Risk factors for deep venous thrombosis in pediatric trauma patients: A review of the National Trauma Data Bank from 2017 to 2022

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INTRODUCTION: Pediatric trauma patients rarely receive venous thromboembolism (VTE) prophylaxis but have low rates of deep venous thrombosis (DVT). Patients with lower extremity orthopedic injuries, patients with traumatic brain injuries, more severely injured patients, and older children may be at higher risk, but these risk factors have not been examined together for a large population.

METHODS: The National Trauma Data Bank was queried from 2017 to 2022 for patients 17 years or younger and patients with DVT to create a retrospective cohort study with this subset compared with pediatric patients without DVT. Categorical variables were analyzed with χ^2 test, and continuous variables, with *t* test. A logistic regression model was performed to determine risk factors for DVT in pediatric trauma patients.

RESULTS: From 2017 to 2022, there were 693,729 pediatric trauma patients, of which 786 (0.11%) had a DVT. The DVT group was older (13.64 vs. 9.70 years, $p < 0.0001$) and more likely to be male (71.63% vs. 64.65%, $p < 0.0001$), proceeded immediately to operating room (41.6% vs. 14.63%, $p < 0.001$), received packed red blood cells (PRBCs) ≤4 hours (47.71% vs. 9.94%, $p < 0.0001$), received fresh frozen plasma ≤4 hours (33.46% vs. 1.22%, $p < 0.0001$), and had an Injury Severity Score (ISS) of >15 (87.02% vs. 43.19%, $p < 0.0001$). A logistic regression model demonstrated that patients age 13 years or older had an odds ratio of 2.444 (confidence interval, 1.137–5.250; $p = 0.022$). Other significant risk factors included PRBC ≤4 hours of arrival (odds ratio, 3.436; confidence interval, 1.574–7.502; $p = 0.022$), ISS of >15 (odds ratio, 3.650; confidence interval, 1.071–12.440; $p < 0.038$), increased lower-extremity Abbreviated Injury Scale scores (odds ratio, 1.665; confidence interval, 1.236–2.243; $p = 0.001$), and VTE prophylaxis administered more than 6 days after admission (odds ratio, 11.590; confidence interval, 5.695–23.584; $p < 0.0001$).

CONCLUSION: Venous thromboembolism prophylaxis should be considered in pediatric patients who are 13 years or older, have received PRBC early, and have severe ISS and/or higher lower-extremity Abbreviated Injury Scale score; delayed VTE prophylaxis beyond 6 hospital days increases risk of DVT in patients with these risk factors. (*J Trauma Acute Care Surg.* 2025;99: 533–540. Copyright © 2025 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Prognostic and Epidemiological; Level III.
KEY WORDS: Pediatric; DVT; risk factors.

Pediatric trauma is the leading cause of death in pediatric patients,[1] with the incidence of pediatric trauma increasing annually in the United States: approximately 18.1% of pediatric emergency department visits in 2019 were due to trauma, compared with 16.3% in 2010.[2] Historically, firearm injuries were the second overall leading cause of mortality in the United States but have recently become the leading cause of mortality.[3] Among hospitalized pediatric trauma patients younger than 18 years, venous thromboembolisms (VTEs), including deep venous thrombosis (DVT) and pulmonary embolism, have an estimated frequency of less than 1%.[4–6] Carrillo et al.[7] reported a VTE rate of 0.3% in trauma patients younger than 15 years with central venous catheters (CVCs), with Injury Severity Score (ISS) greater than 15 and increased length of stay (LOS) being the strongest risk factors. Existing models for predicting pediatric VTE diagnosis have included age older than 13 years, low Glasgow Coma Scale scores of 8 or less, mechanical ventilation, blood transfusions, major surgery, ICU admission, CVCs, pelvic and lower extremity fractures, and ISS greater than 25.[5,8–10] A recent prospective observational cohort study identified a higher rate of DVT in high-risk pediatric trauma patients who received the first dose of pharmacologic VTE prophylaxis later than 24 hours postadmission.[11]

Current trauma guidelines variably address which pediatric trauma patients should be considered for pharmacologic VTE prophylaxis. The Eastern Association of the Surgery of Trauma conditionally recommends pharmacologic and mechanical VTE prophylaxis in patients older than 15 years and postpubertal patients with ISS greater than 25.[12] Several tertiary trauma care centers outline prophylaxis usage for several high-risk factors: lower extremity orthopedic operation, spinal cord injury, major lower

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extremity injury, lower extremity CVC, infection, burn injuries, and pregnancy.[13–16]

Our study used the National Trauma Data Bank (NTDB) to define the incidence and risk factors for DVT in the pediatric trauma population. We hypothesize that patients 13 years or older will correlate with a higher incidence of DVT. Based on the current literature, we also hypothesize that ISS of >15, presence of CVC, female sex, increased lower-extremity Abbreviated Injury Scale (AIS) scores, and mechanical ventilation will also be associated with increased risk of DVT.

