Research Article

The Importance of a Standardized Screening Tool to Identify Thromboembolic Risk Factors in Pediatric Lower Extremity Arthroscopy Patients

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Abstract

Introduction: Deep vein thrombosis and pulmonary embolism are major complications that can occur in common orthopaedic procedures such as knee arthroscopy. The purpose of this study is to determine the incidence of venous thromboembolism (VTE) risk factors in adolescent patients undergoing elective lower extremity arthroscopy. A second objective is to determine whether a targeted, standardized screening tool is both cost- and clinically effective in the identification of VTE risk factors in adolescents.

Methods: A standardized VTE screening tool was prospectively administered to all elective arthroscopic procedures in a pediatric sports medicine practice. A comparison cohort that did not complete the screening tool was isolated through a retrospective chart review identifying VTE risk factors. The incidence and cost between the two cohorts were compared.

Results: Of 332 subjects who did not receive a targeted screening (TS) tool, 103 risk factors were noted. One pulmonary embolism case was identified with a total incidence of 0.15% over 3 years. With TS, we identified 325 subjects with 134 identifiable risk factors. Six patients (1.8%) were noted to be very high risk, requiring consultation with hematology. No VTEs were reported. When compared with the retrospective review, TS identified 30% more risk factors. A significant increase in the identification of family history of blood clots ($P < 0.001$), history of previous blood clot ($P = 0.059$), recurrent miscarriages in the family ($P = 0.010$), and smoking exposure ($P = 0.062$) was found. Additionally, the total cost of screening was less than the cost of prophylaxis treatment with no screening ($20.98 versus $23.51 per person, respectively).

Discussion: Risk factors for VTE may be present in 32.5% of elective adolescent arthroscopic patients. A TS model for VTE identified 30% more risk factors, especially a significant family history, and was shown to be a cost-effective way to safely implement a VTE prevention program.

Level of Evidence: Level II

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J Am Acad Orthop Surg 2019;27: 335-343

DOI: 10.5435/JAAOS-D-18-00390

Lower extremity arthroscopy is the most common orthopaedic surgical procedure performed in the United States.[1] The incidence of anterior cruciate ligament reconstructions in patient's ages 15 to 18 years has nearly

doubled in the last 10 years.[2,3] Major complications following a knee arthroscopy in the pediatric and adolescent population are rare;[4] however, serious complications such as venous thromboembolism (VTE) have been reported in this age group following elective arthroscopy.[5]

The incidence of VTE in elective pediatric orthopaedic surgery and elective arthroscopy was considered low, previously reported at around 0.052% to 0.1%[5-8] and 0.12% to 14.9%,[8-14] respectively. However, recent reports demonstrate a 70% increase in VTE diagnosis in pediatric hospitals. VTE is the second largest contributor to harm diagnosed in pediatric hospitals behind central line–associated blood stream infections.[15] The Center for Medicare and Medicaid Services considers hospital-acquired VTE to be a preventable condition, and in most instances, reimbursement is not given for such complications.[7,16]

Our understanding of VTE risk factors in the adolescent age group, also one of the peak ages for VTE, is limited. This is partly (or largely) due to the lack of inclusion of adolescents in studies looking at VTE risk in elective arthroscopy.[9] Retrospective data in pediatric orthopaedic surgery and trauma admissions since 2000 demonstrate a significant increase in the rate of VTE.[6,17] Age-related risk factors such as lifestyle changes, initiation of oral contraceptives (OCPs), smoking, and the rising obesity epidemic have been identified as important etiologic factors for adolescent VTE and may be important to identify before an elective orthopaedic procedure.[8,18-22] The purpose of this study was to determine the incidence of VTE risk factors noted in adolescent patients undergoing elective lower extremity arthroscopic procedures. A secondary objective is to compare the identification of risk factors in adolescents with the use of a standardized screening tool compared with a similar cohort by chart review without standardized screening. Additionally, the cost associated with VTE screening and the fiscal implications of further patient evaluation or prophylaxis were evaluated.

