29 Preventing Venous Thromboembolism Across the Surgical Care Continuum

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"The disconnect between evidence and execution as it relates to DVT prevention amounts to a public health crisis."

—American Public Health Association

Abbreviations

AAOS	The American Academy of Orthopedic Surgeons
ACCP	The American College of Chest Physicians
AHRQ	The Agency for Healthcare Research and Quality
APHA	The American Public Health Association
CDS	Clinical decision support
CPOE	Computerized provider order entry
DVT	Deep vein thrombosis
EAST	The Eastern Association for the Surgery of Trauma
INR	International normalized ratio
IVC	Inferior vena cava
LMWH	Low molecular weight heparin
PCORI	Patient-Centered Outcomes Research Institute
PE	Pulmonary embolism
SC	Subcutaneous
SCDS	Sequential compression devices
TEDS	Thromboembolic deterrent stockings
US	United States
V/Q	Ventilation/perfusion scan
VTE	Venous thromboembolism

Background

Prevention of venous thromboembolism (VTE) is a critical patient safety practice as well as an important measure of healthcare quality. VTE refers to deep vein thrombosis (DVT), pulmonary embolism (PE), or the presence of both. As many as 350,000–900,000 people each year in the United States (US) will be harmed by VTE, and over 100,000 people will die from VTE each year [1]. National annual expenditures for treatment of VTE may be as high as $10 billion [2]. While high-quality evidence-based guidelines for VTE prevention are available and strongly encouraged for adoption, studies continue to show that hospitalized patients are not routinely provided with risk-appropriate VTE prophylaxis [3, 4]. One study has demonstrated that only 42 % of patients diagnosed with DVT during hospitalization had received VTE prophylaxis [5]. Another showed

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J.A. Sanchez et al. (eds.), *Surgical Patient Care*, DOI 10.1007/978-3-319-44010-1_29

that <60 % of surgical patients worldwide received appropriate prophylaxis [4].

Numerous groups have recognized VTE as a public health and safety problem. The American Public Health Association (APHA) issued a White Paper in 2003 stating, "The disconnect between evidence and execution as it relates to DVT prevention amounts to a public health crisis" [6]. The US Surgeon General recognized VTE as "a major public health problem" and issued "A Call to Action to Prevent Deep Vein Thrombosis and Pulmonary Embolism" in 2008 [1]. The Agency for Healthcare Research and Quality (AHRQ) has identified VTE prophylaxis as "the number one patient safety practice" to prevent in-hospital death [7–9]. Most recently, AHRQ has placed "Strategies to increase appropriate prophylaxis for VTE" on the list of top 10 "Strongly Encouraged Patient Safety Practices" [3, 10]. The collective attention from these groups has raised awareness that passive strategies to improve VTE prophylaxis are not as likely to be impactful as active strategies, especially since well-done evidence-based guidelines for VTE prophylaxis are widely disseminated and available [11].

Closer evaluation of the VTE example reveals that the outcome measure of interest (decreased incidence of VTE) is best improved by critically evaluating the system of care and improving the component process measures involved in prevention of VTE [12]. For example, risk-appropriate VTE prophylaxis is a process including assessment and prescription by a provider, administration by a nurse, and acceptance by the patient. Active strategies, including a reminder to providers to assess individual patient risk for VTE and prescribe prophylaxis as part of a standard electronic order set, are more likely to improve outcomes than passive dissemination of guidelines [10, 13–15]. Similarly, active attempts to understand nursing practices and beliefs can identify barriers to the administration of prescribed prophylaxis [16]. Finally, since many patients are not aware of VTE or its potential consequences, patients may not recognize the importance of accepting prescribed prophylactic medications [6]. A cohesive approach to decreasing the incidence of VTE must address all aspects of the system of care.

