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ORIGINAL RESEARCH

Improving Hospital Venous Thromboembolism Prophylaxis With Electronic Decision Support

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BACKGROUND: Venous thromboembolism (VTE) disease prophylaxis rates among medical inpatients have been noted to be <50%.

OBJECTIVE: Our objective was to evaluate the effectiveness and safety of a computerized decision support application to improve VTE prophylaxis.

DESIGN: Observational cohort study.

SETTING: Academic medical center.

PATIENTS: Adult inpatients on hospital medicine and nonmedicine services.

INTERVENTION: A decision support application designed by a quality improvement team was implemented on medicine services in September 2009.

MEASUREMENTS: Effectiveness and safety parameters were compared on medicine services and nonmedicine (nonimplementation) services for 6-month periods before and after implementation. Effectiveness was evaluated by retrospective information system queries for rates of any VTE prophylaxis, pharmacologic VTE prophylaxis, and hospital-acquired VTE incidence. Safety was evaluated by queries for bleeding and thrombocytopenia rates.

RESULTS: Medicine service overall VTE prophylaxis increased from 61.9% to 82.1% ($P < 0.001$), and pharmacologic VTE prophylaxis increased from 59.0% to 74.5% ($P < 0.001$). Smaller but significant increases were observed on nonmedicine services. Hospital-acquired VTE incidence on medicine services decreased significantly from 0.65% to 0.42% ($P = 0.008$) and nonsignificantly on nonmedicine services. Bleeding rates increased from 2.9% to 4.0% ($P < 0.001$) on medicine services and from 7.7% to 8.6% ($P = 0.043$) on nonmedicine services, with nonsignificant changes in thrombocytopenia rates observed on both services.

CONCLUSIONS: An electronic decision support application on inpatient medicine services can significantly improve VTE prophylaxis and hospital-acquired VTE rates with a reasonable safety profile. *Journal of Hospital Medicine* 2013;8:115–120. © 2012 Society of Hospital Medicine

Over 900,000 incident and recurrent venous thromboembolism (VTE) events occur in the United States each year, resulting in nearly 300,000 fatalities.[1] VTE, including deep vein thrombosis (DVT) and pulmonary embolism (PE), is among the most common causes of death in the United States, with more people dying annually from VTE than motor vehicle accidents and breast cancer.[2]

Accordingly, healthcare policy makers and regulators have placed greater emphasis on VTE prevention, including use of VTE prophylaxis measures in the Centers for Medicare and Medicaid Services (CMS) value-based purchasing (pay for performance) program and the Joint Commission's adoption of a national hospital patient safety goal related to anticoagulation therapy.[3,4] Beginning in 2008, VTE events following hip and knee procedures were included as 1 of 10 hospital-acquired conditions for which CMS would not pay for associated additional costs of care.[5]

A typical 300-bed hospital can expect roughly 150 cases of hospital-acquired VTE annually.[6] Up to 75% of these cases will occur on the medicine service, where nearly every patient has 1 or more VTE risk factor.[7] Although effective preventive modalities exist, prophylaxis rates among medical patients have been noted to be <50%.[8,9] While quality improvement interventions have been shown to be effective in improving compliance with VTE prophylaxis, there are few studies describing effectiveness of these interventions in electronic health record (EHR) environments.[10] As EHR implementation accelerates, it will be essential to define the strengths and limitations of various decision support approaches to optimally improve patient safety.

We sought to evaluate the effectiveness and safety of a computerized decision support application, which was designed as part of a quality improvement initiative to improve rates of VTE prophylaxis rates on the medicine services at 2 hospital sites.

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METHODS

Setting

The initiative was conducted at Montefiore Medical Center, an academic medical center in the Bronx, New York. This article describes results from an effort to improve inpatient VTE prophylaxis rates as part of an overall medical center initiative to improve anticoagulation management beginning in 2007. The initiative was led by an interdisciplinary committee consisting of administrators, medical and surgical physicians, nursing staff, and information technology and performance improvement personnel.

