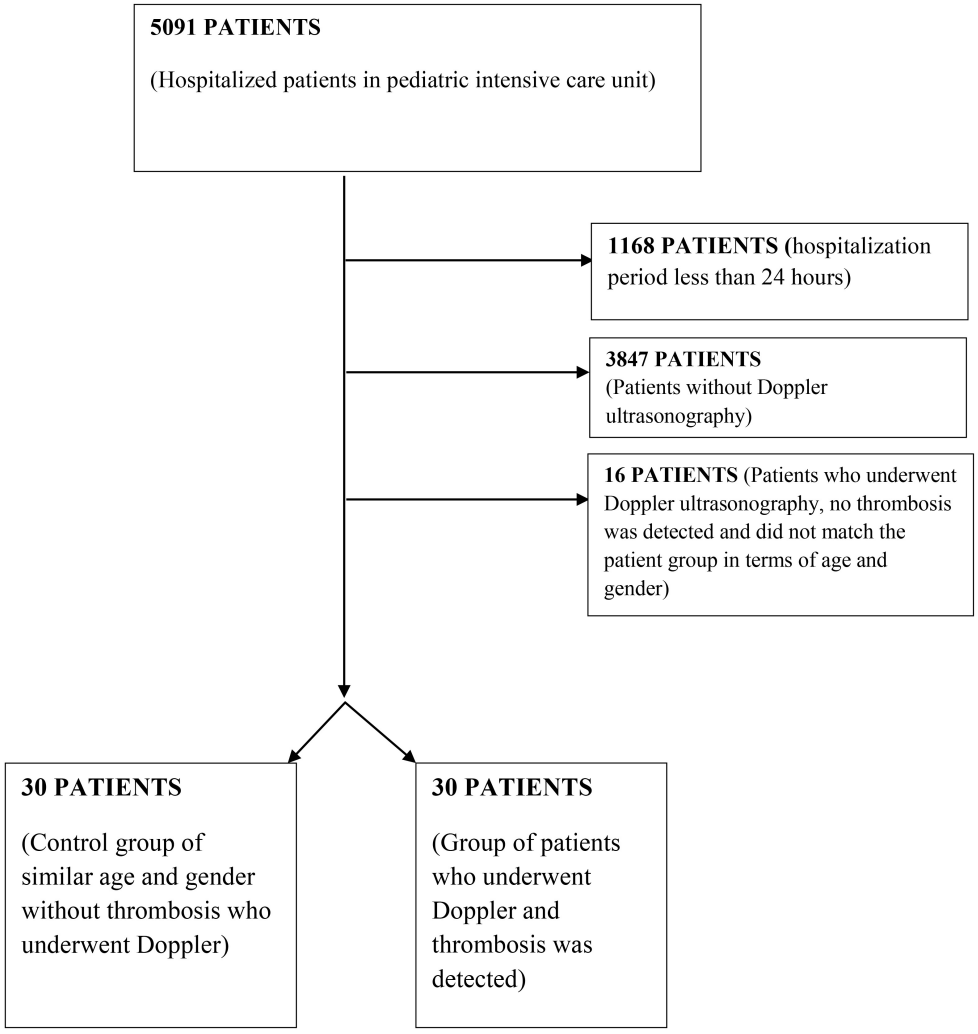

FIGURE 1. Flow diagram illustrating how to include and exclude patients.

continuous measurements among different groups, the distribution normality was assessed through the Shapiro-Wilk test. If the numerical parameters followed a normal distribution, the independent sample *t*-test was employed, whereas the Mann-Whitney U test was used for numerical parameters that did not exhibit normal distribution. The statistical significance threshold for all tests was set at 0.05.

3. Results

Thirty pediatric patients admitted to the intensive care unit with thrombus detected by Doppler ultrasonography were compared with 30 control children without thrombus (Fig. 1). The female sex ratio was 63.3% in the thrombosis group and 43.3% in the control group (p = 0.121). The mean age was 84.7 ± 68.3 months in the patient group and 81.2 ± 58.1 months in the control group (p = 0.828). No significant differences were found in anthropometric measurements between the two groups. The majority of children in both groups were in Tanner Stage 1, and there were no statistically significant discrepancies in disease severity scores and Braden Q scores between the thrombosis and non-thrombosis groups (Table 1).

Venous thrombosis was observed in 73.3% (n = 22) of the patients, while arterial thrombosis was present in 26.7% (n = 8). All thromboses developed in the lower extremities in 16 patients, the upper extremities in ten patients, and the portal vein in four patients. Among the 22 individuals with venous thrombosis, 15 (68.1%) were found to have a central venous catheter. Venous thrombosis occurred in 13 lower extremities, 5 upper extremities, and 4 portal veins. Of the CVCs, 11 (73.3%) were positioned in the lower extremity, while 4 (26.6%) were in the jugular vein. The eight patients with arterial thrombosis (5 in the upper extremity and 3 in the lower extremity) all had an invasive arterial catheter (Table 2).