PATIENTS AND METHODS

After obtaining Institutional Review Board approval, the NTDB was queried from 2017 to 2022 for pediatric patients, aged 17 years or younger. The authors chose to look at risk factors applicable to all pediatric patients, as the definition of admitted pediatric patients varies by each center. The NTDB is an unbiased US-based collection of data from trauma centers. Each center submits deidentified data concerning their respective trauma patients from arrival in the emergency department through discharge from the hospital. The retrieved data from the NTDB consisted of age, demographics, sex, ISS, AIS scores for each body region, emergency department discharge disposition, blood product administration (packed red blood cell [PRBC], fresh frozen plasma [FFP], platelet, and cryoprecipitate), penetrating injury, long bone fracture, hospital complications, VTE prophylaxis administration, and total ventilator days. Comparison groups were defined based on the diagnosis of DVT or no diagnosis of DVT. The diagnosis of DVT is reported by each individual institution as a tracked in-hospital complication in the NTDB. The primary outcome in our study is age 13 years or older, labeled as "adolescence" in our data collection. The secondary outcomes include ISS of >15, presence of CVC, female sex, increased lower-extremity AIS score, and mechanical ventilation.

Immediate operative intervention was identified from the emergency department discharge disposition, and immediate PRBC or FFP administration was identified from PRBC or FFP administration within 4 hours of arrival, respectively. Patients in the population were identified as 13 years or older, and 12 years or younger. Severe ISS was defined as ISS 15 of 24, very severe ISS was defined as 25 to 49, and critical ISS was defined as ≥50.[17,18] Early VTE prophylaxis administration was defined as administration within 6 days of admission, and late VTE prophylaxis was defined as administration 6 days or later postadmission, as the median length of stay for patients receiving pharmacologic VTE prophylaxis in this study was 6 days. Presence of CVC was identified by the *International Classification of Diseases, Tenth Revision*, procedure coding system for "percutaneous or open approach insertion of infusion or intraluminal device into subclavian, internal jugular or femoral vein," and presence of peripherally inserted central catheters (PICC) was identified by the *International Classification of Diseases, Tenth Revision*, procedure coding system for "insertion of infusion or intraluminal device into basilic and cephalic veins." The patients with a DVT diagnosis were the quasi-experimental group, and the patients without a DVT were the control group. The STROBE checklist for cohort studies was used to enhance the quality and transparency of the study (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/E639).

Statistical Analysis

Categorical variables were reported as frequencies with percentages, and continuous variables were reported as means with SD. Categorical variables were analyzed with χ^2 test, and continuous variables were analyzed with *t* test or Mann-Whitney *U* test, both with *p* values reported. A logistic regression model was performed to determine risk factors for DVT in pediatric trauma patients, controlling for sex, age 13 years or older, head AIS, immediate operative intervention, immediate PRBC administration, immediate FFP administration, CVC presence, ISS of ≥15, penetrating injury, VTE prophylaxis administration 6 days or later postadmission, and mechanical ventilation. Odds ratios, confidence intervals, and *p* values were reported for the logistic regression. A *p* value of <0.05 is considered to be a statistically significant result at a 95% significance level. All analyses, tables, and figures were produced using STATA version 18 (STATA Corp, College Station, TX).

RESULTS

From 2017 to 2022, there were 696,592 pediatric trauma cases in the NTDB with patients younger than 18 years. A total of 2,863 patients were excluded because of incomplete or missing information, creating an experimental group of 786 patients and a control group of 692,943 patients, with a DVT incidence of 0.11% (see Fig. 1). Deep venous thrombosis patients had a higher mean age (13.65 vs. 9.70 years, $p < 0.0001$) and more males (71.63% vs. 64.65%, $p < 0.0001$) than the control group. While both groups were predominantly White (54.96% vs. 65.08%, respectively), there was a higher percentage of White race in the control group ($p < 0.0001$). However, among Black patients, the incidence of DVT was higher ($p < 0.0001$). An overwhelming majority of the DVT patients had a severe ISS (35.62%, $p = 0.042$) or very severe ISS (51.4%, $p < 0.001$), whereas the control group was almost equally split between minor ISS (43.62%) and severe ISS (39.17%). Penetrating injuries were higher in the DVT group (5.85% vs. 1.01%, $p < 0.0001$), as were long bone fractures (1.40% vs. 0.18%, $p < 0.001$). Almost half of the DVT patients required emergent operative treatment or PRBC transfusion within 4 hours of admission, which was significantly higher compared with the control group. The frequency of CVCs (24.81%) and PICCs (5.47%) was higher in DVT patients than the control group (0.94% and 0.47%, respectively, $p < 0.0001$). Of those with CVC, only 2.9% were diagnosed with a DVT during their hospitalization (195 of 6,720 patients). The DVT patients were more likely to receive pharmacologic VTE prophylaxis, with 39.31% receiving VTE prophylaxis within 6 days of admission and 41.35% receiving VTE prophylaxis after 6 days from admission. The mean AIS was significantly higher in all body areas for the DVT group versus the control group, with the highest difference existing for the head AIS. Almost 80% of DVT patients were ventilated compared with a little over 5% in the control group ($p < 0.0001$) as demonstrated in Table 1.

To evaluate our primary outcome of age 13 years or older, the number of patients diagnosed with DVT was graphed over