Intervention

As part of the initial quality improvement project, the group analyzed factors associated with and rates of hospital-acquired VTE. Among the findings was a predominance of hospital-acquired VTE cases and suboptimal rates of VTE prophylaxis on medicine services. Accordingly, the medicine service, whose discharge volume was 36,500 in 2010, was the population of focus for the improvement effort. The analysis also demonstrated a 99% agreement rate between administratively coded VTE events and VTE diagnoses verified from chart review, validating the utility of institutional administrative data for ongoing study of VTE events. As the hospital sites had computerized physician order entry, the group sought to develop an electronic clinical decision support module. The primary objective of the quality improvement effort was to increase VTE prophylaxis rates and decrease VTE incidence among medicine patients.

A range of clinical decision support approaches was explored. Based on team review, key decision support design objectives were to:

- Minimize alert fatigue
- Utilize existing clinical information system variables to:
  - Avoid de novo physician data entry solely to support the application
  - Automatically identify and exclude patients in whom pharmacologic VTE prophylaxis was contraindicated
- Utilize the 8th edition of the American College of Chest Physicians VTE guidelines[8] as a basis for recommendations (as the study was conducted prior to the 9th edition release)

The VTE decision support module was comprised of order sets with the following features:

- Patients were identified as on the medicine service based on admitting service designation.
- An order set was populated from this triggering mechanism offering pharmacologic VTE prophylaxis options, or alternately, options to document lack of a clinical indication for pharmacologic VTE prophylaxis, planned therapeutic anticoagulation, or contraindication to VTE prophylaxis.
- Alternate order sets were offered with mechanical VTE prophylaxis options if the physician indicated pharmacologic VTE prophylaxis was contraindicated or if the information system identified a clinical contraindication.
- If pharmacologic VTE prophylaxis was not prescribed, the rules logic was repeated every 5 days.

Analyses

The evaluation sought to assess the effectiveness and safety of the decision support module. VTE processes and outcomes for the 6-month periods immediately before and after full scale decision support go-live on September 9, 2009, were evaluated. This time window was chosen in relation to CMS' requirement that hospitals use ''present on admission'' codes for discharge diagnoses (including VTE) on October 1, 2007, and first implementation of a hospital-acquired condition policy on October 1, 2008.[5] The 6-month period prior to September 2009 was within the first calendar year where both CMS policies were in effect.

Effectiveness of the decision support module was measured by evaluating the proportion of medicine service discharges before and after module deployment who:

- Received any VTE prophylaxis modality
- Received a pharmacologic VTE prophylaxis modality
- Developed a hospital-acquired VTE

Successful receipt of any VTE prophylaxis modality was defined as use of compression stockings, pneumatic compression devices, or pharmacologic VTE prophylaxis modalities, including therapeutic anticoagulation (eg, mechanical heart valve). Medications counting toward the definition of pharmacologic agents included unfractionated heparin, dalteparin, warfarin, fondaparinux, lepirudin, argatroban, or bivalirudin, which are all on formulary at the medical center. Heparin used as an intravenous flush or associated with dialysis was excluded. Hospital-acquired VTE was defined by the numerator International Classification of Diseases, 9th Revision (ICD-9) discharge diagnosis codes for DVT or PE events as specified in the Agency for Healthcare Research and Quality (AHRQ) postoperative PE or DVT Patient Safety Indicator 12, and where the codes were not present on admission.[11]

Patient discharges excluded from analyses were those with patient age <18 years, length of stay 1 day or less, VTE diagnosis present on admission, or patient with an inferior vena cava filter during the stay. For evaluation of pharmacologic VTE prophylaxis, patients were additionally excluded if they had a platelet count <50,000/μL during their stay, were a neurosurgical patient, or had a discharge diagnosis that included gastrointestinal bleeding or coagulopathy.