As public reporting and pay-for-performance initiatives have developed as effective tools to improve the quality of healthcare, it is prudent to recognize that even when patients are prescribed and administered VTE prophylaxis according to guidelines, VTE may still not be preventable in as many as 50 % of cases [17]. VTE prevention is quite effective but cannot drive the event rate to zero without undue risk of bleeding [17–19]. National bodies, including the Centers for Medicare and Medicaid Services, impose financial penalties when hospitalized patients develop VTE, despite the fact that many of these VTE events are truly not preventable with current best-practice prophylaxis [19]. Policy changes at the regional and national level should focus on a more impactful approach. A true benchmark of patient safety and quality care should not focus on the incidence of VTE (outcome measure), without considering how frequently patients are prescribed and administered VTE prophylaxis according to best-practice guidelines (process measure). Rather than measuring incidence of VTE alone, some experts argue for a pure process measure approach or combined process and outcome measure instead [12, 13, 20, 21].

Definitions

DVT is the partial or complete occlusion of the venous system from formation of venous thrombi, typically in the lower extremities. A proximal DVT involves thrombosis at the popliteal vein or above, while a distal DVT is confined to the deep veins of the calf. The "superficial femoral vein" is part of the deep venous system, and any thrombus identified within this vein must be treated as a deep, true DVT. PE refers to occlusion of the pulmonary vasculature and is thought to result from embolism secondary to DVT. More recent data suggest that primary thrombosis of the pulmonary vasculature may be the cause of some PE events [22]. The severity of PE determines mortality risk and is typically stratified according to hemodynamics and assessment of right ventricular cardiac function. Massive or high-risk PE is associated with hypotension, signs of cardiogenic

shock, and/or cardiac arrest. Submassive or intermediate-risk PE is associated with preserved hemodynamics but evidence of right ventricular dysfunction or myocardial necrosis. These immediately life-threatening PE events mandate immediate intervention to salvage life.

Incidence and Cost

Each year in the USA, there may be as many as 350,000–900,000 cases of VTE [1]. More than 100,000 people will die from VTE, making VTE the most common cause of death from cardiovascular disease after heart attack and stroke [23]. Over one third of patients with DVT will experience PE [24]. Autopsy studies have identified PE in 7–27 % of patients postmortem, and in most of these cases, there was no clinical suspicion of PE before death [25]. A single DVT or PE event has been estimated to cost an additional $7700–$10,800 or $9500–$16,600, respectively, for treatment in the hospital setting during the initial event [9, 26]. As many as 5–14 % of these patients with VTE will require readmission to the hospital, the readmission cost may vary from $11,000 to $16,000 [26]. Post-thrombotic syndrome, the most common long-term complication affecting patients with DVT, has been estimated to cost at least $200 million annually in the USA [27]. National annual expenditures for treatment of VTE in total may be as high as $10 billion [2]. While the costs of VTE are high and in many cases represent preventable expenditures, the true cost of VTE to patients and society is considerably higher when considering the harm to patients.

Harm to Patients

Post-thrombotic syndrome, chronic thromboembolic pulmonary hypertension, recurrent VTE, and risks of anticoagulation treatment are only some of the harms associated with VTE [9, 28, 29]. Post-thrombotic syndrome may affect as many as 23–60 % of patients with DVT [27]. Symptoms include chronic calf swelling and skin changes and in 5–10 % of cases skin ulcerations and chronic wounds [29]. Chronic thromboembolic pulmonary hypertension may occur in 2–4 % of patients after acute PE and can result in dyspnea both at rest and with exertion [23]. Some of these patients will ultimately succumb to right heart cardiac ventricular failure and/or sudden cardiac death. One group has recognized the need to provide rehabilitation services to patients after PE to improve dyspnea and functional capacity [30]. Risk of recurrent VTE is highest during the first 6–12 months after the initial episode, but the cumulative risk of recurrence at 10 years may be as high as 30 % [31, 32].

Anticoagulation remains the mainstay of treatment for VTE to prevent recurrence and associated sequelae, but clinically relevant or major bleeding can occur with any anticoagulant, especially at the beginning of treatment. Furthermore, VTE may recur even with appropriate anticoagulation treatment. The RIETE Registry, a prospective, ongoing, multicenter international registry, documents consecutive patients with confirmed symptomatic acute VTE [33]. In this series of over 19,000 patients with VTE, 2.4 % had major bleeding after anticoagulation was started, and one of every three cases of major bleeding proved fatal.