No significant difference was observed between the thrombosis and control groups in terms of coagulation parameters, platelet counts, protein C, protein S, homocysteine levels, and mutations predisposing to thrombosis (Table 3). The average time of thrombosis development was 6.9 ± 4.9 days of hospitalization. There was no significant difference in the duration of stay in the intensive care unit between the thrombosis and control groups. The most prevalent reason for hospitalization in the thrombosis group was post-operative follow-up (n = 7, 23.3%). During the analysis, it was noted that patients in the thrombosis cohort underwent mechanical ventilation less frequently (15/30 *vs.* 24/30, p = 0.015). Hemodialysis utilization was significantly lower in patients with thrombosis (3/30 *vs.* 13/30, p = 0.004).

There was no significant difference between the thrombosis and control groups regarding the administration of blood transfusions and vasopressor therapy. Moreover, no statistically significant variations were found between the risk factors of trauma, infection, heart failure, malignancy, history of chemotherapy, immobilization, history of surgical intervention, family history, nephrotic syndrome presence and thrombosis development ($p > 0.05$). Notably, limb edema was more prevalent in the thrombosis group (73.3% *vs.* 36.7%, p = 0.004). Although the incidence of bruising at the thrombus site was higher in the thrombosis group compared to the control group, the difference was not statistically significant (36.7% *vs.* 16.7%, p = 0.08). Among the control group, 29/30 patients received no treatment, and with only one patient (3.3%) receiving enoxaparin sodium. Conversely, in the thrombosis group, 20/30 (66.7%) patients received enoxaparin sodium, one patient (3.3%) was administered heparin, and one patient (3.3%) with arterial thrombosis was treated with tissue plasminogen activator.

4. Discussion

Intensive care unit hospitalization and the duration of invasive mechanical ventilation have been identified as significant risk factors for thromboembolic events [9]. Risk factors for thromboembolic events in intensive care unit patients include the presence of a central venous catheter, mechanical ventilation, total parenteral nutrition, underlying primary disease such as trauma or malignancy and immobilization. Central venous catheterization has been identified as the most crucial risk factor for thrombosis development among acquired and inherited risk factors [4–6]. In our study, 68.2% of 22 patients with venous thrombosis had undergone central venous catheterization, confirming the association between catheters and thrombosis.

Among patients with venous thrombosis, lower extremity thrombosis was found in 81.8% of those with femoral catheters and upper extremity thrombosis in 75% of those with jugular catheters. While thrombosis typically occurs more frequently in the lower extremities in adults [10], the rates of thrombosis in the lower and upper extremities are similar in children due to the common use of lower extremity catheters in pediatric intensive care units and upper extremity catheters in other units. Sandoval *et al.* [11] found that lower extremity thrombosis was observed in approximately 90% of patients in the pediatric intensive care unit. De Angelis *et al.* [12] reported that all children with lower extremity thrombosis had a central venous catheter in the lower extremity.

Previous studies have shown that the incidence of arterial thrombosis is lower than venous thrombosis [6, 13]. In our study, only patients with thrombosis confirmed through Doppler ultrasonography were included, and all cases of arterial thrombosis were associated with arterial catheters. Further investigation into the frequency of thrombosis in patients with arterial catheter placement is warranted.

Gonzalez *et al.* [14] found no discernible age discrepancy between the patient and control groups in their exploration of risk factors associated with hospital-acquired venous thromboembolism. Similarly, Higgerson *et al.* [15] did not uncover any correlation between gender and thrombosis in the pediatric intensive care unit. In our study, 63.3% of thrombosis cases manifested in female patients, while 36.7% occurred in males; nevertheless, no statistically significant difference was observed between the thrombosis and control groups with respect to gender distribution. The preponderance of individuals with thrombosis (66.7%) were classified as being in Tanner stage 1, with only 23.4% categorized as stages 4 and 5. These findings suggest a potential need to explore whether gender could serve as a predisposing factor for thrombosis prior to the onset of adolescence when its impact becomes more prominent.

A study conducted by Stokes *et al.* [16] in a pediatric

TABLE 1. Patients' demographic information and clinical characteristics.

