VENOUS THROMBOEMBOLIC COMPLICATIONS IN SCOLIOSIS SURGERY: A REVIEW OF THE LITERATURE

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Objective. To present modern scientific information on the problem of venous thromboembolic complications (VTECs) following scoliosis surgery in children and adolescents.

Material and Methods. The search for scientific sources was carried out in the PubMed, GoogleScholar and eLibrary databases for the period of 2012—2024. The content of 57 articles covering the issues of frequency, etiology, risk factors for the development of venous thromboembolic complications and thromboprophylaxis in the pediatric cohort as a whole and in the cohort of children and adolescents operated on for scoliosis was analyzed.

Results. The incidence of VTECs during surgical correction of scoliosis is insignificant and does not exceed 1.0 %. Etiology of VTEC is multifactorial, since there is both genetic predisposition and acquired risk factors. For children and adolescents, the most important factors are patient age, family or personal thrombotic history, surgical site, duration of surgical intervention more than 120 minutes, repeated and complicated surgeries, blood loss, anemia, infections, immobilization for more than 48 hours, long hospital stay, and the presence of chronic diseases or concomitant hemostatic disorder in the form of hypercoagulation. In adolescence, smoking, use of oral contraceptives and obesity are acquiring particular importance. It is recognized that the presence of four of these factors requires classifying the patient to a group with a high risk of developing venous thrombosis and embolic complications.

Conclusion. Given the low incidence of VTECs in scoliosis surgery, potential risks of using anticoagulant drugs, as well as effective postoperative patient care through early activation and use of external compression devices, the drug prophylaxis in scoliosis surgery is not recommended. At the same time, the lack of regulatory documents on screening and prevention of VTECs for this category of patients is associated with difficulties in identifying those clinical cases where drug prophylaxis is absolutely indicated.

Key Words: scoliosis surgery; postoperative complications; venous thrombosis in children and adolescents; thrombotic risk factors; thrombosis prevention.

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Venous thromboembolic complications (VTECs) are a generally recognized complication following spine surgery in adults. There are few data on the incidence of VTECs in children and adolescents after spine surgery, especially during surgical correction of scoliosis. Because of its extensiveness, traumatic nature, duration, and blood loss volume, such surgery is associated with the risk of perioperative complications and is an inherently risk factor for VTECs. However, it is still not clear how often complications happen in children and adolescents with this condition, and information on the necessity, efficacy, and safety of thromboprophylaxis in these cases is limited.

The objective of the review is to cover the issue of venous thromboembolic complications (VTECs) following scoliosis surgery in children and adolescents.

Material and Methods

The article is a review of scientific literature. The scientific sources were searched in PubMed, Google Scholar, and eLibrary databases for 2012–2024 using the following keywords and phrases: orthopedic surgery, venous thrombosis in children, postoperative complications in scoliosis surgery, and thrombosis prevention. Inclusion criteria: orthopedic surgeries in children and adolescents; presence of postoperative VTECs, thrombosis prevention; access to full-text sources of domestic and foreign authors.

Overall, 250 scientific sources were found. According to the inclusion criteria, 57 full-text journal articles in the form of original studies and reviews covering the incidence, etiology, and risk factors of VTECs development and thrombosis prevention in the pediatric cohort in general and in the cohort of children and adolescents who underwent scoliosis surgery were selected for analysis.

Results

General information on the incidence and etiology of VTECs in children and adolescents

There is numerous scientific evidence regarding the incidence and risks of VTECs, which include venous thrombosis or pulmonary embolism (PE), in children and adolescents. The findings in pediatric studies suggest that the

incidence of VTECs in children is lower than in adults, ranging from 0.07 to 0.14 events per 10,000 children. Nevertheless, the rate is higher in those children who were admitted to the hospital, reaching approximately 5.3 events per 10,000 children [1–3]. Such complications are most often recorded in the first year of life and in adolescence [4, 5].

More recently, it is generally recognized that the incidence is escalating, especially in children with complex chronic pathologies associated with multiple hereditary and acquired triggering factors: infections, catheterization, injuries, malignancies, and surgeries [5–7]. For instance, Baker et al. [8] estimated the incidence of VTECs in pediatric orthopedics to be 10 per 10,000 pediatric hospitalizations. According to Mulpuri et al. [9,] the incidence of VTECs for patients with pediatric orthopedic pathology is higher – 17 events per 10,000 cases.

Only 5 % of all observed VTECs events in children are considered idiopathic in etiology compared to 40 % in adults. Moreover, the etiology of VTECs is multifactorial, as there are both genetic predispositions and acquired risk factors [10–12]. Unprovoked thrombosis in children is uncommon; however, 70% of provoked thrombosis have shown a considerable association with the presence of inherited thrombophilic risk factors [13, 14].