Risk Factors

Virchow described the basic etiology of venous thromboembolism as vascular endothelial injury, venous stasis, and hypercoagulability. This classic framework can be used to understand the etiology of risk factors that predispose patients to VTE. Vascular endothelial injury may be iatrogenic (e.g., central venous catheter, surgery) or traumatic. Venous stasis results from factors causing immobilization such as bed rest, prolonged sitting, stroke, immobilization (i.e., long-bone stabilization for trauma), pharmacologic paralysis, or traumatic paralysis (e.g., spinal cord injury). Hypercoagulability may be inherited (e.g., factor V Leiden) or acquired (e.g., malignancy, hormone/contraceptive use). Specific major and minor risk factors are listed in

Table 29.1 Risk factors for venous thromboembolism

Major VTE risk factors
• Malignancy • Personal history of previous VTE • Family history of VTE • Prolonged surgical procedure (>2 h) • Major general surgery • Major traumatic injury • Hip or leg fracture • Hip or knee replacement • Acute spinal fracture • Acute spinal cord injury (<1 month) • Acute stroke (<1 month) • Pregnancy/postpartum (up to 6 weeks) • Known thrombophilia (e.g., factor V Leiden, lupus anticoagulant, anticardiolipin antibodies, antithrombin deficiency, protein C or S deficiency, etc.) • Central venous catheter • Respiratory failure/mechanical ventilation
Minor VTE risk factors
• Older age • Bed rest • Immobility from prolonged sitting (e.g., airplane travel or prolonged car travel) • Laparoscopic surgery • Inflammatory bowel disease • Obesity • Pregnancy/antepartum • Acute infection • Varicose veins • Arteriovenous malformations • Tobacco use • Estrogen/selective estrogen receptor modulators (e.g., tamoxifen) • Contraceptives

VTE venous thromboembolism

Table 29.1. The AHRQ recently published an updated report "Preventing Hospital-Acquired Venous Thromboembolism - A Guide for Effective Quality Improvement" which promotes accepted approaches for VTE prevention in hospitalized patients [9]. This report summarizes numerous risk assessment models that have been created to stratify patient risk for acquiring VTE during hospitalization. University of California (UC) San Diego and Johns Hopkins employ a bucket model, while others use a point allocation system (e.g., Caprini, Padua, Rogers, IMPROVE) [14, 34–38]. The Caprini model is a complex scoring system but has been validated in surgical patients [35]. The Padua model is somewhat less complex but is derived from a relatively small study in a single Italian hospital [36].

Prevention

Pharmacologic Prophylaxis

Guidelines for VTE prophylaxis are available and widely disseminated. The guidelines from the American College of Chest Physicians (ACCP) are often considered the definitive resource [11]. This group has specific recommendations for prophylaxis in non-orthopedic surgery patients [39]. Guidelines for specific populations at risk, such as trauma patients and orthopedic surgical patients, are available from specialty societies such as the Eastern Association for the Surgery of Trauma (EAST) and the American Academy of Orthopedic Surgeons (AAOS), respectively [40, 41].

Most protocols use subcutaneous (SC) injection of unfractionated heparin or low molecular weight heparins (LWMH) such as enoxaparin, dalteparin, or fondaparinux for VTE prophylaxis. Trauma and orthopedic literature typically supports the use of LMWH over unfractionated heparin [40]. Patients with unstable renal function or creatinine clearance less than 30 mL/min should receive unfractionated heparin instead of LMWH due to risks associated with bioaccumulation of some LMWHs in patients with reduced renal clearance. Newer oral anticoagulants are being promoted for VTE prevention, although at this time, the only well-studied indication is for patients undergoing hip or knee replacement surgery.