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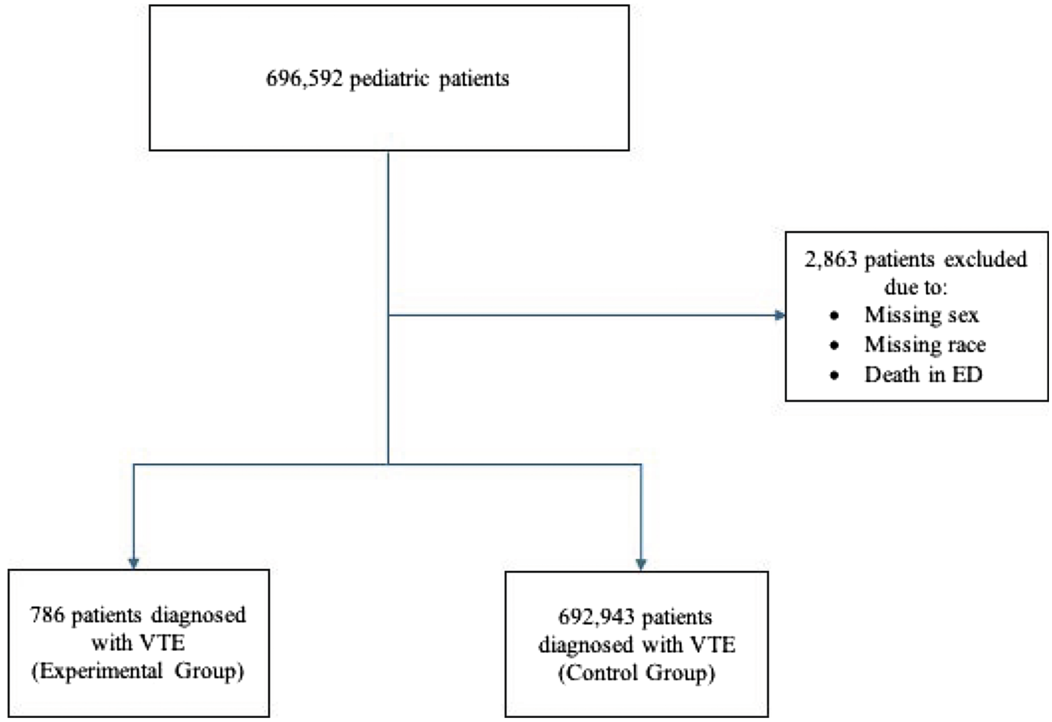

Figure 1. Flow diagram of included patients.

age in 1-year increments. The number and incidence of DVTs sharply increased from 16 patients at age of 12 years to 40 patients at age of 13 years and continued to increase by age, with 242 patients diagnosed with a DVT in the 17-year-old group (see Fig. 2). Similarly, the proportion of DVT patients at a given age increases sharply after 13 years old. Although the control group also has a similar uptick in distribution after age 13 of years, it is not as sharp as the DVT group, with 30.79% of the DVT patients being 17 years old on admission versus 9.55% in the control group. Although incidence of DVT is very low for each year of age individually, the incidence by year also increased sharply starting at age of 13 years, as depicted in Table 2.

A logistic regression analysis was performed to identify risk factors associated with DVT in pediatric patients. Late VTE prophylaxis (more than 6 days after admission) and ISS of ≥15 were associated with higher odds ratios (11.590, $p < 0.0001$ and 3.650, $p = 0.038$, respectively). Higher AIS scores for the lower extremity and PRBC transfusion within 4 hours were also associated with significantly increased odds ratios (1.665, $p = 0.001$; 3.436, $p = 0.002$, respectively). Adolescence, defined as age 13 years or older, was associated with an odds ratio of 2.444 ($p = 0.022$). Higher head AIS score also correlated with increased risk of DVT (odds ratio, 1.467; $p = 0.007$). Presence of a CVC and mechanical ventilation did not confer additional risk of DVT (see Table 3).

DISCUSSION

Although the incidence of DVT in pediatric trauma patients is significantly lower than adults, it has increased by over 70% in the last 20 years in the literature,[19] mirroring the increased incidence of pediatric trauma.[2] The increase in DVT incidence is multifactorial, with increased utilization of ultrasonography as a possible contributor. At a single tertiary pediatric trauma center, they had a DVT rate of 6.2% in pediatric intensive care unit patients. The authors found that the presence of CVC, use of TPN, deep sedation, neuromuscular blockade, and recombinant factor VIIa administration were risk factors for DVT.[20,21] In their review of the NTDB from 2001 to 2005, O'Brien and Candrilli[22] used the American Academy of Pediatrics definition of pediatric patients of up to 21 years of age and found a DVT rate of 0.6%. Both these rates are higher than our reported rate of 0.11%, but our study covers a longer time period and contains a large heterogeneous population. One explanation could be that pharmacologic VTE prophylaxis was more commonly used in our patient population compared with the populations in those studies. It is also unclear which, if any, DVT screening protocols were used in these studies or in our study.

Our data show that DVT occurs at a much higher rate in the pediatric trauma population beginning at 13 years of age, confirming one of our primary hypotheses. Despite the incidence of the control group increasing each year after age of 13 years, this is sharply contrasted with the incidence of DVT in both the DVT group and in the pediatric trauma group overall per year of age. This pattern suggests that the increased rate of DVT is not merely due to a larger sample size being studied, but rather highlights that age itself as a risk factor. The mean age was significantly higher in the DVT group, and this reflects trends described in the literature.[5,23] Currently, Eastern Association for the Surgery of Trauma guidelines conditionally recommend providing both pharmacological and mechanical prophylaxis in children older than 15 years and postpubertal children younger than 15 years if they have an ISS of 25 or greater.[12] Our data support broadening these recommendations given that

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TABLE 1. Patient Demographics