The risk of VTECs varies depending on the type of genetic mutation. For example, heterozygosity for FVL increases the risk of venous thromboembolism by 9.45 times, PT20210A – by 3.17 times, and fibrinogen gamma-chain mutation – by 1.5 times. The role of other genetic mutations, particularly MTHFR and PAI-1, is controversial, whereas they may further increase the risk of thrombosis, especially when combined with other thrombogenic factors [15, 16]. For instance, one study showed that a single thrombophilic risk factor was detected in 24.4 % of cases and combined thrombophilic factors – in 15.1% of cases [17].

Oncul et al. [5] performed a study at the Department of Hematology and Oncology, where 84 patients with VTECs aged 0–18 years were tested for genetic thrombophilic status. The frequency of a single genetic risk factor in the etiology of thrombosis among those examined was 20.2 %, and the frequency of acquired risk factors in combination with genetic risk factors was 33.3 %. The authors found that the most common mutations in patients with thromboembolism were PAI-1 4G>5G, MTHFR C677T, and MTHFR A1298C mutations. Moreover, at least one homozygous mutation was found at a frequency of 44 %, whereas one heterozygous mutation was found at a frequency of 65.4 % [5]. Other researchers have also reported on thrombogenic risk factors in children and adolescents, including poor personal and family history [18].

Among the acquired factors that are most commonly considered as prognostic risk factors for VTECs are patient age, diagnosis, presence of cardiovascular disease, obesity, and type and site of surgical intervention [9].

Among all pediatric VTECs, 20 % occur in early infancy because of narrow blood vessels, immaturity of the hemostatic system, and more frequent use of central venous catheters. Approximately 50% of VTEC cases occur in children aged 11–18 years. The condition of the hemostasis system in this age group is quite comparable to that of adults. Peak incidence in adolescents is associated with the presence of risk factors: use of contraceptives, smoking, and obesity [4, 19, 20].

According to previous studies, 95 % of children with VTECs suffer from at least one comorbid condition [10, 12]. For example, pediatric patients with orthopedic pathology had gastrointestinal, renal, and hematological disorders; an increased level of aspartate aminotransferase; abnormal partial thromboplastin time; and hyponatremia [8]. Other study indicates that risk factors for VTECs in children and adolescents with orthopedic conditions are coagulopathy, spinal cord injury, blood loss, anemia, external fixation, obesity, and diabetes [11].

There are several publications reporting a risk of recurrent thrombosis, which ranged from 6 % to 10% in children. It is indicated that the recurrence rate is considerably higher in children with diagnosed hereditary thrombophilia and increases in the presence of multiple risk factors [21]. There is evidence that the recurrence rate dependents on age recurrence rates and reaches 3 % in newborns and can be as high as 21 % in children in cases with unprovoked thrombosis [22]. An important role in recurrent VTECs in children is attributed to the prothrombin G20210A mutation, deficiency of protein C, protein S, and antithrombin [23].

Frequency and nature of VTECs in scoliosis surgery

Over the past decades, there has been a progressive but obvious development of surgical techniques used in the treatment of scoliotic deformities of different etiology in children and adolescents. Meanwhile, idiopathic scoliosis is the most frequent structural deformity of the spine among children aged 10 to 18 years, with a prevalence of 0.5–5.2 % in the population [24–26]. For cases of severe or rapidly progressive spinal deformity, surgery is the only effective option for achieving correction and stabilization of the existing deformity, as well as for improving the quality of life of patients [26]. Yet, spine surgeries, because of their extensive, injury-related nature and duration, are associated with the risk of perioperative complications and are considered to be a risk factor for VTECs [27–29]. At the same time, data from scientific sources show that VTECs in scoliosis surgery are relatively rare complications [30–32].

For example, Jain et al. [33] studied the incidence of VTEC development in pediatric surgical patients with idiopathic, congenital, and syndromic cases of scoliosis, spinal injuries, and posterior fusion. Over a decade-long time, the authors recorded 21 complications per 10,000 fusions done, a rate of 0.21 %. Depending on the age of the patients, the incidence of venous thrombosis ranged from 9.6 to 38.5 events per 10,000 surgeries, and the incidence of PE ranged from 0 to 6 events per 10,000 surgeries (mean two events per 10,000).

Vigneswaran et al. [32] used a five-year database including 20,346 patients

aged 0 to 21 years who were admitted for surgical treatment of idiopathic scoliosis to analyze the incidence of VTECs. The authors reported the incidence of clinically relevant venous thrombosis or PE to be less than 1.0%, but they only studied in-hospital events and did not consider VTECs arising after discharge of patients from the hospital.

In another study, it was mentioned that the incidence of venous thrombosis or PE in 36,335 adolescent patients after surgical correction of scoliosis was also not significant and was less than 0.2 % [34].