VTE prophylaxis should generally be provided throughout the inpatient hospitalization, but some literature also supports extending prophylaxis to the outpatient setting for a limited duration after discharge from the hospital. This may be of particular use in patients at high risk for perioperative VTE including orthopedic surgery patients, or those with major abdominopelvic oncologic resections. Dosing of unfractionated heparin is typically 5000 units SC every 8 h for many patients, while less frequent dosing (5000 units SC every 12 h) may be appropriate for some patients at lower risk. Dosing for a common

LMWH, enoxaparin, is typically once daily with 40 mg SC for most surgical patients yet should be 30 mg twice daily for trauma patients [42]. VTE prophylaxis is typically administered 1–2 h before any major surgical procedure and resumed 12–24 h postoperatively. Contraindications to pharmacologic prophylaxis include active bleeding, high risk of bleeding, systemic anticoagulation, coagulopathy with international normalized ratio (INR) ≥1.5, or thrombocytopenia (platelet count <50,000).

Mechanical Prophylaxis

Mechanical prophylaxis may include sequential compression devices (SCDS) and thromboembolic deterrent stockings (TEDS). SCDS are preferred over TEDS alone, and TEDS may be associated with ulcers or skin breakdown, especially in patients with stroke, peripheral vascular disease, or chronic lower extremity wounds [43]. Compliance with these devices in surgical patients is poor even without any specific contraindications, and efforts to improve compliance by addressing misconceptions will be discussed later in the chapter. Although very little data support its use, ambulation has been suggested as an effective adjunct to VTE prophylaxis when feasible [44]. However, this should not be considered an acceptable replacement to pharmacologic and/or mechanical prophylaxis in hospitalized patients at risk for VTE.

Prophylactic Inferior Vena Cava Filters

Inferior vena cava (IVC) filters have been used as prophylaxis in certain high-risk patients without VTE who are unable to receive pharmacologic prophylaxis. The strongest data for this indication come from the trauma literature [45]. EAST offers a level III recommendation (based on retrospective data and/or expert opinion) that a prophylactic IVC filter may be considered in very high-risk trauma patients who are unable to receive pharmacologic VTE prophylaxis [40]. This recommendation may apply to patients with both increased bleeding risk and an injury pattern rendering them immobile for a prolonged period (e.g., severe closed-head injury, spinal cord injury with paraplegia or quadriplegia, or multiple long-bone fractures). However, there is considerable disagreement on this topic, and the ACCP states that "for major trauma patients, we suggest that an IVC filter should not be used for primary VTE prevention (Grade 2C)" [39].

While the trauma literature has identified a potential benefit, IVC filters may also be associated with increased morbidity and mortality in other patient populations. In the bariatric surgery literature, prophylactic IVC filters are associated with higher mortality and higher risk of DVT [46]. Further research is needed to truly understand the implications and safety considerations for IVC filter use in different patient populations.

If a retrievable IVC filter is used, it is important to remove the IVC filter as soon as the patient's acute risk of VTE decreases. In many cases, patients do not return for IVC filter removal. One study of 446 trauma patients who received retrievable IVC filters demonstrated that only 22 % actually had their IVC filter removed [47]. Filter endothelialization may occur as soon as 3 weeks after placement, yet many can still be recovered years later. Patients may experience complications from prolonged indwelling IVC filters, including perforation of the IVC noted on subsequent CT imaging and strut fracture and embolization [48, 49].

Numerous efforts are underway to identify strategies to ensure better rates of filter retrieval. One group has applied the DMAIC (Define, Measure, Analyze, Improve, Control) methodology of the Six Sigma paradigm and increased filter retrieval rates from a baseline of 8 to 52 % by employing automated clinic visit scheduling for 4 weeks after IVC filter placement [50]. A group in New Zealand implemented an "IVC filter pathway" and increased retrieval rates from 63 to 100 % [51]. Focused efforts to improve poor IVC filter removal rates in trauma have been successful and increased rates to 59 % at one US hospital and 87 % at a Canadian trauma center [52, 53].