TABLE 1. Rates of Any VTE Prophylaxis Ordering, Pharmacologic VTE Prophylaxis Ordering, and Hospital-Acquired VTE, Before and After Decision Support Module Implementation in Medicine Intervention and Nonmedicine Comparison services

	Medicine Service				Nonmedicine Services			
	Pre % (n)	Post % (n)	Relative Change	Significance	Pre % (n)	Post % (n)	Relative Change	Significance
Any VTE prophylaxis								
Eligible	N = 15,254	N = 15,065	N/A	N/A	N = 8566	N = 8162	N/A	N/A
Received	61.9 (9443)	82.1 (12,372)	+32.7%	$P < 0.001$	70.5 (6040)	73.6 (6010)	+4.4%	$P < 0.001$
Pharmacologic VTE prophylaxis								
Eligible	N = 14,768	N = 14,588	N/A	N/A	N = 7883	N = 7567	N/A	N/A
Received	59.0 (8712)	74.5 (10,869)	+26.3%	$P < 0.001$	59.3 (4677)	63.3 (4791)	+6.7%	$P < 0.001$
Hospital-acquired VTE incidence								
Susceptible	N = 15,254	N = 15,065	N/A	N/A	N = 8566	N = 8162	N/A	N/A
Developed	0.65 (99)	0.42 (64)	−34.5%	$P = 0.008$	0.82 (70)	0.72 (59)	−11.5%	$P = 0.486$

NOTE: **Abbreviations**: N/A, not applicable; Post, after decision support module implementation; Pre, before decision support module implementation; VTE, venous thromboembolism.

The safety of the decision support application was measured by assessing the proportion of medicine service discharges before and after decision support deployment who developed bleeding or thrombocytopenia. Bleeding was defined as receipt of 1 or more packed red blood cell units following administration of an anticoagulant medication at a VTE prophylaxis dosage range. Exclusion criteria for bleeding evaluation were patients aged <18 years, with length of stay 1 day or less, VTE diagnosis present on admission, platelet count <50,000/μL during the stay, were a neurosurgical patient, or had diagnoses of anemia, hematologic malignancy, or inferior vena cava filter during the stay, or diagnoses of gastrointestinal bleeding, hemorrhage, or hematoma on admission.

Thrombocytopenia was defined as a >50% decrease from the initial platelet count during the hospital stay, or a decrease from an admission platelet count of >100,000/μL to <100,000/μL during the hospital stay. Criteria for exclusion from these analyses were age <18 years, length of stay 1 day or less, diagnosis of VTE present on admission, and vena cava filter during the stay.

A medical center comparison group was defined to contrast the magnitude of change in study end points on medicine services where the intervention was deployed with the change on other services where decision support was not used, and to distinguish potential changes observed on medicine services from secular trends. The comparison group consisted of discharges from cardiology, cardiothoracic surgery, family medicine, general surgery, surgical subspecialty, oncology, psychiatry, and rehabilitation medicine services. Newborn, neurosurgery, obstetrics, and pediatrics service discharges were excluded from the comparison group because of their being at low risk for VTE or in a high-risk group in whom pharmacologic VTE prophylaxis was frequently contraindicated. All parameters described above were evaluated in the comparison group using inclusion and exclusion criteria similar to the intervention group. Outcomes (hospital-acquired VTE, bleeding, thrombocytopenia) were assessed similarly across index admissions and readmissions.

The significance of change in rates of prescribing, VTE incidence, and adverse event occurrence, were tested by comparing event proportions before and after decision support module implementation in both groups. As all variables were categorical, significance was assessed using 2-sided Pearson χ^2 tests at an α level of 0.05. Statistical analyses were performed using SPSS software (IBM, Armonk, NY). This project was reviewed by the Albert Einstein College of Medicine/Montefiore Medical Center institutional review board (protocol number 12-02-058X) and deemed exempt. Design of the decision support module and definition of the implementation and evaluation plan required approximately 1 year of monthly interdisciplinary team meetings and 200 hours of programmer development time.