Erkilinc et al. [35] found that during the treatment of 1,471 patients aged 1 to 18 years who underwent surgery for scoliosis, venous thrombosis was registered only in two patients, which was 0.13 %, and no cases of PE were registered.

One of recent studies with an analysis of a database including 11,775 patients with idiopathic scoliosis undergoing surgical correction of spinal deformity reported only 38 cases of VTEC, or 0.3%. Meanwhile, 28 complications developed within 30 postoperative days (0.2 %), and another 10 (0.08 %) developed within 90 days of the postoperative period. Out of 28 complications that developed within the first 30 days after surgery, four patients were diagnosed with PE and 24 with deep vein thrombosis. The undoubted advantage of this study was the period of postoperative follow-up that provided the authors with more objective data on the incidence of VTECs in patients with idiopathic scoliosis who underwent surgical correction of spinal deformity [36].

The accurate rates of mortality associated with thrombosis in children are unknown. A systematic review published in 2024 and analyzing 56 scientific information sources showed that only three studies reported fatal outcomes in cases of VTEC in pediatric orthopedics [9]. In one of these studies, the mortality rate associated specifically with a VTEC event was found to be 5.4 % among a cohort of pediatric orthopedic patients [12]. Similar information for patients operated on specifically for scoliosis was not found in the scientific information sources included in this review.

Although in the context of the presented data it is obvious that the incidence of VTECs during surgical treatment of scoliosis is extremely low, knowledge of risk factors for VTEC development is required, both for patients with pediatric orthopedic pathology in general and for the cohort of patients with structural spinal deformities requiring surgery.

Risk factors for the development of VTECs in scoliosis surgery

It is known that extensive reconstructive procedures in various fields of surgery, particularly in traumatology and orthopedics, adversely affect the condition of the hemostatic system and increase the incidence of VTECs, in some cases being fatal [11, 37, 38].

A group of Canadian authors, with the involvement of external experts, unanimously adopted several risk criteria for VTECs in orthopedic surgical patients: age over 14 years, body mass index over 30, limited or altered mobility for more than 48 hours, cardiovascular insufficiency syndrome, blood flow abnormalities, and metabolic syndromes. Since central venous catheters are among the most widely recognized risk factors for VTECs in the pediatric literature, the presence of a central venous catheter should be managed as a separate risk factor. According to expert opinion, surgeries longer than 120 min, as well as repeated and complex surgeries, were considered risk factors. It has been recognized that the presence of four of these factors requires a patient to be considered at high risk of VTECs, and a hematologist should be involved to identify the need for and extent of thrombosis prevention measures in the perioperative period [39].

When studying risk factors for VTEC development in patients with scoliotic deformities, Jain et al. [33] found that only the patient's diagnosis was strongly associated with the development of complications. The incidence of VTECs was considerably higher in children with congenital and syndromic scoliosis compared to idiopathic scoliosis (odds ratios: 4.21, 7.14, and 12.59, respectively). Besides the significance of the etiology of the disease, the occurrence of VTECs was found to be associated with the age of the patients: each year of life increased the incidence by 1.37 times ($p < 0.01$). The positive side of this study was the attempt to identify predictors of VTEC development in this category of patients; the negative side was the absence of any data on their prevention [33].

According to a systematic review of 42 scientific sources performed by Boulet et al. [40], it was found that a positive family history of thrombotic complications increases the risk of complications 2.2 times, and the age over 16 years increases the incidence of VTECs by 8 times compared to children under 12 years. The authors identified predisposing factors associated with adolescence specifically: smoking, use of oral contraceptives, and obesity. At the same time, it is noted that female adolescents who use oral contraceptives are 3-5 times more likely to develop VTECs than male adolescents are. Moreover, children with neurological and hematological pathology and renal and intestinal disorders should be included in the high-risk group. Risk factors for complications include immobilization for more than 48 hours, extended hospital stay, treatment in the intensive care unit, and the installed central venous catheter. It has been highlighted that musculoskeletal infections combined with excessive activation of the clotting cascade by inflammatory mediators considerably increase the risk of VTECs in children and adolescents [40].

According to Rudic et al. [36], a secondary diagnosis of hypercoagulation was most associated with the occurrence of VTECs (odds ratio: 13.5; $p < 0.0001$). It was found that the presence of a concomitant hypercoagulation in patients with idiopathic scoliosis was associated with a 14-fold increase in the risk of complications in the postoperative period. The authors pointed out that 18.4 % of patients with a pre-existing diagnosis of hypercoagulation developed VTECs. Patients aged 15 to 19 years, obese patients, and patients who underwent fusion of 13 or more segments were also found to be at increased risk of complications, although the overall risk of VTECs in this category was less than 1.0 %.