Systems of Care to Improve Prevention

While guidelines for VTE prevention are widely available, VTE prophylaxis remains underutilized in a significant proportion of hospitalized patients [11, 40, 41]. One study included over 68,000 hospitalized patients at risk for VTE in 32 countries and determined that only 59 % of surgical patients and 40 % of medical patients received guideline-recommended VTE prophylaxis [4]. As with most quality improvement interventions, improved outcomes are best achieved by evaluating the system of care and identifying the component process measures. By improving specific process measures, better outcomes may follow. VTE presents an important example of how to improve healthcare quality and patient safety through active interventions targeting specific aspects of the system of care. A basic framework for the VTE prophylaxis system of care includes risk assessment and prescription of appropriate prophylaxis by a provider, administration of all prescribed prophylaxis doses by a nurse, and acceptance of all doses by the patient (Fig. 29.1).

VTE Risk Assessment and Prescription of Prophylaxis

One approach to improve documentation of VTE risk status and compliance with evidence-based guidelines is to utilize a mandatory computerized provider order entry (CPOE) clinical decision support (CDS) tool, as suggested by the AHRQ [8, 9]. Computer order entry system requires the prescribing provider to complete a checklist of VTE risk factors and contraindications specific for the patient. Based on this checklist, the patient is risk stratified, and the appropriate prophylaxis, according to current guidelines, is determined. The provider is then prompted to order the appropriate prophylaxis regimen. This approach has demonstrated dramatic improvements in both prescription of risk-appropriate VTE prophylaxis for medical and surgical patients and an associated decrease in the rate of preventable harm from VTE [14, 15]. When this strategy was implemented at the Johns Hopkins Hospital, compliance with guideline-appropriate prophylaxis in trauma patients increased from 66.2 to 84.4 % ($p < 0.001$), and the rate of preventable harm from VTE decreased from 1.0 to 0.17 % ($p = 0.04$).

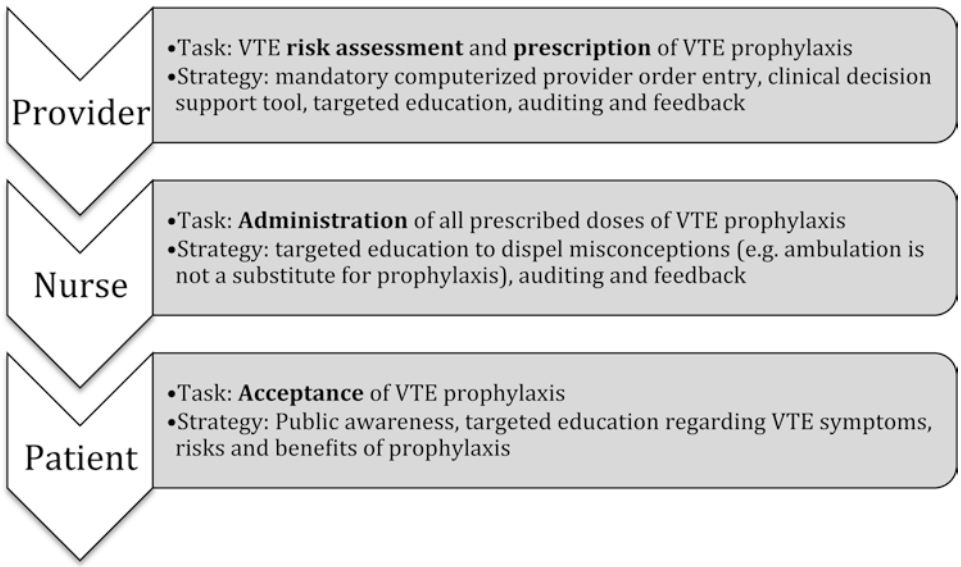

Fig. 29.1 VTE prophylaxis system of care and strategies for improvement (*VTE*, venous thromboembolism)