Methods

Prospective Targeted Screening for Venous Thromboembolism Risk Factors

After obtaining approval and consent waiver from the Institutional Review Board, we collected data from a prospective standardized targeted screening (TS) of VTE risks in all elective lower extremity arthroscopies performed at a single institution between December 2013 and November 2014 (12 months). A multi-disciplinary group of orthopaedic surgeons and hematologists developed a VTE risk screening tool. Patients and guardians were required to review and identify VTE risk factors before scheduling elective arthroscopy (Figure 1).

All patients, ages 5 to 19 years old, scheduled for an arthroscopic procedure by one of two fellowship-trained pediatric sports medicine surgeons were included. Arthroscopic procedures of the upper extremity or procedures considered emergent were excluded from analysis. Risk factors of patients receiving bilateral procedures were counted only one time, avoiding duplication. If the patient or guardian could not complete the form, the nurse verbally confirmed the risk factors.

Positive findings on the targeted risk screening tool would lead to a secondary discussion between the clinic staff and the patient or guardian. The clinic staff estimated the interactions between the them and the patient or guardian to be approximately 2 minutes. Upon completion of the secondary discussion, risk factors were confirmed, documented, and discussed with the surgeon. Risk factors were classified as very high, major, and minor (Table 1). Any patient having one or more very high risk factors was referred to hematology for evaluation, screening, and prophylaxis recommendations before the procedure. These referred patients underwent testing to evaluate for protein S, protein C, antithrombin deficiency, factor V Leiden (FVL), and prothrombin gene mutation at the discretion of the hematologist. Patients with additional risk factors received prophylaxis measures such as compression hose, sequential compression devices, or aspirin. Recommendations for VTE prophylaxis were based on an algorithm developed by the multidisciplinary group.

Additional clinical information including demographic data, type of surgery, length of surgery, tourniquet time, and VTE prophylaxis was obtained. Postoperatively, all patients were recommended for early mobilizations, when applicable, through a handout in their postoperative packet.

Dr. Ellis or an immediate family member serves as a paid consultant to Smith & Nephew; has received nonincome support (such as equipment or services), commercially derived honoraria, or other non-research–related funding (such as paid travel) from Allosource, Ossur, and Varicel; and serves as a board member, owner, officer, or committee member of Pediatric Orthopaedic Society of North America and Pediatric Research in Sports Medicine. Dr. Wilson or an immediate family member has received research or institutional support from Allosource and Ossur and serves as a board member, owner, officer, or committee member of American Academy of Orthopaedic Surgeons and Pediatric Orthopaedic Society of North America. None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Ms. Sabatino, Mr. Clarke, Mr. Dennis, Ms. Fletcher, Mr. Wyatt, and Dr. Zia.

Assessments for signs and symptoms of postsurgical deep vein thrombosis or pulmonary embolism (PE) were performed and documented up through 90 days after surgery.

Retrospective Cohort Collection of Venous Thromboembolism Risk Factors With No Screening

A retrospective chart review of surgeries completed from November 2011 through November 2013 was performed. This period preceded the TS. The data collected for this cohort were used to identify the incidence of VTE risk factors without the use of a TS tool. All lower extremity arthroscopies were performed by the same two surgeons and were queried based on CPT codes. Initial evaluations and the preoperative history and physical examination, performed by the orthopaedic surgeon, anesthesiologist, and associated clinical staff, were reviewed for the identification of VTE risk factors. Demographics, weight, type of surgery, length of surgery, and tourniquet time were recorded for comparison. Between the TS and no screening (NS) retrospective cohort time periods, there were no changes in clinic operations or documentation except for the completion of the screening tool.