Variable	Patients With DVT (n = 786)	Patients Without DVT (n = 692,943)	*p*
Age, mean (SD), y	13.64 (4.49)	9.70 (5.17)	<0.0001
Sex			<0.0001
Male	563 (71.63%)	447,961 (64.65%)	
Female	223 (26.37%)	244,982 (35.35%)	
Race			
White	432 (54.96%)	450,999 (65.08%)	<0.0001
Black	222 (28.24%)	124,359 (17.95%)	<0.0001
Asian	10 (1.27%)	15,210 (2.18%)	0.081
Pacific Islander	5 (0.64%)	2800 (0.40%)	0.306
American Indian	9 (1.15%)	7736 (1.12%)	0.939
Other	34 (4.33%)	19,580 (2.83%)	0.011
Minor ISS (0–8)	15 (1.91%)	302,274 (43.62%)	<0.0001
Moderate ISS (9–14)	87 (11.07%)	91,389 (13.19%)	0.079
Severe ISS (15–24)	280 (35.62%)	271,415 (39.17)	0.042
Very severe ISS (25–49)	404 (51.40%)	27,865 (4.02%)	<0.0001
Critical ISS (50–75)	35 (4.45%)	4,679 (0.68%)	<0.0001
ISS >15	684 (87.02%)	299,282 (43.19%)	<0.0001
Penetrating injury	46 (5.85%)	7,013 (1.01%)	<0.0001
Blunt injury	740 (94.15%)	685,930 (98.99%)	<0.0001
Long bone fracture	11 (1.40%)	1,230 (0.18%)	<0.0001
Immediate operating room	327 (41.60%)	101,332 (14.62%)	<0.0001
Immediate PRBC transfusion	375 (47.71%)	68,893 (9.94%)	<0.0001
Immediate FFP transfusion	263 (33.46%)	8,482 (1.22%)	<0.0001
Median hospital length of stay	6 (3–11)	2 (1–3)	<0.0001
CVC during hospitalization	195 (24.81%)	6,525 (0.94%)	<0.0001
PICC during hospitalization	43 (5.47%)	3,263 (0.47%)	<0.0001
Early VTE prophylaxis (<6 d postadmission)	309 (39.31%)	33,333 (4.81%)	<0.0001
Late VTE prophylaxis (≥6 d postadmission)	325 (41.35%)	14,482 (2.09)	<0.0001
AIS, mean (SD)			
Head	3.86 (1.28)	2.31 (1.20)	<0.0001
Face	3.36 (1.46)	2.09 (1.15)	<0.0001
Neck	2.01 (1.20)	1.48 (0.81)	<0.0001
Thorax	2.41 (1.16)	1.54 (0.84)	<0.0001
Abdomen	3.01 (1.02)	2.12 (1.06)	<0.0001
Spine	2.96 (1.23)	2.10 (1.12)	<0.0001
Upper extremity	2.56 (1.13)	1.90 (0.79)	<0.0001
Lower extremity	2.05 (0.85)	1.77 (0.59)	<0.0001
Ventilated	627 (79.77%)	37,532 (5.42%)	<0.0001

patients 13 years or older and an ISS of greater than 15 were more likely to develop a DVT. This may reflect an earlier onset of puberty and its effects on the clotting cascade[24] with multiple studies having demonstrated physiologic differences due to sexual dimorphism in adolescent patients that occurs related to puberty.[25,26] Liras et al.[27] found that, although TEG results on admission did not demonstrate a strong hypercoagulable state in pediatric patients, the rate of VTE sharply increased at 13 years old. They suggest that puberty and hormonal changes likely lead to increased hypercoagulability that is not necessarily detected on TEG.[27] Although sexual dimorphism with increased hypercoagulability in females can be present in TEG profiles after puberty,[28] our study did not demonstrate an increased risk for DVT formation in females despite the observed hypercoagulability of females as an effect of estradiol. This could be due to the complexity of the clotting cascade and other effects of estradiol, such as decreased inflammation.[25]

Patients in our study with higher AIS score of the lower extremity also had increased risk of DVT, which affirms the findings of Murphy et al.[29] The presence of more severe injuries to the lower extremities is likely a marker for delayed ambulation or nonambulatory status, contributing to venostasis in the deep venous system. Additionally, transfusion of PRBCs within 4 hours of admission may be an indication for pharmacologic VTE prophylaxis. Rothstein et al.[30] found a similar correlation between preoperative PRBC transfusion and postoperative DVT diagnosis in pediatric patients undergoing surgery between 2012 and 2017. Massive transfusion protocol, defined as at least 6 U of PRBC transfused, has also been shown to correlate with an increased risk of a VTE[31]; our data did not demonstrate an increased risk

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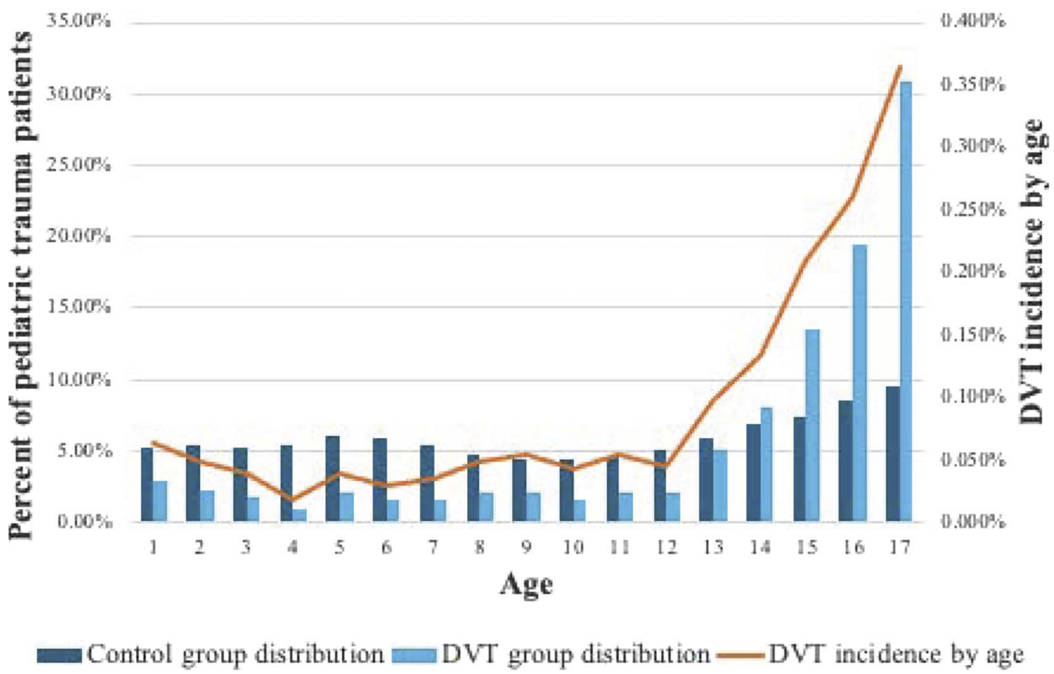