It is important to ensure that interventions designed to improve prescription of VTE prophylaxis are targeted at the appropriate individuals. At many academic institutions, quality measures attributed to attending physicians (e.g., rate of compliance with appropriate VTE prophylaxis) may actually reflect the average performance of both highly compliant and noncompliant residents. One study compared the proportion of risk-appropriate VTE prophylaxis orders written by each resident and attributed to attending physicians [54]. While there was no difference in proportion of risk-appropriate VTE prophylaxis when attributed to attending physicians, there was a significant difference among residents. Over half of the residents prescribed optimal prophylaxis for every patient they admitted, but there was a minority of residents (9.3 %) who failed to prescribe optimal prophylaxis for *any* of the patients they admitted. This study demonstrates the importance of targeting the providers actually responsible for entering the prophylaxis orders. Furthermore, this suggests that an educational intervention with the limited number of residents not prescribing appropriate prophylaxis might be most effective. Accordingly, a system designed to audit resident compliance with VTE prophylaxis and provide individualized performance feedback was implemented and has been shown to significantly improve compliance with guidelines, reduce incidence of VTE, and improve residents' satisfaction with their education [55].

Administration of VTE Prophylaxis

Once risk-appropriate VTE prophylaxis is ordered, it does not necessarily mean that all ordered doses of prophylaxis will actually be administered. Even missing one dose of VTE prophylaxis is associated with VTE events as demonstrated by a 2014 analysis of 202 trauma and general surgery patients [56]. This study showed an overall incidence of DVT of 15.8 %, and 58.9 % of patients had missed at least one dose of prescribed VTE prophylaxis. DVT occurred in 23.5 % of patients who missed at least one dose of prophylaxis and in 4.8 % of patients who missed no doses of prophylaxis ($p < 0.01$). A 2015 study examined 128 medical and surgical patients with hospital-acquired VTE and determined that 72 % (92 patients) of these VTE events were potentially preventable [17]. The VTE events that were not preventable were attributed to the presence of a central venous catheter [57]. Of the 92 patients who experienced potentially preventable VTE events, 79 (86 %) were prescribed optimal prophylaxis, yet only 43 (47 %) received defect-free care. Of the 49 patients (53 %) who were noted to have defects in their care, 13 (27 %) were not prescribed risk-appropriate VTE prophylaxis, and 36 (73 %) missed at least one dose of appropriately prescribed prophylaxis. A retrospective review examined the medication administration record for patients prescribed VTE prophylaxis over a 7-month period at one academic medical center [58]. Over 100,000 doses of VTE prophylaxis were ordered, but 12 % of these doses were not actually administered to patients. Patient refusal was the most commonly documented reason for nonadministration in about 60 % of cases. This study also demonstrated that a small group of patients (approximately 20 %) constituted the majority (80 %) of all nonadministered doses. Heterogeneity in terms of administration of VTE prophylaxis across nursing floors was noted which suggests that targeting interventions to specific nursing floors, individual nurses, or individual patients may be effective.

Patient Engagement and Education

Many patients are not aware of VTE or its potential consequences, which may lead some patients to refuse VTE prophylaxis without a clear understanding of the risks and benefits of this decision. An APHA telephone survey established that fewer than one in ten Americans know about DVT and are familiar with its symptoms or risk factors [6]. Recently, for World Thrombosis Day (October 13, 2014), Wendelboe surveyed 7233 participants in nine countries to determine the awareness of VTE. They found awareness to be lowest for DVT (44 %) and PE (54 %) compared

to other common conditions such as breast cancer (85 %), stroke (85 %), prostate cancer (82 %), and heart attack (88 %) [59]. Initiatives to increase awareness among patients and the public are also important to decrease the incidence of VTE. For example, US Congress has designated the month of March as DVT Awareness Month to help highlight the symptoms of this common disease. Ongoing efforts must incorporate patient-centered interventions to ensure that patients understand the importance of VTE prophylaxis and the inherent risks associated with refusal of prophylaxis. Recently, our group has been funded to address this problem by the Patient-Centered Outcomes Research Institute (PCORI) for a project titled "Preventing Venous Thromboembolism: Empowering Patients and Enabling Patient-Centered Care via Health Information Technology" [60]. Patient educational materials are readily available in both paper (http://www.Hopkinsmedicine.org/Armstrong/bloodclots) and video (http://bit.ly/bloodclots) formats, which can be used for this purpose.