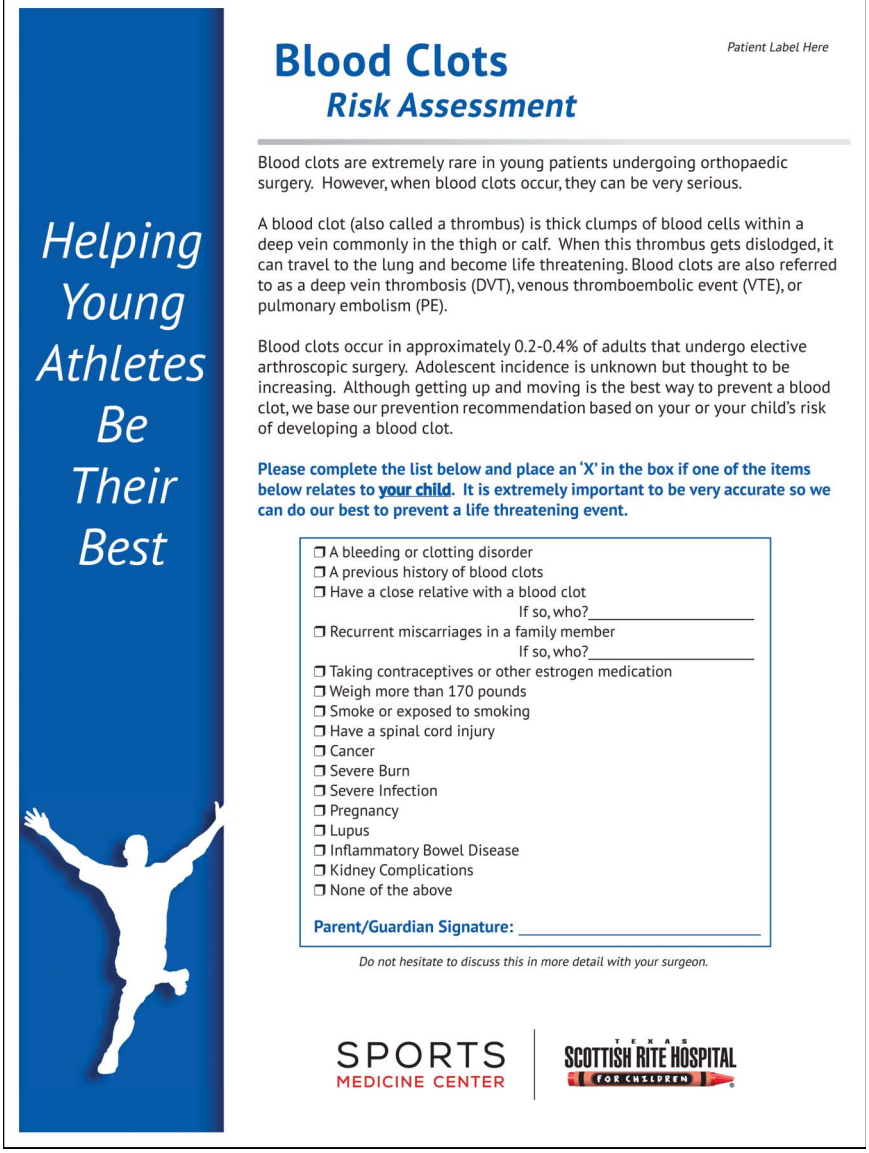
Statistical Analysis

The two cohorts were compared using a Fisher exact test. Continuous variables were summarized with means, standard deviations, and ranges and compared using a Mann–Whitney test; categorical variables were summarized with percentages and analyzed using Fisher exact test.

