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Posttraumatic Deep Vein Thrombosis in Collegiate Athletes: An Exploration Clinical Case Series

Chris Hummel, MS, ATC; Paul R. Geisler, EdD, ATC; Tim Reynolds, PT, DPT, OCS, CSCS; Todd Lazenby, MA, ATC

Ithaca College, NY

Background: Although athletes are typically at low risk for developing venous thromboembolism (VTE), injured and noninjured athletes alike can be exposed to many acquired risk factors, including intense training, dehydration, trauma, immobilization, oral contraceptive use, and long-distance travel. Additionally, the risk of developing VTE might be increased by unidentified genetic clotting disorders. Due to the potential for fatal outcomes, knowledge of VTE pathoetiology and recognition of deep vein thrombosis (DVT) presentation should be an inherent part of the evaluation process for all who attend to athletes, regardless of age and apparent risk profile.

Objective: To present an exploration clinical case series consisting of 2 otherwise healthy, college-aged female athletes who, despite their ages and relative low risk profiles, experienced DVTs after lower extremity trauma. Each case will be discussed relative to known clinical prediction rules (CPRs) and published evidence.

Conclusions: Collectively, both cases reinforce the need for the attending clinicians to perform a thorough history and pay attention to subtle clinical findings, regardless of the relatively low risk in college-aged athletes. Although the Wells' CPRs for DVT can be used as a diagnostic guideline in the general population, it might not fully address the risks inherent in a young, otherwise healthy athletic population. We propose a risk-screening tool that is based on and modified from our experiences with these 2 patients and the known prediction rules and positive probability influences.

Key Words: clinical prediction rules, risk-screening tool

Venous thromboembolism (VTE) is the collective term for deep-vein thrombosis (DVT) and pulmonary embolism (PE). The Virchow triad consists of 3 variables that together are thought to contribute to the pathogenesis of a VTE: venous stasis, endothelial injury, and a hypercoagulable state.[1] Although somewhat common in certain populations and patient settings, VTEs are not typically considered a common occurrence in otherwise healthy and young athletic populations. However, several high-profile professional athletes have recently been diagnosed with VTEs that have understandably stalled their competitive careers and, more importantly, placed their health in jeopardy due to the potentially fatal outcomes that can occur. These high-profile events demonstrate that despite these individuals' apparent health and vitality, VTEs are not a novel condition for highly conditioned and younger athletes. In short, fitness, talent, and vitality are not strong prophylactic factors for all when it comes to VTEs.

The model of VTE risk assessment using the classic risk factors (ie, obesity, sedentary lifestyle, >60 years old, etc) along with the Homans sign as part of the physical examination is neither evidence based nor applicable to the athletic population.[1,2] Although athletes are typically at low risk of VTE development, injured and noninjured athletes alike can be exposed to or possess many acquired risk factors, including intense training, dehydration, trauma, immobilization, oral contraceptive (OC) use, and long-distance travel.[1–3] Additionally, the risk of developing VTE might increase due to unidentified genetic clotting disorders.[1] Due to the potential for fatal outcomes, specific knowledge of the pathoetiology and occurrence rates for VTE and the ability to recognize a patient with DVT should be an inherent part of the evaluation process for all who attend to athletes, regardless of the apparent or presumed risk profile.

About 30 first-time cases of DVT occur annually for every 100 000 persons in the 25- to 35-year age range.[4] The authors of a recent systematic review[5] found that the rate of DVT development in patients after anterior cruciate ligament (ACL) reconstruction who did not receive postoperative pharmacologic anticoagulation was a somewhat alarming 8.4%, whereas the rate of PE in these patients was 0.2%. Troublingly, 73% of these patients with DVTs were asymptomatic. Across populations, an estimated 600 000 new patients with DVT are diagnosed each year, with 1% of those cases resulting in fatalities.[6] The cause of death is primarily due to the development of a thrombus that migrates to the pulmonary artery, resulting in hypoxia and eventual cardiac compromise that can be fatal if not diagnosed and treated early. Up to 70% of patients diagnosed with PE had an existing lower extremity DVT as the genesis of the PE, which emphasizes the significance of accurately diagnosing potential DVTs in patients and implementing early intervention.[7]

The purpose of this paper is to present a case series consisting of 2 otherwise healthy college-aged female athletes who, despite their apparently low-risk profiles, experienced DVTs after common lower extremity trauma. In doing so, we will compare and contrast their presenta-

tions and experiences from onset to diagnosis and discuss their cases relative to known clinical prediction rules (CPRs) and published evidence. Clinical prediction rules are evidence-based tools used by clinicians to assist in making a specific diagnosis, prognosis, or outcome predictions. Although these tools (eg, the CPRs of Wells et al[8]) can be quite useful, clinicians need to understand their possible limitations.