Figure 2. Age distributions.

with FFP transfusion within 4 hours of admission, suggesting that the PRBC transfusion may be a greater risk factor than FFP transfusion.

In adults, penetrating injuries that cause iliocaval injuries are independently associated with increased VTE risk, but the overall risk of VTE between blunt and penetrating injuries appears to be similar.[32,33] Our data demonstrated that the DVT group had a higher proportion of penetrating injuries than the control group, with 5% of the DVT patients having a penetrating injury. Immediate operative intervention constituted a larger proportion of DVT patients, with over 41% of DVT patients going to the operating room from their trauma resuscitation. Major surgery has been identified as a risk factor for VTE formation, but this is the first demonstration that emergent operation from the emergency department is significantly higher in pediatric trauma patients diagnosed with a DVT.[5,9,34] Mechanical ventilation was higher in our DVT group, with almost 80% of this group requiring mechanical ventilation, which is a similar rate described by Connelly et al.,[5] who found that 74% of pediatric VTE patients were mechanically ventilated. This likely correlates

TABLE 2. Age Distribution

Age	No DVT	Control Group Incidence by Age	Control Group Distribution	DVT	DVT Incidence by Age	DVT Group Distribution	Total (Per Age)
1	35,756	99.94%	5.16%	23	0.064%	2.93%	35,779
2	37,447	99.95%	5.40%	18	0.048%	2.29%	37,465
3	36,483	99.96%	5.26%	14	0.038%	1.78%	36,497
4	37,997	99.98%	5.48%	7	0.018%	0.89%	38,004
5	41,627	99.96%	6.01%	16	0.038%	2.04%	41,643
6	41,398	99.97%	5.97%	12	0.029%	1.53%	41,410
7	37,436	99.97%	5.40%	13	0.035%	1.65%	37,449
8	33,195	99.95%	4.79%	16	0.048%	2.04%	33,211
9	30,883	99.94%	4.46%	17	0.055%	2.16%	30,900
10	30,183	99.96%	4.36%	13	0.043%	1.65%	30,196
11	31,779	99.95%	4.59%	17	0.053%	2.16%	31,796
12	35,184	99.95%	5.08%	16	0.045%	2.04%	35,200
13	40,709	99.90%	5.87%	40	0.098%	5.09%	40,749
14	47,237	99.87%	6.82%	63	0.133%	8.02%	47,300
15	50,653	99.79%	7.31%	106	0.209%	13.49%	50,759
16	58,809	99.74%	8.49%	153	0.259%	19.47%	58,962
17	66,167	99.64%	9.55%	242	0.364%	30.79%	66,409
Total	692,943	99.89%	100.00%	786	0.113%	100.00%	693,729

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TABLE 3. Logistic Regression Analysis

	Odds Ratio	Confidence Interval 95%		*p*
Female sex	1.176	0.618	2.237	0.622
Adolescence (age >13 y)	2.444	1.137	5.250	0.022
Head AIS	1.467	1.111	1.939	0.007
Immediate operating room	1.137	0.548	2.361	0.730
PRBC within 4 h	3.436	1.574	7.501	0.002
FFP within 4 h	0.666	0.2734	1.620	0.370
CVC presence	1.0	—	—	—
ISS ≥15	3.650	1.071	12.440	0.038
Penetrating injury	1.325	0.266	6.597	0.731
Lower-extremity AIS	1.665	1.236	2.243	0.001
VTE prophylaxis after 6 d	11.590	5.695	23.584	<0.0001
Mechanical ventilation	1.0	—	—	—

to more severe injuries and immobility, leading to an increased risk of DVT formation. However, our study did not demonstrate mechanical ventilation as a significant risk factor for DVT diagnosis in pediatric trauma patients in our logistic regression.