Cost Analysis

The cost of a TS model was compared with the cost of an NS model with routine prophylaxis as recommended by Solutions for Patient Safety and Agency for Healthcare Research and Quality.[15,23] All identified costs were confirmed as accurate with the hematology service. A TS model included risk-based prophylaxis. Assumptions for TS include nursing time spent to collect and screen patients at approximately 2 minutes per patient and hourly wages at $60 per hour. This amounted to an estimated cost of approximately $2 per patient. In the TS model, costs were also included for the percentage of patients who reported a previous history of VTE or strong family history of VTE who would be referred for consultation to hematology, with additional consideration of screening for hypercoagulable conditions (ie, blood work) and possible prophylaxis (ie, the addition of chemoprophylaxis). Although consideration of an adjusted quality of life is invaluable for prolonged VTE-related conditions, this could not feasibly be

Figure 1



The targeted screening tool used to identify venous thromboembolism risk factors.

Table 1

Risk Factors Identified in a Pediatric and Adolescent Population Undergoing Elective Lower Extremity Surgery Developed by a Multi-disciplinary Team for the Purposes of Identifying Those That May Require VTE Prophylaxis

Very high risk factors
Known acquired or inherited thrombophilia
Previous history of a VTE
More than one family member with a known VTE
Family history of a VTE in a 1st-degree relative younger than 40 years
Major risk factors
OCPs
Estrogen-containing medication
Lower extremity central venous catheter
Cancer
Minor risk factors:
Obesity (weight >80 kg)
Inflammatory bowel disease
Smoking exposure
Systemic lupus
Nephrotic syndrome
Erythropoiesis-stimulating agents
Spinal cord injury
Burns
Active infection
Pregnancy

OCP = oral contraceptive, VTE = venous thromboembolism
Risk factors were classified as very high, major, or minor risk based on their influence in developing a VTE in this age group.

calculated. To compare the cost between the models in even groups, a review of the TS and NS model with routine prophylaxis was performed per 1,000 patients.

Results

Venous Thromboembolism Risk Factors in the Targeted Screening Cohort

During the TS, 325 elective lower extremity arthroscopies were screened for VTE risk factors (Table 2). The most common procedures performed were an anterior cruciate ligament reconstruction (148) and a knee arthroscopy without ligament reconstruction (140). A total of 134 VTE risk factors were documented in 109 patients. Five subjects had three or more risk factors. Table 3 demonstrates the incidence of VTE risk factors in this cohort.

The most common risk factors were weight >170 pounds (n = 65; 20%) and smoking and/or smoking exposure (20; 6.2%). Of the 162 young women in this cohort, 4% reported taking OCPs at the time of their elective arthroscopy. Based on the risk factors identified, 28 subjects, or 8.6%, had a prophylactic intervention (compression hose [27] or pharmacoprophylaxis [5]).

Six patients (1.8%) were screened to be very high risk and underwent a consultation with a hematologist. Of these, three patients underwent screening or blood work and no additional prophylaxis was recommended. Three patients required mechanicoprophylaxis and pharmacoprophylaxis, one patient with a history of protein S deficiency and two subjects due to newly diagnosed blood disorders. Protein S deficiency and FVL were each identified in subjects through TS and consultation with hematology. During the study period, no subjects reported a VTE nor required imaging to screen for VTE.

Venous Thromboembolism Risk Factors in the Retrospective Cohort

Of the 332 retrospective charts reviewed, 103 risk factors were documented, 94% of which were a combination of weight >170 pounds, smoking and/or smoking exposure, and contraceptive use. One PE was identified in the retrospective review, for a total incidence of 0.15% over 3 years (TS and NS cohorts combined). The single patient was a 15-year-old female with contraceptive initiation as the only documented risk factor. A family history of VTE was not noted either in the orthopaedic surgeon or anesthesiologist evaluation or in the preoperative history and physical examination. Following admission to the ICU, the patient was discovered to have a family history of FVL.