RESULTS

Table 1 compares the effectiveness of the decision support module intervention in medicine intervention and in nonmedicine (nonintervention) services. Among medicine service patients, any VTE prophylaxis ordering increased from 61.9% to 82.1% ($P < 0.001$), and pharmacologic VTE prophylaxis increased from 59.0% to 74.5% ($P < 0.001$). Smaller but significant increases were observed on nonmedicine services. Hospital-acquired VTE incidence on medicine services decreased significantly, from 0.65% to 0.42% ($P = 0.008$) and nonsignificantly on nonmedicine services.

Table 2 shows ordering patterns for major VTE prophylaxis modalities. Among eligible medicine service patients, rates of low molecular weight heparin prophylaxis increased from 13.0% to 23.7% ($P < 0.001$), and of unfractionated heparin prophylaxis from 35.1% to 40.7% ($P < 0.001$). On nonmedicine services, there was no significant change in low molecular weight heparin use, and unfractionated heparin use increased significantly from 37.2% to 40.9% ($P <$

TABLE 2. Rates of Ordering of VTE Prophylaxis Modalities Included in the Medicine Service Decision Support Module in Medicine Intervention and Nonmedicine Comparison Services

	Medicine Service				Nonmedicine Services			
	Pre % (n)	Post % (n)	Relative Change	Significance	Pre % (n)	Post % (n)	Relative Change	Significance
Eligible for pharmacologic VTE prophylaxis	N = 14,768	N = 14,588	N/A		N = 7883	N = 7567	N/A	
Low molecular weight heparin	13.0 (1922)	23.7 (3463)	+82.4%	$P < 0.001$	15.3 (1206)	15.9 (1204)	+4.0%	$P = 0.294$
Unfractionated heparin	35.1 (5181)	40.7 (5936)	+16.0%	$P < 0.001$	37.2 (2932)	40.9 (3093)	+9.9%	$P < 0.001$
Warfarin	10.8 (1594)	10.0 (1461)	−7.2%	$P = 0.029$	6.8 (532)	6.4 (483)	−5.4%	$P = 0.359$
Other agent	0.1 (15)	0.1 (9)	−39.3%	$P = 0.232$	0.1 (7)	0.2 (11)	+63.7	$P = 0.303$
Mechanical prophylaxis or did not receive	41.0 (6056)	25.5 (3719)	−37.8%	$P < 0.001$	40.7 (3206)	36.7 (2776)	−9.8%	$P < 0.001$

NOTE: **Abbreviations**: N/A, not applicable; Post, after decision support module implementation; Pre, before decision support module implementation; VTE, venous thromboembolism.

0.001). Proportions of patients receiving mechanical prophylaxis or not receiving prophylaxis decreased significantly by 37.8% on medicine services and by 9.8% on nonmedicine services Table 3 shows the safety of the decision support module. Bleeding rates increased on medicine services from 2.9% to 4.0% ($P < 0.001$) and on nonmedicine services from 7.7% to 8.6% ($P = 0.043$). Nonsignificant changes in thrombocytopenia rates were observed on both services.

DISCUSSION

Following implementation of a computerized decision support application to improve VTE prophylaxis on 2 hospital medicine services, we observed a significant increase in the rate of overall and pharmacologic VTE prophylaxis use and a significant decrease in the incidence of hospital-acquired VTE. Changes were of greater magnitude and significance on medicine services where the intervention was deployed.

Rates of any VTE prophylaxis and pharmacologic VTE prophylaxis ordering on medicine services increased significantly by 32.7% and 26.3%, respectively. These rates increased on nonmedicine comparison services by a more modest 4.4% for any VTE prophylaxis and 6.7% for pharmacologic VTE prophylaxis. Although the medicine service intervention was designed to be agnostic to the type of prophylactic heparin preparation, the intervention resulted in a significant 82.4% increase in low molecular weight heparin use and a significant 16.0% increase in unfractionated heparin use. With respect to outcomes, we observed a 34.5% decrease ($P < 0.001$) in hospital-acquired VTE incidence on medicine services and a nonsignificant decrease on nonmedicine services.

