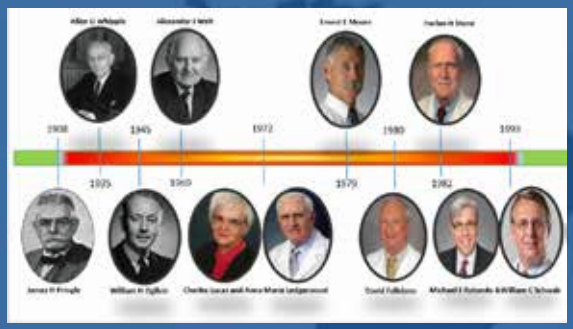
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Implementing Sustainable Systems for Achieving Excellence in Venous Thromboembolism Prevention

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Abstract
Venous thromboembolism (VTE) is a common preventable cause of morbidity and mortality in hospitalized patients. Despite robust guidelines and decades of data, there is still underperformance in three important aspects of defect-free VTE prevention. The objectives

of this perspective are threefold: first, to delineate the critical steps of risk-appropriate VTE prevention i.e., 1) risk assessment (balancing risks of VTE and bleeding), 2) prescription of risk-appropriate prophylaxis, and 3) reliable administration of all prescribed VTE prophylaxis doses. Second, to examine why existing systems fail to deliver consistent risk-appropriate care; and third, to propose a pragmatic and scalable accountability framework to close these gaps. Drawing from evidence and implementation science, we propose a system-wide strategy that integrates electronic clinical decision support, individualized clinician feedback, and targeted nurse-specific and patient-centered education to reduce missed doses. Sustained success will require institutions to integrate the evidence-based processes within system-level infrastructure, with ongoing surveillance and quality improvement.

Key words: Deep Vein Thrombosis, Pulmonary Embolism, Venous Thromboembolism, Quality Improvement, Patient Safety, Thromboprophylaxis

Introduction

Venous thromboembolism (VTE) comprising deep venous thrombosis (DVT) and pulmonary embolism (PE), is a serious and often fatal complication experienced by hospitalized patients.[1,2] Surgical patients, especially those with trauma, orthopedic surgery, or cancer, are among the highest-risk populations. The American Heart Association estimates that recent surgery accounts for approximately one-quarter of VTE events, with highly heterogeneous risk across demographic and clinical factors.[2,3]

Across the surgical population, symptomatic VTE is estimated at 1.6% in the early postoperative period, and as many as 56% of events are first detected following discharge.[2] Rates are estimated to be higher for emergency and some nonemergent procedures alike, and may be attributable to approach (laparoscopic versus open), duration and complexity.[2,4,5] The procedure-level data illustrate the gradient in VTE variation based on surgery type, for example, <0.1% after laparoscopic cholecystectomy, ≤4% after open small-bowel resection and ≤10% following emergency open total proctocolectomy.[4,5] The VTE risk after oncologic procedures is amplified by advanced staging and nonminimally invasive approach.[6] Additional risk factors include age, body mass index, previous VTE, reduced mobility, cardiopulmonary diseases,[7–9] and other clinical parameters.[9]

Prior to the implementation of routine VTE prophylaxis the downstream morbidity was substantial.[2,10] Post-thrombotic syndrome was noted in 30–50% of patients after proximal DVT, and chronic thromboembolic pulmonary hypertension in <4% of PE survivors within the first two years.[2,10] The burden on healthcare systems also aligns with the disability burden. Higher readmission rates and extended hospital stay have been associated with VTE, leading to increased resource utilization.[11,12] In the context of financial implications, the economic footprint is large. The direct medical costs are approximated at $12,000-$15,000 per patient in the first year and ≥$23,000 following complications.[2,10] The overall estimated cost for VTE in the United States is $7-10 billion.[2]