The mentioned risk factors for the development of VTECs are certainly of clinical importance for the identification of the risk group and should be included in the surgeon's decision-making regarding the need for drug thromboprophylaxis in the postoperative period [36].

Some domestic publications have reported on hypercoagulable disorders, particularly after surgical correction of scoliosis, characterized by decreased values of activated partial thromboplastin time and thrombin clotting time and increased fibrinogen concentration [37, 41]. We have reported previously on the presence of hemostatic system specificities in 80 % of cases in patients with idiopathic scoliosis even in the preoperative period [42]. This data is clinically significant due to the fact that more than 50.0 % of cases of VTEC development occur in patients with a tendency to hypercoagulation because of a situational risk factor in the form of surgery [43].

Considering the contribution of hypercoagulable disorders to the pathogenesis of thrombosis and the insufficient informativity of routine laboratory tests, the diagnostic capabilities of thromboelastography and thromboelastometry are increasingly used in various fields of surgery, providing the detection both hypocoagulable and hypercoagulable conditions [44–46].

Despite the association of genetic risk factors with VTECs, screening for thrombophilia in offspring from thrombosis-prone families is still controversial. Refusal of blinded testing for thrombophilia in patients with VTECs is listed in the Choosing Wisely panel approved by many scientific communities [47–49]. Most researchers believe that testing for thrombophilia in children should be based on an individualized approach. There is an opinion about the benefit of diagnostic testing for thrombophilia in patients with the development of VTECs after surgical correction of scoliosis in the absence of a pre-existing diagnosis of hypercoagulation, in patients with recurrent thrombosis, and when thrombosis develops in an unexpected vascular site [36, 50, 51].

Thrombosis prevention in scoliosis surgery

There are many risk factors for the development of VTECs during spine surgery. According to a number of previous studies, it has been illustrated that drug prophylaxis with anticoagulant drugs significantly reduces the incidence in adults. Nevertheless, it has also been shown in studies that drug prophylaxis is associated with a higher development rate of hematomas requiring repeated surgeries and a higher rate of surgical site infection [52–54].

However, there is an opinion that administration of anticoagulant drugs one day before surgery and three days after surgery is safe for patients even at high risk of VTECs. The researchers came to this conclusion by analyzing the outcomes of elective spine surgeries in 6,869 patients receiving (n = 1,904) and not receiving (n = 4,965) anticoagulant drugs. The mean time to start drug prophylaxis was 1.46 days postoperatively. Epidural hematomas were recorded in 0.20 % (n = 4) of cases in the anticoagulant group and 0.18 % (n = 9) of cases in the group without drug prophylaxis ($p = 0.622$) [55].

Kochai et al. [56] provide data on the outcomes of non-drug and drug prophylaxis of VTECs in adolescents who underwent elective surgery for idiopathic scoliosis. There were three study groups: Group A – administration of low-molecular-weight heparin 8 hours after surgery; Group B – administration of low-molecular-weight heparin 24 hours after surgery; and Group C – no drug prophylaxis. The authors did not record VTECs in any of the groups. The mean postoperative drainage blood loss was 400 ml in Group A, 450 ml in Group B, and 150 ml in Group C ($p < 0.001$). Patients in groups A and B had more wound discharge and superficial infections, but without statistically significant intergroup differences in these parameters. Meanwhile, statistically significant differences were obtained for the duration of hospital stay ($p < 0.001$). The authors concluded that drug prophylaxis is not essential for patients with adolescent idiopathic scoliosis without diagnosed additional risk factors. Early activation and the use of external compression devices are appropriate preventive measures in addition to the usual postoperative management of patients [56]. Other authors have also reported that the use of drug thromboprophylaxis enhances the overall incidence of hemorrhagic complications.

The authors of another study also did not find evidence for the routine use of anticoagulant drugs in this surgical cohort, convincingly demonstrating the effectiveness of external compression devices, frequent repositioning of the patient in bed, performance of leg exercises, and early postoperative patient activation [35]. Other researchers have also reported that drug prophylaxis after surgery for idiopathic scoliosis in pediatric patients is not indicated because of the very low incidence of VTECs since it has more risks than benefits [8, 36].

Nevertheless, the use of drug prophylaxis for VTECs after surgical correction of scoliosis is more frequently recommended for patients with identified hypercoagulation in high-risk cases. At the same time, children with recurrent unprovoked venous thromboembolism should have long-term/lifelong prophylaxis [57].

Conclusion

Given the low incidence of VTECs in scoliosis surgery, potential risks of using anticoagulant drugs, as well as effective post operative patient care through early activation and use of external compression devices, the drug prophylaxis in scoliosis surgery is not recommended. At the same time, the lack of regulatory documents on screening and prevention of VTECs for this category of patients is associated with difficulties in identifying those clinical cases where drug prophylaxis is absolutely indicated.

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The study was approved by the local ethics committee of the institution.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

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