In assessing intervention safety, increased usage of VTE prophylaxis was not accompanied by an increase in thrombocytopenia, but was associated with an increase in bleeding from 2.9% to 4.0% ($P < 0.001$) on medicine services and from 7.7% to 8.6% ($P = 0.043$) on non-medicine services. As our intervention was a quality improvement project, we conducted a brief post hoc analysis to evaluate the increased bleeding rate on the medicine service following intervention. A random sample of 50 records of medicine patients who had received VTE prophylaxis and had a subsequent bleeding event was reviewed. Findings are summarized in Table 4. Prophylaxis was used appropriately in 100% of cases. Bleeding episodes were minor in that no case required more than 2 U of packed red blood cells. The most common clinical scenario was a patient with baseline anemia, typically with chronic kidney disease, who had a slight decrease in hematocrit of unclear etiology requiring 1 U of blood.

Although the intervention occurred on medicine services, favorable albeit smaller changes were observed on nonmedicine services. We expected this favorable secular trend because of VTE prophylaxis awareness efforts across the organization as a whole. There was also ongoing focus on VTE prevention and outcomes by policymakers, regulatory agencies, and professional societies during the time period of

TABLE 3. Rates of Bleeding and Thrombocytopenia Before and After Decision Support Module Implementation in Medicine Intervention and Nonmedicine Comparison Services

	Medicine Service				Nonmedicine Services			
	Pre % (n)	Post % (n)	Relative Change	Significance	Pre % (n)	Post % (n)	Relative Change	Significance
Bleeding								
Susceptible	N = 13,614	N = 13,445	N/A		N = 7372	N = 7061	N/A	
Developed	2.9 (401)	4.0 (534)	+34.8%	$P < 0.001$	7.7 (565)	8.6 (606)	+12.0%	$P = 0.043$
Thrombocytopenia								
Susceptible	N = 15,254	N = 15,065	N/A		N = 8566	N = 8162	N/A	
Developed	7.4 (1123)	6.9 (1047)	−5.6%	$P = 0.164$	8.7 (749)	8.8 (716)	+0.3%	$P = 0.948$

NOTE: **Abbreviations**: N/A, not applicable; Post, after decision support module implementation; Pre, before decision support module implementation; VTE, venous thromboembolism.

TABLE 4. Characteristics of Patient Bleeding Episodes Among Medicine Service Patients Associated With Pharmacologic VTE Prophylaxis in the Period Following Deployment of Electronic Decision Support

Characteristic	% (N = 50)
Prophylaxis indication	
Pharmacologic VTE prophylaxis indicated*	100.0
Clinical characteristic	
Anemia upon admission	92.0
Chronic kidney disease	66.0
Suspected bleeding source	
Unclear	62.0
Gastrointestinal	18.0
Catheter/external device site	8.0
Operative	6.0
Epistaxis	4.0
Gynecologic	2.0
Medication use	
Prophylactic agent associated with bleeding	
Unfractionated heparin	66.0
Dalteparin	34.0
On antiplatelet agent at time of bleed†	52.0
Transfusion outcome	
Required >2 packed red blood cell units	0.0

NOTE: **Abbreviations**: VTE, venous thromboembolism.
*Pharmacologic VTE prophylaxis indicated based on presence of 1 or more clinical risk factors and lack of contraindication to pharmacologic agent at time of ordering.
† Antiplatelet agent = aspirin or clopidogrel.

study.[3–5,12] Public reporting of CMS inpatient surgical VTE prophylaxis measures was required throughout the study period.[13] Changes observed on medicine services occurred during a period where there were no publicly reported measures of VTE prophylaxis for inpatient medicine services.