Finally, we will discuss the lack of clinical utility for the Homans sign in each patient. We will present a clinical risk-screening tool developed to specifically address the college-aged athletic population based on our clinical experiences with these 2 patients and published evidence on CPRs and positive probability factors.

PATIENT 1

An otherwise healthy, 20-year-old collegiate female soccer athlete presented to the athletic training clinic complaining of deep and diffuse right knee pain after a noncontact dynamic valgus mechanism while playing indoor soccer. Her medical history included a successful right ACL reconstruction 3 years earlier without complication, along with regular OC use. Upon physical examination, she presented with diffuse swelling and a pain level of 3 out of 10 that increased with weight bearing and palpation over the lateral joint line and lateral tibial plateau. Passive range of motion (ROM) was limited to 90° of flexion, and a 5° terminal extension lag was obvious. The McMurray test was negative, while the Lachman test was equivocal. Based on this presentation, meniscal and recurrent ACL injuries were suspected, and initial treatment involved protection, rest, ice, compression wrap, and crutches for pain-free, partial weight-bearing ambulation.

The patient was referred to the team physician, who ordered magnetic resonance imaging, which revealed a small osteochondral defect along the lateral femoral condyle and a subadjacent cartilage defect along the lateral tibial plateau. Subchondral bone marrow edema was present in the distal femur and proximal tibia; also present were a moderate suprapatellar joint effusion and normal ACL and menisci. The team physician prescribed a nonsurgical plan of care.

Early conservative care resulted in significant improvements in pain and ROM within 1 week, so the physician ordered a continuation of this plan of care and maintenance of partial weight-bearing status until the follow-up appointment in 10 days. Based on initial improvements, the patient was cleared by the team physician to travel on an overseas training trip with her collegiate soccer team; this required 5 hours on a bus and an additional 5-hour flight to the final destination. Four days after her departure date, she complained of increasing pain in the posterior aspect of her right calf, redness, and marked edema in the lower leg. As pain increased, her ability to ambulate deteriorated from weight bearing as tolerated to non-weight bearing. Her discomfort was only somewhat relieved with elevation and rest. It is important to note that the team was not accompanied by any medical staff to provide immediate evaluation or care while away from campus. On her return to campus 3 days after the dramatic increase in symptoms, the athletic training staff noted the following:

- Diffuse edema in the popliteal fossa extending distally into the calf
- Calf pain recorded as 4+/10 (during gait)
- Knee pain decreased to 0/10
- Negative Homans sign
- Normal distal pulses (posterior tibialis, dorsal pedis)
- Discolored skin on the anterior and posterior aspects of the lower leg
- Inability to perform a standing single-leg calf raise (plantar flexion) secondary to pain

At that point, we were unsure if her pain and edema were due to increased activity and travel or possibly to a DVT. Although she clearly had a negative Homans sign, we consulted the CPRs of Wells et al[8] for the presence of a DVT. According to these CPRs, the presence of 3 or more major and 2 or more minor criteria indicates with 98% specificity that a DVT may be present.[8] Our patient's major criteria were (1) prolonged immobilization (10 hours total travel), (2) complaints of localized tenderness, and (3) calf and lower leg swelling. Her minor criteria were (1) a history of recent trauma and (2) pronounced erythema in her affected calf and lower leg.