While previous studies have demonstrated a risk of DVT with CVCs, our model's odds ratio was 1.0, suggesting that a DVT diagnosis and CVC are independent of each other. We found that a rate of 2.9% of patients with a CVC developed a DVT, which is relatively low compared with other quoted rates from 3.3% to 29.9%.[22,35–38] O'Brien and Candrilli[22] posited that CVC was associated with an increased risk of DVT, but this association was weaker than major vascular injury and age older than 14 years in their model. A recent study examining the risk of DVT in pediatric patients with severe traumatic brain injuries admitted to the pediatric intensive care unit for ≥72 hours with a CVC had a rate of 29.9%.[37] We did not analyze this specific subset of the population in our study, so we cannot comment which factors contributed more to this high rate of DVT. Historically, the strong association between CVCs and DVT in pediatric patients is suggested in other studies that often include pediatric populations with other comorbidities that may act as confounders, such as malignancy,[39,40] congenital heart disease,[41] obesity,[8,42] and the presence of a tunneled catheter.[39,43]

Use of pharmacologic VTE prophylaxis in pediatric populations is highly variable, as demonstrated by a survey of pediatric orthopedic surgeons in Canada.[44] In the United States, there are recommendations from Cincinnati Children's Hospital and American College of Chest Physicians guidelines for initiating pharmacologic VTE prophylaxis, but applicability to pediatric trauma patients is unclear.[45] Our data suggest that pharmacologic VTE prophylaxis initiation after hospital day 6 is a risk factor for DVT diagnosis. Witte et al.[11] found that VTE events were diagnosed at a median of day 6 postinjury, and in their study, the median initiation of pharmacologic VTE prophylaxis occurred at 4.2 days. Most patients (75.2%) in their study received VTE chemoprophylaxis after 24 hours, but two common injury patterns delayed VTE chemoprophylaxis for at least 24 hours in their protocol: TBI and solid organ injury. This protocol demonstrates that a goal of 24 hours for VTE chemoprophylaxis is likely not realistic in this patient population.[11] Patients in our population who received pharmacologic VTE prophylaxis had a median length of stay of 6 days,[3–11] and this correlation could be a marker of increased injury severity, necessitating a longer length of stay and delay to initiation of pharmacologic VTE prophylaxis.

Despite DVT being rare in the pediatric population, DVT constitutes a significant morbidity, as it is associated with increased length of stay,[7,10,22] increased costs,[10,46] and pulmonary embolisms.[7,45,47] Our study incorporates the most recent and updated data—a significant strength considering the inherent heterogeneity of the pediatric trauma population. Furthermore, because the incidence of pediatric DVT is so low, using a national data bank provided sufficient power and generalizability to our study's conclusions to suggest reasonable updates to current practice guidelines. The usage of the NTDB also provides valuable information for identifying risk factors for DVT diagnosis specific to the United States and Canadian trauma patient populations, which have different patterns than the rest of the world. Our findings corroborate a validated DVT prediction model, with increased risk for age older than 13 years, transfusion of PRBCs, and more severe head injury correlating to increased risk of DVT.[5,34]

Limitations

This retrospective review is limited by the accuracy of preexisting data and the lack of a true matched control and experimental cohorts. Although most PICC lines are inserted in upper extremities, they can be inserted in lower extremities, and we did not evaluate for these in our data set, which could underestimate the total number of PICC lines in the population. Our review also suggests correlations for risk factors, but these correlations are not absolute, and there is a possibility of confounding due to the heterogeneity of the data. Furthermore, our findings serve to emphasize the need to address the ever-increasing risk of DVT in pediatric patients but does not address the issue of method, duration, or risks of VTE prophylaxis once at-risk patients are identified.

CONCLUSION

Despite having a low incidence, pediatric DVT can still lead to increased morbidity and resource utilization, especially in the pediatric trauma population. The authors recommend expanding the current guidelines to include age 13 years or older, higher AIS scores for head and lower extremities, PRBC transfusion within 4 hours of admission, and ISS of >15 as triggers for initiating pharmacologic VTE prophylaxis. Although there are many factors to consider prior to initiating pharmacologic VTE prophylaxis, our data suggest that patients with the risk factors listed previously should initiate prophylaxis as soon as reasonably possible, with a goal of initiating therapy within 6 days postadmission. Future studies examining the efficacy of chemical, mechanical VTE prophylaxis, or both modalities in pediatric trauma populations will help further refine clinical guidelines.

AUTHORSHIP

J.G. and T.I. contributed in the conception and study design. J.G., T.I., S.M., and S.X. contributed in the literature review. J.G. contributed in the data acquisition. J.G. contributed in the data analysis. J.G., T.I., S.M., S.X., A.M., and D.K. contributed in the drafting of the manuscript.

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DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E640).