Current Guideline Consensus and Areas of Controversy

Consensus

Major societies including the American Society of Hematology, American College of Chest Physicians, and National Institute for Health and Care Excellence provide guidance on several key principles for VTE prevention in surgical patients.[1,3,4,8] This guidance converges on the need to stratify, balance measures between prophylaxis and bleeding risk and consider extended prophylaxis when post-discharge risk remains elevated.[1,3,4,8]

Individualized risk assessment using validated tools such as Caprini, Rogers, or a "bucket model" can help translate procedure class and patient factors into an actionable risk stratum.[1,3,4,8] For patients in the moderate or high-risk strata without a prohibitive bleeding profile, pharmacologic prophylaxis is routinely recommended.[1,3,13] When anticoagulation is contraindicated or deferred for immediate postoperative concern, mechanical prophylaxis using sequential compression devices is recommended. Importantly, the effectiveness of these devices is tied to adherence in use.[1,3] Combination therapy with pharmacologic and mechanical prophylaxis is appropriate for patients at the highest risk stratum when bleeding risk is acceptable.[1] Additionally, extended prophylaxis typically for up to 4 weeks is also recommended in surgical patients[1,3,4] similar to nonsurgical patients.[14]

Areas of Controversy

Despite broad consensus, meaningful gaps remain. There is a commonly held misbelief that ambulation alone provides effective VTE prophylaxis. Early mobilization remains desirable for recovery and cardiopulmonary

benefits, but it is not an adequate stand-in for pharmacologic or mechanical prophylaxis. Patients should not have pharmacologic VTE prevention withheld or discontinued solely because they are ambulating, absent of a competing contraindication.[15] Subspecialty risk stratification also remains debated with limited head-to-head comparisons.[3,4,8,16,17] Except for orthopedic and oncology, the ideal duration of prophylaxis is poorly defined and real-world adherence to extended prophylaxis varies.[18–20] Furthermore, unfractionated heparin or low-molecular weight heparin have been the mainstay of prophylaxis in hospitalized patients. However, newer data on the use of aspirin for prophylaxis is spreading from patients undergoing orthopedic joint replacement to other populations such as trauma.[21,22] The data from the PREVENT CLOT pragmatic, multicenter, randomized noninferiority trial, conducted in 21 trauma centers across North America demonstrated that aspirin was noninferior to low-molecular weight heparin for preventing mortality and symptomatic VTE in patients with a fracture. These findings support risk-appropriate, patient-specific strategies rather than universal heparin-based regimens.[21] Aspirin has been used for decades for VTE prophylaxis after joint replacement surgery. This paper now shows that aspirin is also effective for VTE prevention in the orthopedic trauma population.

System-Level Interventions Highlighting the Evidence and Impact

Risk-appropriate Prescribing Practices

The Johns Hopkins collaborative improved VTE prophylaxis by incorporating risk assessment and tools to assist frontline clinicians with prescribing VTE prophylaxis into everyday workflow.[23] Starting in 2005, a multidisciplinary team designed a paper checklist and then transitioned to a mandatory computerized provider order entry (CPOE) decision support tool that encouraged completion of risk stratification embedded within admission orders.[23,24] Early initiatives exposed barriers to adoption, informing transition to a decision support tool with auto-populated patient data, default risk-appropriate prophylaxis guidance, and a true mandatory function.[23] Performance was monitored via a database with routine feedback to services and individual clinicians. This full compendium was coupled with targeted education and local champions to maintain momentum. This effort resulted in a stepwise improvement from paper to electronic implementation i.e., risk-appropriate prophylaxis prescribing increased to 80% in surgery subspecialties and 92% on medicine services by 2011, and continuous improvements after dedicated feedback cycles were established.[23]