According to the equation of Wells et al,[8] the presence of these 5 key features (3 major and 2 minor criteria) indicated a positive likelihood ratio of 39. In other words, the clinical findings (Table 1) meant that our young and healthy patient was 39 times more likely to be experiencing a DVT in her lower leg compared with the likelihood of a false-positive result on the CPRs. Given such strong evidence, our patient was immediately referred to the local hematology department for a diagnostic ultrasound. Imaging indicated extensive occlusive DVTs within the distal femoral, popliteal, posterior tibial, and peroneal veins. Furthermore, her negative Homans sign was a false-negative clinical finding. This confirmed the poor clinical utility of the Homans sign when diagnosing a DVT.[2]

After confirmation of the DVTs, the attending hematologist immediately initiated anticoagulation therapy consisting of 60-mg dosages of enoxaparin sodium (via subcutaneous injection) bid for 2 weeks and 5 mg of warfarin sodium po daily. Weekly blood tests monitored the patient's international normalized ratio (INR) to ensure desired therapeutic levels (ie, 2–3 INR). Subsequent follow-up testing revealed this patient to be positive for the genetic risk factor V Leiden, which drastically increases prothrombotic events in otherwise healthy individuals. Coumadin treatments were continued for 4 months until the clots were completely dissolved, which was determined with follow-up Doppler ultrasound examination. One month after DVT diagnosis and comprehensive anticoagulation interventions, the patient was cleared by both the attending hematologist and team physician to begin light exercise. Four months after the initial trauma and standard therapeutic interventions for the orthopaedic injury, the patient was cleared by the team physician to begin a pain-free return to running.

To decrease the likelihood of future clot formation, the medical team recommended the patient take several long-term prophylactic actions. A compression stocking was prescribed for any travel-induced immobilization lasting longer than 2 hours, as well as air travel of any duration. Also, OC use was discontinued due to the possibility of

Table 1. The Wells et al[8] Clinical Prediction Rules Findings for Each Patient

Criteria	Patient 1	Patient 2
Major		
Active cancer	No	No
Paralysis	No	No
Recently bedridden (prolonged immobility)	Yes	Yes
Localized tenderness	Yes	Yes
Thigh or calf swelling	Yes	Yes
Family history of clotting	No	No[a]
Total (positive $\geq$3)	3	3
Minor		
Recent trauma	Yes	Yes
Pitting edema	No	No
Dilated superficial veins	No	No
Hospitalized within the last 6 mo	No	No
Erythema	Yes	No
Total (positive $\geq$2)	2	1

[a] The response of *no* was given because the patient did not know about a positive family history until after the Wells et al[8] clinical predication rules were used and her initial diagnosis was made.

Adapted from *The Lancet*, Vol. 345, Wells PS, Hirsh J, Anderson DR, et al, Accuracy of clinical assessment of deep-vein thrombosis, 1326–1330, Copyright 1995, with permission from Elsevier.

increased risk of clot development, especially given that this patient was positive for factor V Leiden. At 5 months after her DVT diagnosis, anticoagulant medication was discontinued and no additional follow-up appointments were indicated. She returned to full competition without difficulty and has not experienced a DVT recurrence.

PATIENT 2

A healthy 19-year-old collegiate female track athlete, with no prior significant medical history other than regular OC use, sustained a traumatic knee injury while engaging in recreational downhill skiing. After standard assessment and diagnostics, she was confirmed to have sustained a left knee tibial plateau fracture, a grade III ACL tear, a grade III medial collateral ligament tear with tibial avulsion, and a posterior horn medial meniscus tear. Her attending surgeon recommended complete non–weight-bearing ambulation and immobilization for 6 weeks to facilitate bony (fracture) and soft tissue healing before ACL reconstruction and meniscal repair.

Ten days postinjury, on her return to school, she presented to our clinic complaining of significant lower extremity pain and edema after her 6.5-hour commute to campus. Initial treatment focused on addressing her current impairments: swelling, decreased ROM, pain, and muscle weakness. The patient was provided with a compression sleeve to facilitate edema reduction around the knee joint and instructed in active ROM exercises for the ankle, passive exercises for knee extension, quadriceps neuromuscular re-education, and open chain hip strengthening. Within 3 days, significant improvements in both pain and edema were noted, along with improvements in overall knee ROM, specifically regaining full pain-free extension and 90° of passive flexion. Based on these improvements, she was instructed to continue her rehabilitation as directed and she chose to discontinue the prescribed pain medications.