REFERENCES

1. Oliver J, Avraham J, Frangos S, Tomita S, DiMaggio C. The epidemiology of inpatient pediatric trauma in United States hospitals 2000 to 2011. *J Pediatr Surg*. 2018;53(4):758–764.
2. Lee LK, Porter JJ, Mannix R, Rees CA, Schutzman SA, Fleegler EW, et al. Pediatric traumatic injury emergency department visits and management in US children's hospitals from 2010 to 2019. *Ann Emerg Med*. 2022;79(3): 279–287.
3. Goldstick JE, Cunningham RM, Carter PM. Current causes of death in children and adolescents in the United States. *N Engl J Med*. 2022;386(20): 1955–1956.
4. Van Arendonk KJ, Schneider EB, Haider AH, Colombani PM, Stewart FD, Haut ER. Venous thromboembolism after trauma: when do children become adults? *JAMA Surg*. 2013;148(12):1123–1130.
5. Connelly CR, Laird A, Barton JS, Fischer PE, Krishnaswami S, Schreiber MA, et al. A clinical tool for the prediction of venous thromboembolism in pediatric trauma patients. *JAMA Surgery*. 2016;151(1):50–57.
6. Thompson AJ, McSwain SD, Webb SA, Stroud MA, Streck CJ. Venous thromboembolism prophylaxis in the pediatric trauma population. *J Pediatr Surg*. 2013;48(6):1413–1421.
7. Carrillo LA, Kumar A, Harting MT, Pedroza C, Cox CS Jr. Venous thromboembolism risk factors in a pediatric trauma population. *Pediatr Surg Int*. 2019;35(4):487–493.
8. Petty JK. Venous thromboembolism prophylaxis in the pediatric trauma patient. *Semin Pediatr Surg*. 2017;26(1):14–20.
9. Yen J, Van Arendonk KJ, Streiff MB, McNamara L, Stewart FD, Conner KG, et al. Risk factors for venous thromboembolism in pediatric trauma patients and validation of a novel scoring system: the risk of clots in kids with trauma score. *Pediatr Crit Care Med*. 2016;17(5):391–399.
10. Bigelow AM, Flynn-O'Brien KT, Simpson PM, Dasgupta M, Hanson SJ. Multicenter review of current practices associated with venous thromboembolism prophylaxis in pediatric patients after trauma. *Pediatr Crit Care Med*. 2018;19(9):e448–e454.
11. Witte AB, Van Arendonk K, Bergner C, Bantchev M, Falcone RA Jr., Moody S, et al. Venous thromboembolism prophylaxis in high-risk pediatric trauma patients. *JAMA Surg*. 2024;159(10):1149–1156.
12. Mahajerin A, Petty JK, Hanson SJ, Thompson AJ, O'Brien SH, Streck CJ, et al. Prophylaxis against venous thromboembolism in pediatric trauma: a practice management guideline from the Eastern Association for the Surgery of Trauma and the Pediatric Trauma Society. *J Trauma Acute Care Surg*. 2017;82(3):627–636.
13. Surgery Department. Pediatric Venous Thromboembolism (VTE) Guideline & Algorithm McGovern Medical School 2023. Updated October 2023. Available at: https://med.uth.edu/surgery/pediatric-venous-thromboembolism-vte-guideline-algorithm/. Accessed October 12, 2024.
14. Evidenced Based Medicine Committee of the Children's Hospital of Orange County. Pediatric VTE Prophylaxis Guideline 2017. Updated July 17, 2017. Available at: https://choc.org/wp-content/uploads/careguidelines/PediatricVTEProphylaxisGuideline.pdf. Accessed October 12, 2024.
15. Austin MML, Toale K. Venous Thromboembolism (VTE) Prophylaxis for Hospitalized Surgical Pediatric Patients (Age 10–17 years) MD Anderson Cancer Center. Updated April 18, 2023. Available at: https://www.mdanderson.org/content/dam/mdanderson/documents/for-physicians/algorithms/clinical-management/clin-management-vte-prophylaxis-pedi-web-algorithm.pdf. Accessed October 12, 2024.
16. Loi MKJ, Kuldanek S, Reichert K, Wang M, Carpenter T, Reiter P, Schardt T. Venous Thromboembolism (VTE) Prevention 2021. Updated May 6, 2021. Available at: https://www.childrenscolorado.org/globalassets/healthcare-professionals/clinical-pathways/venous-thromboembolism-vte-prevention_external.pdf?v=4a1482. Accessed October 12, 2024.
17. Baker SP, O'neill B. The injury severity score: an update. *J Trauma Acute Care Surg*. 1976;16(11):882–885.
18. Garcia MF, Gomes RT, Pugliesi EC, Santos JPVD, Martino FD, Gomes KHV, et al. Comparação entre o Injury Severity Score (ISS) e o New Injury Severity Score (NISS) na predição da mortalidade de traumas torácicos atendidos em um hospital terciário. *Rev Col Bras Cir*. 2024;51:51.
19. Raffini L, Huang YS, Witmer C, Feudtner C. Dramatic increase in venous thromboembolism in children's hospitals in the United States from 2001 to 2007. *Pediatrics*. 2009;124(4):1001–1008.
20. Hanson SJ, Punzalan RC, Arca MJ, Simpson P, Christensen MA, Hanson SK, et al. Effectiveness of clinical guidelines for deep vein thrombosis prophylaxis in reducing the incidence of venous thromboembolism in critically ill children after trauma. *J Trauma Acute Care Surg*. 2012;72(5):1292–1297.
21. Hanson SJ, Punzalan RC, Greenup RA, Liu H, Sato TT, Havens PL. Incidence and risk factors for venous thromboembolism in critically ill children after trauma. *J Trauma*. 2010;68(1):52–56.
22. O'Brien SH, Candrilli SD. In the absence of a central venous catheter, risk of venous thromboembolism is low in critically injured children, adolescents, and young adults: evidence from the National Trauma Data Bank. *Pediatr Crit Care Med*. 2011;12(3):251–256.
23. Hoffmann I, Lewis ER, Marini C, McNelis J, Viswanathan S, Posti JP, et al. Venous thromboembolism risk among pediatric patients with traumatic brain injury: a nationwide study of 44,128 patients. *J Neurosurg Pediatr*. 2023; 32(3):285–293.
24. Eckert-Lind C, Busch AS, Petersen JH, Biro FM, Butler G, Brauner EV, et al. Worldwide secular trends in age at pubertal onset assessed by breast development among girls: a systematic review and meta-analysis. *JAMA Pediatr*. 2020;174(4):e195881.
25. Coleman JR, Gumina R, Hund T, Cohen M, Neal MD, Townsend K, et al. Sex dimorphisms in coagulation: implications in trauma-induced coagulopathy and trauma resuscitation. *Am J Hematol*. 2024;99 Suppl 1(Suppl 1): S28–S35.
26. Kolodziej JH, Spinella PC, Brown JB, Lu L, Josephson CD, Leonard JC, et al. Patient sex and outcomes in children with life-threatening hemorrhage. *Transfusion*. 2024;64(S2).
27. Liras IN, Rahbar E, Harting MT, Holcomb JB, Cotton BA. When children become adults and adults become most hypercoagulable after trauma: an assessment of admission hypercoagulability by rapid thrombelastography and venous thromboembolic risk. *J Trauma Acute Care Surg*. 2016;80(5): 778–782.
28. Hrebinko KA, Strotmeyer S, Richardson W, Gaines BA, Leeper CM. Sex dimorphisms in coagulation characteristics in the pediatric trauma population appear after puberty. *J Trauma Acute Care Surg*. 2022;92(4):675–682.
29. Murphy RF, Naqvi M, Miller PE, Feldman L, Shore BJ. Pediatric orthopaedic lower extremity trauma and venous thromboembolism. *J Child Orthop*. 2015;9(5):381–384.
30. Rothstein DH, Cairo SB, Schaefer BA, Lautz TB. Association of perioperative red blood cell transfusion with postoperative venous thromboembolism in pediatric patients: a propensity score matched analysis. *Pediatr Blood Cancer*. 2019;66(10):e27919.
31. Bradburn EH, Ho KM, Morgan ME, D'Andrea L, Vernon TM, Rogers FB. Massive transfusion protocol and subsequent development of venous thromboembolism: statewide analysis. *Am Surg*. 2021;87(1):15–20.
32. Karcutskie CA, Meizoso JP, Ray JJ, Horkan D, Ruiz XD, Schulman CI, et al. Association of mechanism of injury with risk for venous thromboembolism after trauma. *JAMA Surg*. 2017;152(1):35–40.
33. Haqqani MH, Levin SR, Kalish JA, Brahmbhatt TS, Richman AP, Siracuse JJ, et al. High mortality and venous thromboembolism risk following major penetrating abdominal venous injuries. *Ann Vasc Surg*. 2021;76:193–201.
34. Labuz DF, Cunningham A, Tobias J, Dixon A, Dewey E, Marenco CW, et al. Venous thromboembolic risk stratification in pediatric trauma: a Pediatric Trauma Society Research Committee multicenter analysis. *J Trauma Acute Care Surg*. 2021;91(4):605–611.
35. Higgerson RA, Lawson KA, Christie LM, Brown AM, McArthur JA, Totapally BR, et al. Incidence and risk factors associated with venous thrombotic events in pediatric intensive care unit patients. *Pediatr Crit Care Med*. 2011;12(6):628–634.
36. Cyr C, Michon B, Pettersen G, David M, Brossard J. Venous thromboembolism after severe injury in children. *Acta Haematol*. 2006;115(3–4):198–200.
37. Lovett ME, Daniel M, Keesari R, MacDonald J, Rodriguez V, Muszynski J, et al. Catheter-associated deep vein thrombosis in children with severe