Comparison of Risk Factors Among Cohorts

When comparing 1 year of NS to TS, NS had 103 VTE risk factors documented compared with 134 with TS, with the most notable increases noted in the documentation of very high risk factors. A significant increase in the notation of family history of blood clots was documented with the TS compared with the NS (19 versus 1; $P < 0.001$). There was also an increase in the documentation of the history of previous blood clot ($P = 0.059$), recurrent miscarriages in the family ($P = 0.010$), and smoking

Table 2

Demographic and Clinical Presenting Data of All Subjects Reviewed for VTE Risk Factors

Variables	Prospective (n = 325)	Retrospective (n = 332)	*P* Value
Age in years (range)	14.9 ± 2.3 (6-19)	14.7 ± 2.2 (7-20)	0.200
Male sex (%)	163 (50.2)	168 (50.6)	0.908
Ethnicity			
Hispanic (%)	88 (27.1)	100 (30.1)	0.591
Non-Hispanic (%)	233 (71.7)	230 (69.3)	
Other/Unknown (%)	4 (1.2)	2 (0.6)	
BMI (range)	**25.1 ± 6.2 (14.7-50.4)**	**24.1 ± 5.6 (14.1-48.5)**	**0.023**
Growth plate status			
Open (%)	80 (24.6)	86 (25.9)	0.515
Transitional (%)	63 (19.4)	77 (23.2)	
Closed (%)	180 (55.4)	168 (50.6)	
Duration of surgery (min)	**84.0 ± 43.7 (11-249)**	**148.7 ± 63.7 (28-438)**	**0.000**
Tourniquet or traction time (min)	**69.2 ± 34.4 (0-160)**	**75 ± 38.7 (0-127)**	**0.045**
No. of risk factors	**0.41 ± 0.66 (0-4)**	**0.31 ± 0.52 (0-3)**	**0.028**

VTE = venous thromboembolism
A comparison was made between those who were reviewed retrospectively with those who were prospectively screened. Statistical significance was noted in bold when $P < 0.05$

exposure ($P = 0.062$). No differences were noted in other risk factors.

Cost Analysis of Venous Thromboembolism Screening

The total cost of screening is approximately $20.98 per person when including collective costs of $2 per patient for the targeting screening questionnaire as well as $334 per patient for a hematology consultation and $1,000 per patient for laboratory tests at a rate of approximately 0.5% of patients screened. Routine use of sequential compression devices for surgical procedures lasting longer than 60 minutes or for inpatient admission in patients older than 10 years is approximately $23.51 per patient. Patients identified as high risk, 1.5% of patients screened in this case, were calculated to include pharmacoprophylaxis at $600 per patient for outpatient treatment.

The current estimated cost for an uncomplicated VTE includes duplex ultrasonography at $859, hospital stay at $3,294 per day, Enoxaparin treatment while being inpatient at $1,800, laboratory costs at $774 per laboratory draw, and potential treatment for post-thrombotic syndrome in as many as 50% of patients at approximately $5,094. According to Brahmandam et al,[24] the average stay

Table 3

Incidence of VTE Risk Factors Documented in Pediatric and Adolescent Patients Following the Completion of a VTE Risk Assessment Tool

Risk Factors	Incidence (%)
None	66.50
A bleeding or clotting disorder	1.23
A previous history of blood clots	0.00
Having a close relative with a blood clot	5.84
Recurrent miscarriages in a family member	2.78
Taking contraceptives or other estrogen medication	2.15
Weighing more than 170 pounds	20.00
Smoking or exposure to smoking	6.15
Having a spinal cord injury	0.00
Cancer	1.23
Severe burn	0.00
Severe infection	0.30
Pregnancy	0.00
Lupus	1.23
Inflammatory bowel disease	0.00
Kidney complications	0.30

VTE = venous thromboembolism

for VTE treatment was approximately 4.77 days. Assuming 0.15% sustain a VTE in this age group, a TS or a NS with routine prophylaxis model is demonstrated to be cost effective (Table 4).