Overcoming Hospital Culture Obstacles

Efforts to improve VTE prophylaxis in accordance with best-practice guidelines may require addressing obstacles attributed to hospital culture [61]. For example, mechanical VTE prophylaxis with SCDS is often prescribed but commonly underutilized in about 50 % of patients [62]. Noncompliance may be largely related to patient discomfort and the ease with which these devices may be removed by the patient. Another well-known contributing factor is lack of available SCD equipment at the time of patient admission. Some hospitals have addressed this issue by assigning SCD equipment to each hospital bed, ensuring that the patient will be provided with clean SCD equipment at the time the bed is made available. There may be a tendency for multidisciplinary staff members to remove SCDS to help a patient out of bed without reapplying the SCDS when returning the patient to bed. This problem requires education of a broader multidisciplinary group including nursing assistants, physical therapists, occupational therapists, and transport teams. A common misconception held by some hospital staff and contributing to noncompliance is that SCDS may cause patient falls. A retrospective study examined the incidence of SCD-related falls and determined that only 0.45 % of falls in the hospital are related to SCDS and SCD-related falls are not more harmful than other types of falls [63].

Active attempts to understand nursing practices and beliefs identified barriers to administration of prescribed VTE prophylaxis in a mixed methods study published in 2014 [16]. The study revealed a nursing belief that nurses are responsible for assessing individual patient risks and benefits of prescribed pharmacological VTE prophylaxis before administering the medication to the patient. One nurse who participated in a focus group during this study stated "We make the clinical decision all the time as to whether a patient needs VTE prophylaxis every day, based on how much the patient is ambulating." This study was able to identify misconceptions held by many nurses and introduced an opportunity to provide additional education to this group.

Public Reporting of VTE Outcomes

Public reporting and pay-for-performance initiatives are effective tools to improve the quality of healthcare [64, 65]. National bodies, including the Centers for Medicare and Medicaid Services, impose financial penalties when hospitalized patients develop VTE, despite the fact that many of these VTE events are truly not preventable with current best-practice prophylaxis [19]. Furthermore, the incidence of VTE is related to screening practices and therefore subject to surveillance bias [66]. Providers who screen more aggressively by performing more Duplex ultrasounds on asymptomatic patients at risk for VTE may identify more cases of VTE and will appear to provide lower-quality care than providers who do not screen or order fewer screening tests.

Screening of Asymptomatic Patients and Surveillance Bias

There is no consensus regarding DVT screening of high-risk asymptomatic patients, and practices among surgeons may vary significantly [66]. ACCP does not recommend routine screening for DVT in critically ill patients [11]. EAST recognizes that some patients at high risk may benefit from routine screening for DVT [40]. However, the clinical importance of asymptomatic DVT detected by routine screening remains unclear. Supporters of routine screening see benefit in performing a relatively inexpensive and noninvasive test (Duplex ultrasonography), in order to diagnose and treat asymptomatic DVT before it progresses to symptomatic or fatal PE. Others feel that increased medical testing, associated costs, and treatment of asymptomatic DVT (which may never have come to clinical attention otherwise) incur not only the risk associated with anticoagulation but also unnecessary costs.

Surveillance bias ("the more you look, the more you find") is a common concern when screening asymptomatic patients for VTE. Studies have clearly shown that increasing screening is associated with increasing rates of VTE, primarily in trauma patients [20, 67, 68]. However, this phenomenon has also been shown in a large sample of nearly one million Medicare patients undergoing a wide range of surgical procedures [69]. While national and regional bodies recognize low incidence of VTE as a marker of quality, this is a biased measurement since hospitals that less commonly screen patients for VTE are going to identify fewer VTE events regardless of associated healthcare quality.