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traumatic brain injury: a single-center experience. *Pediatr Blood Cancer*. 2023;70(1):e30044.
38. O'Brien SH, Haley K, Kelleher KJ, Wang W, McKenna C, Gaines BA. Variation in DVT prophylaxis for adolescent trauma patients: a survey of the Society of Trauma Nurses. *J Trauma Nurs*. 2008;15(2):53–57.
39. Jaffray J, Bauman M, Massicotte P. The impact of central venous catheters on pediatric venous thromboembolism. *Front Pediatr*. 2017;5:5.
40. Dhir A, DeMarsh S, Ramgopal A, Worley S, Auron M, Hupertz V, et al. Central venous line associated deep vein thrombosis in hospitalized children. *J Pediatr Hematol Oncol*. 2019;41(7):e432–e437.
41. Steen EH, Lasa JJ, Nguyen TC, Keswani SG, Checchia PA, Anders MM. Central venous catheter-related deep vein thrombosis in the pediatric cardiac intensive care unit. *J Surg Res*. 2019;241:149–159.
42. Rana AR, Michalsky MP, Teich S, Groner JI, Caniano DA, Schuster DP. Childhood obesity: a risk factor for injuries observed at a level-1 trauma center. *J Pediatr Surg*. 2009;44(8):1601–1605.
43. Revel-Vilk S, Yacobovich J, Tamary H, Goldstein G, Nemet S, Weintraub M, et al. Risk factors for central venous catheter thrombotic complications in children and adolescents with cancer. *Cancer*. 2010;116(17):4197–4205.
44. Curwin J, MacNevin W, El-Hawary R, Kulkarni K. Venous thromboembolism prophylaxis use by pediatric orthopedic surgeons in Canada for the pediatric orthopedic surgical population. *Cureus*. 2022;14:e29933.
45. Fan EM, Lewis D, Presti T, El-Haj N, Chang WW. Concordance of identified cases of pediatric HA-VTE with American College of Physicians and Cincinnati Children's hospital HA-VTE prophylaxis guidelines over a 10-year period. *Glob Pediatr Health*. 2020;7:2333794x20960279.
46. Goudie A, Dynan L, Brady PW, Fieldston E, Brilli RJ, Walsh KE. Costs of venous thromboembolism, catheter-associated urinary tract infection, and pressure ulcer. *Pediatrics*. 2015;136(3):432–439.
47. Branchford BR, Carpenter SL. The role of inflammation in venous thromboembolism. *Front Pediatr*. 2018;6:142.

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