Nine days after the initial evaluation by the athletic training staff and 19 days postinjury, the patient presented with significant insidious-onset, posterior medial knee pain, describing it as a "deep ache in the back of her knee." She denied other lower extremity pain at the time but reported discontinuing use of the compression sleeve 2 days before the onset of her current symptom. On physical examination, she had a recurrence of edema into her foot but no erythema. Although the Homans sign was negative, the athletic trainer remained concerned for the possibility of a DVT based on her history and increased lower leg edema. Additionally, when the CPRs of Wells et al[8] were consulted, this patient had 3 major risk factors and 1 minor risk factor (Table 1), which did not meet the diagnostic threshold for the CPRs as seen in patient 1. The patient was instructed to continue monitoring her signs and symptoms for the next 48 hours until a scheduled follow-up appointment with the team physician. The next day, the patient reported a complete cessation of pain, but her lower leg and foot edema persisted.

After the athletic training staff communicated the patient's presentation and history, the team physician ordered a Doppler ultrasound examination, which was positive for a DVT in her peroneal vein between the mid and distal calf. She was immediately placed on anticoagulation therapy consisting of enoxaparin sodium injections bid for 5 days and oral warfarin sodium 5 mg/day for 5 days, decreasing to 2.5 mg/day once her INR reached 2 to 3. She was instructed to discontinue her OC use, and all rehabilitation ceased until consultation with a hematologist could be obtained.

The hematologist prescribed a continuation of warfarin 2.5 mg/day and cleared her to begin light knee rehabilitation consisting only of quadriceps contractions, ankle and knee ROM, and hip and core strengthening. She was also prescribed compression stockings for 6 weeks. The hematologist ordered genetic testing, which was negative for factor V Leiden. After being prompted to check with her parents about her family history for clotting disorders, our patient informed us that her maternal grandfather had died from a PE after knee surgery at 73 years of age, indicating a post facto positive family history for a clotting disorder.

Three months after resolution of her DVT, the patient underwent successful ACL reconstruction without complications, including an absence of lower extremity clotting, and has now completed her rehabilitation and returned to full activity after 9 months without DVT recurrence.

DISCUSSION

It is well accepted that in certain higher-risk individuals, recent trauma or surgery followed by prolonged immobilization should raise suspicion for the development of VTE, particularly in the lower extremities.[1–5,8] However, there are few documented cases of young and otherwise healthy athletes developing DVT after common orthopaedic trauma.[3,9–11] Due to the serious and significantly hazardous potential outcomes of DVT, including fatalities, clinicians must prudently identify risk factors that may predispose patients to clot formation, regardless of their specific demographics. A thorough medical and pharmacologic

Table 2. Demographic and Risk Factors in the 2 Patients

Risk Factor	Patient 1	Patient 2
Age, y	20	19
Sex	Female	Female
Trauma	Yes	Yes
Prolonged immobility	Yes	Yes
Air travel	Yes	No
Recent travel (>4 h)	Yes	Yes
Personal history of clotting	No	No
Family history of clotting	No	Yes[a]
Genetics	Yes	No
Oral contraceptive use	Yes	Yes
Homans sign	No	No
Thigh or calf swelling	Yes	Yes
Localized tenderness	Yes	Yes
Pitting edema	No	No
Erythema	Yes	No
Total *yes* answers	9	7

[a] The response of *yes* was given because the patient reported a family history of clotting (pulmonary embolism in 73-year-old maternal grandfather) after the initial diagnosis was made.

history is critical to appreciate the relative risks and odds of DVT formation, even in young and healthy athletes presenting with typical sport-related injuries to the lower extremity. Perhaps even more important is for clinicians to strongly reconsider keeping the Homans sign in their clinical toolbox for diagnostic assessment; as we have demonstrated in both patients, the Homans sign should be regarded with deep suspicion at best. Cranley et al[12] reported a sensitivity of 48%, a specificity of 41%, and a diagnostic odds ratio of only 0.64, demonstrating very poor diagnostic utility.

Table 1 shows the criteria met by each patient using the CPRs of Wells et al.[8] Table 2 provides a comparison of the demographic information and the common risk factors associated with the development of DVTs in our 2 young female patients.