Discussion

The TS model for VTE risk factors produced a 30% increase in the noted risk factors. Additionally, the TS model provides benefit to undetected high-risk patients, identifying the need to undergo proper hematologic evaluation and intervention to prevent future adverse VTE events before surgery. Not only was the presence of a positive family history of VTE under-reported in the NS model, but the TS model detected potentially life-threatening risks in many patients. Very little evidence exists in literature regarding VTE prophylaxis in pediatric orthopaedics, and protocols have been slow to develop despite the occurrence of admissions for VTE.[25] Screening programs are becoming standardized at pediatric institutions for good reason, as they may prevent significant adverse events. The TS model, considered to be both low-cost and requiring minimal effort, can potentially prevent a disastrous outcome in the undetected high-risk pediatric patient.

The importance of a family history of VTE must not be overlooked and may be the most common risk factor missed during preoperative assessments. Family history of a VTE may singularly increase the odds ratio of a VTE by 2.2.[26] Additionally, family history of VTE may identify a patient as a carrier of genetic risk factors, which is the strongest link to the development of VTE in youth patients. This risk is compounded when present with other risk factors.

There has been an increased awareness of VTE occurrences in adolescent knee arthroscopy. Murphy et al[27] reported on seven adolescent patients (0.25%), whereas the similarly low incidence noted in this study was 0.15%. Lau et al[5] reported a similar incidence of 0.27%, with a 14-year-old male sustaining a PE. It was later noted that his father had a history of a clotting disorder, further emphasizing the importance of TS to detect potentially life-threatening risks.

Although extremely rare in pediatric and adolescent patients younger than 15 years old with one risk factor,[28,29] the incidence of VTE has been increasing over the past 15 years[18-20,30] with a 10-fold increase reported by a Canadian registry of children with VTE complications.[34] Pediatric trauma and spine specialists have noted increased VTE diagnoses in patients with known risk factors.[25,27,31] Following a large query of 14,776 pediatric orthopaedic procedures, most of the 15 identified cases of VTE were following a posterior spinal fusion (5), arthrotomy for infection (2), and fracture requiring lower extremity fixation (4).[7] Another large query of pediatric orthopedics concludes that patients