	Thrombosis Group (n = 30)	Control group (n = 30)	*p* value
Gender, n (%)			
Female	19 (63.3%)	13 (43.3%)	0.121
Male	11 (36.7%)	17 (56.7%)	
Age (month)			
Mean ± SD	84.7 ± 68.3	81.2 ± 58.1	
Median	62	73	0.828
Min–max	3–192	4–216	
Height (cm)			
Mean ± SD	111.3 ± 39.7	108.2 ± 30.1	
Median	102	108	0.737
Min–max	60–179	58–173	
Weight (kg)			
Mean ± SD	25.5 ± 20.9	22.1 ± 16.9	
Median	15.7	18	0.865
Min–max	4.4–80	5.2–85	
Body mass index (kg/m^2)			
Mean ± SD	17.1 ± 3.4	17.3 ± 3.7	
Median	16.0	16.8	0.855
Min–max	12.2–25.8	11.8–29.0	
PIM score			
Mean ± SD	2.1 ± 1.4	2.6 ± 1.6	
Median	2	2	0.187
Min–max	0.3–5.2	0.8–6.8	
PRISM-2 score			
Mean ± SD	2.9 ± 3.4	3.0 ± 2.1	
Median	1.7	2.4	0.930
Min–max	0.1–17.0	0.7–8.4	
Braden Q score			
Mean ± SD	15.4 ± 3.9	16.7 ± 4.0	
Median	15	16	0.249
Min–max	9–23	11–25	
Tanner stage, n (%)			
Stage 1	20 (66.7%)	23 (76.7%)	
Stage 2	1 (3.3%)	2 (6.7%)	
Stage 3	2 (6.7%)	0 (0.0%)	
Stage 4	5 (16.7%)	2 (6.7%)	
Stage 5	2 (6.7%)	3 (10.0%)	
DVT prophylaxis			
Yes	0	0	
No	30	30	

SD: standard deviation; PIM: pediatric mortality index; PRISM-2: pediatric risk of mortality; DVT: deep vein thrombosis.

TABLE 2. Data on the type and localization of thrombosis.

	Thrombosis group (n = 30)
Type of thrombosis, n (%)	
Venous	22 (73.3%)
Arterial	8 (26.7%)
Thrombosis localization, n (%)	
Upper extremity	10 (33.3%)
Lower extremity	16 (53.3%)
Portal vein thrombosis	4 (13.3%)
Type and localization of thrombosis, n (%)	
Lower extremity venous	13 (43.3%)
Lower extremity arterial	3 (10.0%)
Upper extremity venous	5 (16.7%)
Upper extremity arterial	5 (16.7%)
Portal vein thrombosis	4 (13.3%)
Localization in venous thrombosis, n (%)	
Upper extremity	5 (27.0%)
Lower extremity	13 (59.1%)
Portal vein	4 (18.2%)
Presence of catheter in venous thrombosis	
Yes	15 (68.2%)
No	7 (31.8%)
Venous Thrombosis catheter placement	
Femoral	11 (73.3%)
Jugular	4 (26.6%)
Localization in arterial thrombosis	
Upper extremity	5 (62.5%)
Lower extremity	3 (37.5%)
Presence of catheter in arterial thrombosis	
Yes	8 (100.0%)
No	0 (0.0%)

cohort revealed a heightened incidence of thromboembolic events among individuals with elevated Body Mass Index (BMI). Despite this, our own investigation did not unveil any divergence in BMI levels between the groups with and without thrombosis. Nonetheless, a correlation between BMI and thrombosis has been documented in existing literature [16, 17]. In their study, Higgerson *et al.* [15] found that the majority of patients who developed thrombosis were those who had undergone surgery. In our study, we examined the reasons for hospitalization of patients with thrombosis and identified the post-operative period (23.3%) and after coronary angiography (13.3%) as the two most prevalent causes.

Many previous studies have indicated that individuals carrying the Factor V Leiden mutation are at a heightened risk of thrombosis. This particular gene is widely recognized as one of the most significant risk factors associated with thrombotic events. Another gene that influences thrombosis is the prothrombin *20210A* gene [18]. Elevated homocysteine levels have been identified as a contributing risk factor in numerous thrombotic conditions. Our analysis of mutations potentially linked to coagulation disorders revealed no statistically significant variance between patients with thrombosis and those without. Levels of Protein C, protein S and homocysteine were comparable in both groups. Only one patient without thrombosis exhibited heterozygous Prothrombin *20210A* mutation. While Factor V Leiden mutation was examined in eleven patients with thrombosis and nine without, no mutations were identified in any of them.