Linking Process Measures and Outcome Measures

The standard of patient safety and quality care should not only focus on the incidence of VTE (outcome measure) alone but also consider how frequently patients are prescribed and administered VTE prophylaxis according to best-practice guidelines (process measure). Rather than measuring incidence of VTE alone, some experts argue for a pure process measure approach or combined process and outcome measure instead [12, 13, 20, 21]. Outcome measures are of considerable interest and have been commonly used to determine the quality of care [70]. However, poor outcomes provide no information about how to actually address the underlying problem. Interventions to improve the quality of care must be directed at the process of care [71]. Using the VTE and Outcome Measures example, linking the process measures (prescription and administration of risk-appropriate VTE prophylaxis) and the outcome measure (incidence of VTE) estimates one of the most valuable markers of patient safety and excellent care: the true rate of preventable harm [20, 21].

Quality and Safety Aspects of Diagnosis and Treatment

DVT was historically diagnosed with invasive contrast venography, but in current practice, DVT is almost exclusively diagnosed with Duplex ultrasonography. Duplex ultrasound is safe, noninvasive, and relatively inexpensive. Similarly, invasive pulmonary angiography via right heart catheterization was historically employed to diagnose PE. This invasive, risky, and costly procedure has been replaced with contrast-enhanced computed tomography (CT) angiography for the diagnosis of PE. Current multidetector helical CT angiography allows highly accurate diagnosis of PE [72]. Furthermore, improvements in imaging modalities allow visualization of segmental and subsegmental pulmonary arteries, although the clinical importance of treating peripheral pulmonary emboli is not certain.

Other modalities utilized in the diagnosis of PE may include ventilation/perfusion scan (V/Q scan) or D-dimer assay. V/Q scan is a nuclear medicine test sometimes used to diagnosis PE in patients who are unable to undergo contrast-enhanced CT secondary to renal insufficiency or severe contrast allergy. D-dimer assay is commonly used in emergency department patients and outpatients to rule out VTE due to its high sensitivity. Fibrin D-dimer

measures the final product of the plasmin-mediated degradation of fibrin and is often elevated in patients with acute VTE. However, D-dimer is also common in many other conditions associated with fibrin production including malignancy, trauma, infection, inflammation, and the postoperative state. A negative D-dimer can help rule out the diagnosis, but a positive test is certainly not confirmatory for VTE, especially in hospitalized surgical patients. Both V/Q scan and D-dimer assay must be utilized in conjunction with a pretest probability assessment such as the Wells score or the Geneva score to be clinically useful.

The Choosing Wisely campaign from the American Board of Internal Medicine aims to decrease unnecessary healthcare expenditures and improve patient care [73]. Various medical societies identify the top five tests or treatments that are often ordered inappropriately or too frequently. The ACCP, in conjunction with the American Thoracic Society, has encouraged providers to "choose wisely" when ordering CT angiography to screen for PE. They caution: "Do not perform chest CT angiography to evaluate for possible pulmonary embolism in patients with low clinical probability and negative results of a highly sensitive D-dimer assay" [74].

Conclusions

VTE prevention provides a salient example for targeted interventions to improve healthcare quality and patient safety. VTE is associated with significant morbidity and mortality and in many, although not all, cases is preventable. Strategies to improve VTE prophylaxis must target the system of care to optimize risk assessment and prescription, administration, and acceptance of prophylaxis.

Key Points

- *VTE prevention* is a critical *patient safety practice* for all hospitalized patients.
- As many as 350,000–900,000 people each year in the USA will be harmed by VTE, and over *100,000 people will die* from VTE each year.
- National *annual expenditures* for treatment of VTE may be as high as *$10 billion*.
- *Post-thrombotic syndrome* is the most common long-term morbidity associated with VTE and may affect *over half* of patients with VTE.
- *Evidence-based guidelines for VTE prophylaxis* using pharmacologic and/or mechanical prophylaxis are available and widely disseminated.
- *Not all VTE events are preventable*, even with optimal prescription and administration of risk-appropriate prophylaxis.
- Improved *VTE prophylaxis decreases preventable harm* to patients.
- A true *benchmark of patient safety and quality care* should not focus on the incidence of VTE alone, without considering how frequently patients are prescribed and administered VTE prophylaxis according to best-practice guidelines.

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