In a level-1 trauma service of the same hospital, the same CPOE-embedded decision support tool was evaluated. Risk-stratification documentation within 24 hours increased from 3.0% at baseline to 97.8% after implementation.[25] Risk-appropriate prophylaxis prescribing increased from 66.2% to 84.4%, with the largest improvements observed among patients without contraindications. Furthermore, preventable VTE significantly decreased from 1.0% to 0.17%.[25] Individualized performance feedback was provided to general surgery residents in the context of their individual VTE-prophylaxis prescribing practices. The results were robust, showing significant improvement in appropriate prophylaxis for patients admitted by general surgery residents, increasing from 78.1% to 93.9%.[26] A beneficial unintended consequence of this intervention was observed among advanced practice providers (nurse practitioners and physician assistants). Despite receiving no feedback, they significantly improved in their risk-appropriate prescribing practices from 75.1% to 84.9%.[26]

Frontline Nurses' Perspectives, Administration Practices and Education

The CPOE had unquestionably improved prescription of venous thromboembolism prophylaxis, yet a completed order did not guarantee a risk-appropriate dose was administered to the patient.[27] Patients were not receiving their prescribed doses of prophylaxis medications, even when prescribed appropriately. At the bedside, execution faltered for pragmatic and cultural reasons i.e., patients decline injections, ambulation is incorrectly considered as a waiver, transient clinical changes prompting ad hoc holds and competing tasks or handoffs that disrupted workflow. An early refusal may often cascade into inertia, with subsequent doses occasionally not offered. Additionally, documentation euphemisms such as "off unit" or "patient refused" can obscure true missed opportunities and unit-level cultures drove much of the variation in administration.[27]

We tackled this problem head-on by working with patients and other key stakeholders to create interventions to improve missed doses of prophylaxis in hospitalized patients. A cluster-randomized trial tested whether nurse-focused education, created and imple-

mented with buy-in from nurse leadership, could close the gap between risk-appropriate prophylaxis prescribing and administration practices.[28] There were improvements after implementation of the nurse-focused education module, with significant increases in administration of prescribed risk-appropriate VTE prophylaxis.[28] Our online nurse education module is freely available online via a collaboration with the Anticoagulation Forum (https://acforum.org/VTE-C1/story.html).

Missed Doses Remain a Pervasive Issue

Across hospitals a persistent gap remains between ordering and delivery, turning a preventable event into a predictable one.[29] At our institution, an audit revealed that 12% of prescribed doses of pharmacologic prophylaxis were not given and nearly 60% of these doses not administered were attributable to patient or family refusal.[29] Such refusals are often multifactorial i.e., may reflect transient discomfort, concern about injections or bruising, misconceptions about ambulation and uneven bedside communication.[27–30] Regardless of the cause, the clinical end point is identical as high-risk patients will remain at risk of VTE. Reframing nonadministration as a modifiable delivery failure rather than a fixed patient preference moved the attention from individual blame to system opportunities. We developed a patient-centered education bundle, co-developed by individual patients and organizational support from the National Blood Clot Alliance, providing opportunities for targeted patient communication and reliable bedside workflows that can convert more prescribed risk-appropriate prophylaxis doses into administered doses.

In a controlled implementation effort, we leveraged information technology within the electronic medication administration record that notified a dedicated health educator whenever a risk-appropriate prescribed prophylaxis dose was not given.[30] The educator first clarified the reason with the bedside nurse; if refusal was the driver, the patient received a brief one-time education bundle tailored to their preference including 1) a face-to-face conversation, 2) a two-page multilingual handout, and/or 3) a 10-minute video on a tablet. Content and delivery strategy were created and informed by a modified Delphi process with input from national thrombosis organizations, patient stakeholders, and a patient and family advisory council.[30,31] Despite the educator's part-time presence and delivery to only about one-third of eligible encounters, risk-appropriate VTE prophylaxis administration significantly improved. On intervention units, overall nonadministration significantly reduced from 9.1% to 5.6%, patient refusal decreased from 5.9% to 3.4%, and missed doses for other reasons also decreased from 2.3% to 1.7%.[30]