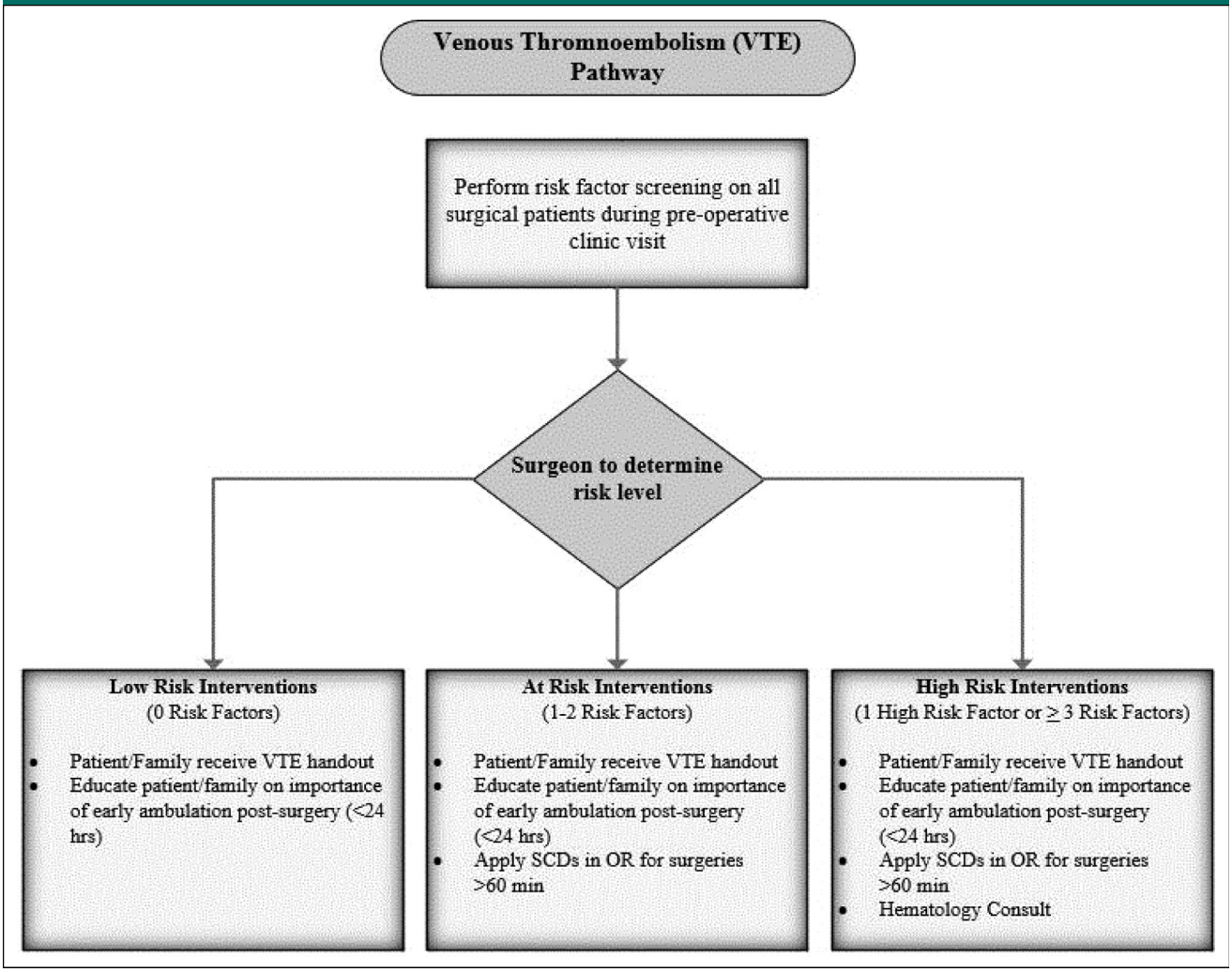
Table 4

Cost Comparison Between Targeted Screening Model and No Screening With Routine Prophylaxis per 1,000 Patients; With a Cost of VTE Diagnosis and Treatment at a Rate of 0.15% per 1,000 Patients if No Screening Provided

	No TS	TS
Screening and prophylaxis		
Nursing time to use targeting screening tool ($2 per patient)	NA	$2,000.00
Hematology consultation (0.5% of patients screened)	NA	$1,670.00
Hematology screening laboratory tests (0.5% of patients screened)	NA	$5,000.00
Sequential compressive device for those with >1 risk factor or while an inpatient or for a surgical procedure lasting for > 60 minutes	$6,842.53	$8,106.62
Pharmacoprophylaxis treatment (1.5% of patients screened)	NA	$4,200.00
Total screening cost	$6,842.53	$20,976.62
VTE diagnosis and treatment (0.15% of 1,000 patients)		
Duplex ultrasound	$1,288.50	
Enoxaparin treatment ($1800 for 90 days of treatment)	$2,700.00	
Laboratory draws in hospital ($774 per draw)	$11,075.94	
Post-thrombotic syndrome (50% of patients diagnosed with DVT)	$3,820.50	
Hospital stay (average stay 4 days)	$23,568.57	
Total cost of a PE	$42,453.51	
Total cost for screening and VTE treatment	$49,296.04	$20,976.62

DVT = deep vein thrombosis, NA = not applicable, PE = pulmonary embolism, TS = targeted screening, VTE = venous thromboembolism

Figure 2



A pediatric outpatient surgical venous thromboembolism prophylaxis algorithm.

having a spine procedure and those of older age were at the highest risk for VTE.[6] A pediatric trauma registry cites that the incidence triples between the age groups of <13 years old, 13 to 15 years old, and >15 years old.[32] Screening programs are an important part of care for any age group; however, they appear to be most valuable when a patient is older than 12 years.