Our study had several limitations. We derived our eligibility criteria for VTE prophylaxis based on administrative data. To address this, we incorporated accepted standardized definitions,[11] used clinical data elements in our queries beyond ICD-9 codes (eg, platelet count), and applied pertinent exclusion criteria (eg, length of stay 1 day or less). VTE events that were present on admission were excluded from analyses. However, as these community-acquired VTE events may be caused by inadequate VTE prophylaxis during a prior hospitalization, the overall true incidence of hospital-acquired VTE was likely underestimated.

With respect to the hospital-acquired VTE outcome, we did not distinguish superficial from deep VTE. A consistent AHRQ definition of 13 ICD-9 VTE codes was used to identify clinically significant VTE events for the periods before and after the intervention. Although the present on admission code identified VTE events that were hospital acquired, 1 new acute VTE ICD-9 code was added in October 2009, allowing for more specific coding of acute, isolated, upper extremity VTE. Accordingly, our postintervention hospital-acquired VTE rate may have slightly underestimated the true hospital-acquired VTE incidence by omitting some coded acute, isolated, upper extremity VTE cases (if not coded using the prior "Other" VTE codes). In a study in a teaching hospital setting, isolated upper extremity VTE accounted for up to 21% of all symptomatic VTE events among adults.[14]

With respect to VTE prophylaxis, the study evaluated use in a dichotomous fashion but did not assess appropriateness, or adequacy of dosing of pharmacologic agents. We did not employ the intervention in a randomized fashion on the medicine service. As our project was a quality improvement intervention, we used a concurrent control group of nonmedicine service patients to assess potential secular trend bias.

With respect to the safety of the intervention, the record review we performed supported the appropriateness of prophylaxis use following the intervention, but was not designed to establish whether the increase in prophylaxis use was the proximate cause of bleeding events observed. Similarly, as specific testing for heparin-induced thrombocytopenia was not used, the lack of significant change in thrombocytopenia rates before and after the intervention cannot directly establish the intervention's safety. Finally, our study also included only in-hospital end points.

The rate of VTE prophylaxis use in hospitals has been noted to be disappointing.[15] Two large multinational studies found that VTE prophylaxis rates in at-risk hospitalized medical patients in the United States were 48% and 52%.[9,16] Amin and colleagues found the overall rate of VTE prophylaxis among 227 US hospitals to be 62%.[17] Accordingly, our intervention, which resulted in an 82% compliance rate on a large medical service and was associated with a significantly reduced VTE incidence, appears to be highly effective. Our results are likely more favorable in that beyond length of stay criteria, we did not exclude less acutely ill medical patients from analyses.

Michota summarized quality improvement studies for VTE prevention.[10] Among 9 studies attempting to improve VTE prophylaxis, 2 used electronic decision support as a primary strategy, and only 1, by Kucher et al., used a computerized approach on a medical service.[18] This study showed significant improvement in VTE prophylaxis and incidence in patients randomized to a provider computer program. The intervention was complex, requiring specification of 8 patient-level risk factors via a customized database, and the physician to recommend specific prophylactic regimens accordingly. Our findings, using a more basic approach, similarly support the effectiveness of using automated decision support, which can be readily modified as evidence-based guidelines evolve.

Overall adoption of information technology systems in US hospitals is low: only 7.6% of hospitals have a basic system, and 17% have computerized physician order entry.[19] As hospitals have been financially incentivized to adopt such systems, our relatively simple intervention may prove to be readily generalizable

across varied vendor systems.[20] The intervention involved order sets triggered by automated logic, corollary information, and a hard stop to prompt VTE prophylaxis. Within the context of intensified emphasis on reducing harm in the inpatient setting and various pay for performance programs, our intervention is also of importance to payers.[3,5] Using national data in year 2000, Zhan and Miller calculated the excess charges per case associated with VTE to be $21,709.[21]

In conclusion, a relatively simple automated clinical decision support application significantly improved rates of VTE prophylaxis and was associated with significantly lower hospital-acquired VTE incidence in hospitalized medicine patients, with a reasonable safety profile.

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