When we reflected retrospectively on patient 1, her risk factors included

- Osteochondral defect along the lateral femoral condyle and subadjacent tibia, as well as subchondral bone marrow edema
- Combined 20 hours of immobilization during the 7-day travel period
- Four plane flights totaling more than 10 hours at significant altitude
- Athlete was taking an OC
- The genetic mutation for factor V Leiden as revealed by blood tests

Patient 2 had similar risk factors with a few exceptions:

- Lateral tibial plateau fracture, ACL and medial collateral ligament sprains, medial meniscus tear
- No air travel but confined car travel for greater than 6 hours
- No erythema on physical examination
- Athlete was taking an OC
- No genetic risk factors found but a family history of PE resulting in death (maternal grandfather)

In the general population, prolonged bed rest, smoking, and advancing age are common and well-appreciated risk factors for the development of VTE, but these are usually not of concern for clinicians working with younger, otherwise healthy patients and competitive athletes.[1] However, as has been shown here, young athletes are not immune to DVT development, so those risk factors that are particularly relevant to athletes need to be further examined.[3]

Each of the previously mentioned risk factors contributed to each patient's DVT, reinforcing the importance of obtaining a thorough medical history to assist the medical team with the diagnosis, including a detailed family history and questions about OCs. Using these risk factors as a guide, clinicians should ask athletes presenting with knee or

Table 3. Athlete Deep-Vein Thrombosis Risk-Assessment Screening Tool

Risk Factors, History	+1 for Each Positive Finding	Physical Examination	+1 for Each 1 Positive Finding
Oral contraceptive use		Erythema (redness) in lower extremity	
Immobilization of lower extremity joint(s) and/or non-weight bearing (crutches, etc) within the past 6 wk		Edema (swelling) in lower extremity (recurrence after acute period)	
Family member clotting history <60 y		Pitting edema	
Recent travel (airline, bus, van) >4 h (in past 6 wk)		Unexplained, achy pain in lower extremity	
Total A		Total B	
Personal history of clotting (+3 to grand total)			
Another diagnosis more likely (−1 to grand total)			
Grand total			
		Grand total = 0–2 (yellow flag)	Monitor closely for changes
		Grand total = 3–5 (orange flag)	Consider referral and discuss patient with team physician
		Grand total ≥6 (red flag)	Immediate referral

Table 4. Athlete Deep-Vein Thrombosis Risk-Assessment Screening Tool: Patient 1

Risk Factors, History	+1 for Each Positive Finding	Physical Examination	+1 for Each Positive Finding
Oral contraceptive use	1	Erythema (redness) in lower extremity	1
Immobilization of lower extremity joint(s) and/or non-weight bearing (crutches, etc) within the past 6 wk	1	Edema (swelling) in lower extremity (recurrence after acute period)	1
Family member clotting history <60 y	0	Pitting edema	0
Recent travel (airline, bus, van) >4 h (past 6 wk)	1	Unexplained, achy pain in lower extremity	1
Total A	3	Total B	3
Personal history of clotting (+3 to grand total)	0		
Another diagnosis more likely (−1 to grand total)	0		
Grand total	6		
		Grand total ≥6 (red flag)	Immediate referral

lower leg trauma or surgery, regardless of age, sex, or initial appearance, the following questions[3]:

- Have you had any period of immobilization or weight-bearing restrictions since your injury or surgery?
- Have you traveled recently or do you intend to travel in the near future (specifically air travel lasting longer than 4 hours)?
- Are you currently taking oral contraceptives or receiving hormonal therapy? If so, what kind?
- Do you or any members of your family have a history of deep vein thrombosis or clotting disorder?

Based on our experience with and reflection of the 2 patients' courses, a critical review of the literature, and real-time application of known CPRs, we have developed and present here a stratified risk-screening tool (Table 3) to assist clinicians in evaluating potential DVT.[13] After examining the findings of this exploration clinical case series, we saw the need to create a tool that specifically addresses the athletic population and the typical risk factors inherent to this otherwise healthy population, and we offer it as a possible option for decreasing the number of potential false-negative findings for DVT. Please note that this tool has only recently been developed and is in the exploratory phase of clinical use. It has not been validated and, as such, is intended only to serve as 1 possible tool for determining the DVT risk in populations that are presumed to be less vulnerable. The clinical utility of this tool needs to be established beyond this small sample.

Furthermore, our experience with these 2 patients supported Cranley et al's[12] conclusion that the clinical utility of the Homans sign is significantly deficient. If our clinicians had relied solely on the negative clinical findings in these patients, DVTs would have been missed in both cases, and the clinical outcomes for these 2 patients might have been very different.