Higgerson *et al.* [15] discovered that patients with thrombosis exhibited significantly higher PIM scores. However, our investigation did not reveal any noteworthy difference in PIM and PRISM-2 scores between the thrombosis and non-thrombosis groups. A high Braden Q score is believed to elevate the risk of thrombosis, as evidenced by a study where the thrombosis group had a higher Braden Q score [19]. Another study reported that the likelihood of VTE increased by 29% with every one-point increment in the Braden Q total score [14]. In our study, we did not find any significant contrast in Braden Q scores between the thrombosis and non-thrombosis groups, potentially due to the limited number of patients.

While mechanical ventilation and hemodialysis typically heighten the risk of thrombosis [19], our study surprisingly revealed higher rates of these interventions in the control group. This unexpected finding may be attributed to the small sample size. Branchford *et al.* [20] reported that the risk of thrombosis escalates in direct correlation with the duration of hospitalization in pediatric patients. However, our study did not encompass the length of hospital stay prior to intensive care unit (ICU) admission. Thrombosis onset occurred at an average of 6.9 $\pm$ 4.9 days of hospitalization in our patients, none of whom received DVT prophylaxis.

The main strength of our study lies in the inclusion of all pediatric patients admitted to the intensive care unit of the largest regional hospital over an extensive period. However, limitations include the retrospective nature of the study, a small number of patients with thrombosis, and incomplete monitoring of patients with central venous catheters and arterial catheters for thrombosis development. Notably, all patients with arterial thrombosis were found to have an arterial catheter. Future prospective studies are warranted to further investigate arterial thrombosis development and assess the role of arterial catheters and other risk factors.

5. Conclusions

In our study, the placement of central venous catheters (CVC) and arterial catheters emerged as the most significant acquired risk factors associated with thrombosis. Therefore, close monitoring is advised for critically ill pediatric patients in the intensive care unit who have undergone CVC and arterial catheter placement, as thrombosis may even occur in prepubertal children. It is imperative that large-scale prospective studies be conducted to explore the frequency of thrombosis and the various factors influencing its development in critically ill pediatric patients.

TABLE 3. Comparison of laboratory parameters and mutations.

	Thrombosis group (n = 30)	Control group (n = 30)	*p* values
aPTT (sec)			
Mean ± SD	29.7 ± 9.8	31.8 ± 16.7	
Median	27.4	27.0	0.723
Min–max	18.1–67.5	12.0–98.0	
PT (sec)			
Mean ± SD	13.7 ± 2.8	14.4 ± 4.8	
Median	13.3	13.1	0.888
Min–max	9.9–21.2	10.9–34.2	
Fibrinogen (g/L)			
Mean ± SD	302.7 ± 162.4	302.9 ± 108.7	
Median	255	293	0.995
Min–max	115–900	108–508	
INR			
Mean ± SD	1.2 ± 0.2	1.2 ± 0.5	
Median	1.1	1.1	0.882
Min–max	0.9–1.9	0.9–3.1	
Platelet (10^3/L)			
Mean ± SD	255,000 ± 139,269	2,344,333 ± 1,652,187	
Median	220,500	225,000	0.604
Min–max	46,000–559,000	7000–583,000	
Protein C			
Mean ± SD	54.7 ± 18.5	56.9 ± 20.9	
Median	52.6	57.9	0.797
Min–max	10.8–84.6	20.7–78.6	
Protein S			
Mean ± SD	74.8 ± 32.5	69.9 ± 10.1	
Median	78.5	68.2	0.703
Min–max	30.6–136.0	55.6–85.9	
Homocysteine (µmol/L)			
Mean ± SD	12.1 ± 11.1	9.3 ± 6.6	
Median	8.4	8.1	0.562
Min–max	2.6–45.4	3.4–24.1	
Prothrombin *20210A* mutation, n (%)			
Normal	11 (100.0%)	8 (88.9%)	0.450
Heterozigot	0 (0.0%)	1 (11.1%)	
FV Leiden mutation, n (%)			
Normal	11 (100%)	9 (100%)	

aPTT: Activated Partial Thromboplastin Time; PT: Prothrombin Time; INR: International Normalized Ratio; FV Leiden: Factor V Leiden; SD: standard deviation.

AVAILABILITY OF DATA AND MATERIALS

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

AA, OOH, DY—designed the research study. AA, OOH, DY, MM, FE, GL, STB—performed the research; wrote the manuscript. AA, OOH, FE—analyzed the data. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical committee approval was received from the Çukurova University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Date: 05 March 2021, meeting number: 109). Because of retrospective research, family consent was not required.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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How to cite this article: Aylin Akti, Ozden Ozgur Horoz, Dincer Yildizdas, Merve Misirlioglu, Faruk Ekinci, Goksel Leblebisatan, *et al*. Thrombus prevalence and risk factors in critically ill pediatric patients. Signa Vitae. 2024; 20(11): 49-55. doi: 10.22514/sv.2024.143.