Mitigating Bias: An Unintended Consequence of Quality Improvement Initiatives

An important lesson from our implementation efforts is that robust, system-level quality improvement can mitigate and eliminate preexisting disparities while improving the standard of care at the bedside.[32–34] The mandatory CPOE increased overall adherence on surgical and medical services, and it also mitigated race-based disparities in risk-appropriate VTE prescribing.[32] Although it was not our primary goal, making the correct choice the default yielded a consequential byproduct of standardized care. Furthermore, subgroup analyses showed that the real-time patient-centered education bundle had comparable reductions in missed risk-appropriate VTE prophylaxis doses across race and sex groups, countering concerns that a technology-enabled, educator-mediated approach may preferentially be advantageous to certain groups.[33,34] Together, these studies highlight two important points. First, disparities are multifactorial and arise from defects across the care continuum i.e., variable clinician judgment at ordering and inconsistent bedside communication during administration. Second, a multidisciplinary, stakeholder-engaged design can mitigate disparities while improving care for all patients.

Success, Scaling, Dissemination, and Implementation Efforts

The successful implementation of these interventions at one academic center in our health system was achieved when three conditions were met: 1) visible leadership accountability (clear buy-in at the service and executive levels), 2) health informatics capacity, and 3) unit-based engagement (charge-nurse stewardship and bedside champions).[35,36] These interventions have subsequently been disseminated to a community hospital in our health system with comparable reductions in missed and refused doses.[36,37] These interventions were implemented at nine trauma centers that are part of the Coalition of Leaders in Thromboembolism study group (CLOTT-3), supported by the Patient-Centered Outcomes Research Institute and run through the Coalition for National Trauma Research.

Opportunities in Low- and Middle-Income Countries (LMICs)

Global inequities in VTE prevention are multifactorial and represent differences in healthcare infrastructure, economic resources, and slow adoption of evidence-based guidelines.[38] In a Vietnamese study, Nguyen and colleagues found that clinicians who understood the risk but underestimated the benefit, and failure to operationalize institutional protocols, were key barriers to the optimal adoption of VTE prevention strategies.[39] In contrast, a European cancer center demonstrated that risk-stratified protocols increased compliance to 91%, reducing postoperative VTE by nearly 80% and sustaining that success for years.[40] While these studies were performed in different settings and with varying institutional capacity, defect-free VTE prevention can be replicated globally. While local resources may differ in different countries, the pillars i.e., risk assessment, education, and operationalizing care do not. Moreover, training, stewardship, and protocols should be the minimum standard of patient safety individualized to match institutional capacity. VTE prophylaxis is cost effective and many of the medications routinely used are relatively inexpensive (i.e. heparin, aspirin).

In summary, our shared architecture is straightforward and can be adopted in different settings. First, defect-free care was a single shared aim which set the expectation and anchored measurement.[41] Second, real-time data capacity must be delivered to the people who can act on it (i.e., nurses see real-time nonadministration alerts, prescribers receive succinct performance reports, and unit leaders track compliance).[35] Third, persistent myth-busting is built into scripts and huddles, especially the misconception that ambulation obviates anticoagulation and the habit of converting a one-time refusal into a standing hold.[15,35] Sustainability followed from making the right action the path of least resistance. We used an implementation toolkit including standardized nurse education, and patient-education materials (freely available online in 13 languages at https://www.hopkinsmedicine.org/armstrong-institute/improvement-projects/vte), posters, badge cards for nurses, and monthly feedback loops embedded in routine leadership rounds.

Conclusion

We present our experience implementing patient-centered interventions directed at the most defect-prone areas in VTE prevention. Across all settings, whether at a tertiary or a community setting in high resourced or LMICs, the principles do not change. The evidence is strong enough to demand action in the context of performing standardized risk assessments, prescribing risk-appropriate prophylaxis, and ensuring every ordered dose is administered. When prevention is integrated into workflow, reinforced by culture, and upheld through accountability, the outcome transcends abstract improvement and becomes a tangible reduction of preventable VTE and the reaffirmation of what reliable care should look like.

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