The rationale for an elevated incidence of VTE in adolescence is partly due to increased thrombin generation as children approach adulthood. Increased exposure to additional risk factors that come with age also plays a role (eg, smoking, OCP).[30] The increase in the use of estrogen-containing OCPs contributes to increased risk in adolescents, with some believing it to be one of the leading causes of VTE.[33] Previous reports show that up to 55% of adolescent girls (ages 15 to 19) use OCPs, which may be under-reported during an orthopaedic evaluation.[18] Additionally, reports show that females who use OCPs are three to five times more likely to have a VTE than males.[18] In adult patients, the use of OCPs during the time of knee arthroscopy was linked to increased odds of VTE by 46.6 times.[32] Only estrogen-containing OCP use is considered a risk factor.

Current guidelines recommend sequential compressive devices in pediatric and adolescent surgical cases lasting longer than 60 minutes based on literature concerning adult patients.[32] Of nine published cases of adolescents diagnosed with VTE, five occurred following cases lasting less than 60 minutes of tourniquet time.[5,27] Most VTEs seen during elective arthroscopy had risk factors that could have been identified preoperatively, including OCP use and obesity. Although blood clots are considered a rare occurrence in

the pediatric arthroscopic patient, VTE can be life-threatening and devastating for the patient and family. A TS model at approximately $20.98 per patient can be a potential low-cost solution to prevent VTE diagnosis and treatment.

Routine screening has been recommended with the associated prophylactic treatment for knee arthroscopy or elective pediatric orthopaedic surgeries. However, according to a recent survey, 23% of pediatric orthopedic surgeons have never used mechanical prophylaxis; 45% never used pharmacoprophylaxis, and, as of 2013, only 16% have a VTE prophylaxis protocol in place.[25] Recently, the Solutions for Patient Safety and the Agency for Healthcare Research and Quality, have published guidelines regarding VTE for pediatric hospitals.[15] Unfortunately, most the recommendations have not been supported by evidence specific to pediatric or adolescent cases. This study and the aforementioned recommendations emphasize the need for better screening techniques to identify the portion of high-risk patients undergoing elective procedures who may benefit from early intervention with prophylactic treatment. Other important considerations are education and encouragement of mobility, as applicable, following a surgical procedure.

A subcommittee of Pediatric/Neonatal Hemostasis Neonatal Hemostasis and Thrombosis made recommendations for standardized VTE risk factor definitions.[34] These definitions have been adopted by our institution, and the newly defined risk factors have been applied to a VTE prophylaxis algorithm (Figure 2). The current algorithm is intended to determine the risk profile of a patient undergoing an admission or elective procedure with recommended prophylaxis to initiate as needed.

The primary limitation of this study is the inability to demonstrate a decrease in the incidence of VTEs using an established TS program. Based on the low incidence, the patient volume to support such a study would not be feasible in this setting. The collective incidence of VTE in this study is similar to previous published reports; however, identification of VTE incidence was not the goal of this study. Another limitation is using a retrospective review to compare the TS method, and, thus, a true validation of the accuracy of screening was not performed. Further, it may be feasible for randomized studies to truly validate accuracy of screening but may not be clinical reasonable. During the retrospective review (NS), all evaluations from the surgeons, nonoperative sports medicine providers, anesthesiologists, residents, fellows, and advanced practice providers were reviewed. Although there were no specific practice changes, the operative times differed between cohorts, likely due to a change or advancement in the surgeon's procedures, which should have little effect on the results. The extensive retrospective review was carried out to ensure no single provider was deemed responsible for overlooking VTE risk factors during evaluation. Additionally, the estimated cost based on reported literature and current hospital cost may over- or underestimate overall costs as they vary by institution.

In conclusion, TS improves identification of important clinical data and should be considered for any condition or situation that affects outcomes or minimize complications. Although initially it might have increased time and clinical cost, in this example, a VTE target screening was proved to be a cost-effective tool in common adolescent arthroscopy. A TS for VTE noted approximately 30% more risk factors, especially a significant family history, and provided a cost savings.

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