The Athlete DVT Risk Screening Tool asks about risk factors and history (first column) and applies +1 for each positive finding in the second column. If any of the 4 physical examination findings (third column) are present, +1 is applied for each item in the fourth column. Tables 4 and 5 show how each patient scored retrospectively. Patient 1 scored a 6, which would have indicated high risk (red flag) and prompted immediate referral. Patient 2 scored a 5, which was at the high end of moderate risk (yellow flag) and would have prompted consideration for referral and discussion with the team physician. In each case, this screening tool would have been successful in properly identifying the DVT risk.

The authors of a recent Cochrane review[14] recommended prophylactic low-molecular-weight heparin for all adults (including athletes) requiring immobilization after traumatic lower extremity injury. This evidence-based recommendation should prompt clinicians to discuss the risks and benefits of adding low-molecular-weight heparin to the treatment of patients with lower extremity injuries requiring immobilization. Pharmacologic intervention might prevent the tragic consequences of undetected VTEs. Additionally,

Table 5. Athlete Deep-Vein Thrombosis Risk-Assessment Screening Tool: Patient 2

Risk Factors, History	+1 for Each Positive Finding	Physical Examination	+1 for Each Positive Finding
Oral contraceptive use	1	Erythema (redness) in lower extremity	0
Immobilization of lower extremity joint(s) and/or non-weight bearing (crutches, etc) within the past 6 wk	1	Edema (swelling) in lower extremity (recurrence after acute period)	1
Family member clotting history <60 y	0	Pitting edema	0
Recent travel (airline, bus, van) >4 h (past 6 wk)	1	Unexplained, achy pain in lower extremity	1
Total A	3	Total B	2
Personal history of clotting (+3 to grand total)	0		
Another diagnosis more likely (−1 to grand total)	0		
Grand total	5		
		Grand total = 3–5 (orange flag)	Consider referral and discuss case with team physician

Eichner[15] suggested daily limb-girth measurements to better assess VTE injury.

Although young, otherwise healthy athletes are not typical candidates for DVT after mild to moderate orthopaedic trauma, the possibility of developing thrombi should be at the forefront of a clinician's thought process when other risk and contributing factors are present.[3] After the initial trauma, each patient presented with only 2 known risk factors for a DVT (limb trauma and OC use). At this point in the diagnostic process, suspicion of a DVT would be limited but should not be eliminated as a potential sequela of VTE. Yet the exacerbation of symptoms shortly after a period of prolonged travel should serve as a red flag to the examining clinician.

The CPRs of Wells et al[8] inform us that a history of cancer, presence of paralysis, or lengthy immobilization are major criteria for increasing the risk for DVT.[8] In young athletic populations, none of these criteria are typically present, nor were they in either of our patients, except for the more than 4 hours of travel that forced each athlete into increased immobilization. However, patient 1 was found to have a genetic risk factor for the condition and presented with 3 key clinical features upon her return trip. Clinicians should be aware of the inheritable and often unidentified genetic risk factors, such as factor V Leiden, protein C, protein S, and antithrombin III, that can complicate the clinical diagnosis and require further exploration through genetic testing.[1]

Collectively, the findings in both patients support the robustness of the CPRs of Wells et al[8] and reinforce the need for attending clinicians to perform a thorough history and pay attention to subtle clinical findings (eg, erythema, repeated limb-girth measurements), regardless of the relatively low risk in college-aged athletes.

CONCLUSIONS

The stratified risk-screening tool for posttraumatic DVT in collegiate athletes was created to address athlete-specific risk factors and allows a clinician to more fully examine the DVT risk in athletes. Although the CPRs of Wells et al[8] can be used as a diagnostic guideline for DVT in the athletic population, they might not fully address the risks inherent in a young, otherwise healthy athletic population. We suggest that evidence-based DVT risk-assessment tools and guidelines for return to play after DVT in athletic populations are worthy of future development and exploration in both clinical practice and research.

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Address correspondence to Chris Hummel, MS, ATC, Ithaca College, Hill Center G69, 953 Danby Road, Ithaca, New York 14850. Address e-mail to chummel@ithaca.edu.