VENOUS THROMBOEMBOLISM PROPHYLAXIS ELECTRONIC HEALTH RECORD IMPLEMENTATION TOOLKIT AND SAMPLE PROJECT

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A CAPSTONE

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Abstract

Statement of Problem

Venous Thromboembolism (VTE) is a blot clot that can develop in hospitalized patients that can cause significant morbidity and mortality. Venous Thromboembolism Prophylaxis (VTE-P) seeks to prevent these blood clots in hospitalized patients through chemical or mechanical means. However, the process of achieving consistent and correct VTE-P is often difficult to achieve. Lahey Hospital and Medical Center (LHMC) sought in 2017 to reduce HAVTE rates after noting 22 cases in one year. Hospital administration asked IT for assistance in creating solutions to improve Hospital Acquired VTE (HA-VTE) outcomes.

Brief Description of Work

The project begins with a literature review to establish best IT practices in VTE-P. These recommendations are summarized in the “20 Commandments for VTE Prophylaxis”. In addition, we describe in detail the IT changes required to support quality improvement. These changes include: risk stratification changes, order sets, patient lists/reports, and alerts.

Results

Similar groups of encounters from 2018 and 2019 were compared with over 50,000 inpatient encounters in each group. The number of HA-VTE cases had begun to fall from 22 to 17 cases/year. In addition, Heparin Induced thrombocytopenia (HIT), a known complication of additional chemoprophylaxis, did not increase changing from 12 to 11 cases. However, the primary process measure, days covered by chemoprophylaxis, did not change from 74.5% to 73.5% year over year.

Conclusions

The project described largely adhered to the 20 Commandments literature based guidelines except guidelines creation and education support plus some IT aspects such as early process measures and dashboards. The project was considered successful from an outcomes perspective but the process measures incompletely supported this. The overall goal is that other implementers can use the evidence based guidelines and IT build described here to support or improve local implementations.

Introduction

Venous Thromboembolism (VTE) is the formation of blood clots in large veins of the body. This can have many causes including immobility, clotting disorders, medications, smoking, obesity, age and cancer. These blood clots can cause significant morbidity and mortality, the risk of which can be reduced by administration of certain medications to prevent blood clots known as anticoagulants. [1]

Venous Thromboembolism Prophylaxis (VTE-P) is the prevention of blood clots and is considered a national patient safety imperative by many US healthcare and patient safety organizations including Center for Medicare and Medicaid Services (CMS), Agency for Healthcare Research and Quality (AHRQ) and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). VTE is a leading cause of increased cost, length of stay, and preventable death in hospitalized patients.[1] Specifically, postoperative hospital acquired VTE is the second most common hospital-acquired complication. 50% of all VTEs are associated in some way with hospitalization.

Guidelines for VTE-P have been available for many years and include guidance from professional societies such as the American College of Chest Physicians and the American Society of Hematology.[2, 3] The two sets of guidelines are primarily in alignment but differ somewhat in the types of medications suggested under specific settings. The general information in the guidelines represents professional consensus but consistent deployment of these guidelines within many hospitals is lacking.

Given the discrepancies between professional guidelines as above, hospitals must produce local expert guidelines to support local quality improvement. These guidelines must be completed before efforts are made to improve quality, particularly in Electronic Health Record (EHR) settings where clinical decision support (CDS) efforts need to match local consensus. Unfortunately many hospitals lack appropriate subject matter experts who are able to modify guidelines for local use.

Risk stratification is a key component of VTE-P as prophylaxis varies based on risk level. Patients at low risk may not receive chemical prophylaxis but patients at highest risk may receive chemical and mechanical prophylaxis. The majority of hospitalized patients have risk factors and should receive prophylaxis. Risk factors in this case include: surgery, acute medical illness, cancer, trauma, immobilization, indwelling catheters, age, and obesity.[1]

System wide interventions can be deployed to bridge this gap between guidelines and implementation in an effort to mitigate risk. The interventions could be considered active, passive, or multifaceted. Passive strategies include: distribution of guidelines, audit and feedback, and preprinted orders either on paper or electronic health record versions (EHR). Active strategies include human or computer based real-time alerts. Multifaceted interventions include some combination of education, feedback, and alerts.[1]

This review will focus on IT and EHR based clinical decision support (CDS) as a means to bridge the gap between guidelines and clinical practice. Successful interventions will be described in 5 categories: risk stratification, order sets, alerts, comprehensive models, and summative recommendations. (See appendix for the summary of studies referenced in this paper.) In addition, a specific complete local implementation will be described. The goal is that this toolkit along the example described will be considered a useful resource for local implementers to improve VTE outcomes.

Literature review

Risk Stratification

VTE risk stratification is the process of assigning a risk of Hospital Acquired Venous Thromboembolism (HA-VTE) in a patient who does not yet have a VTE. Prevention is generally prescribed based on risk level. Patients at low risk are often encouraged to walk. Intermediate risk patients may be prescribed a low dose of a blood thinner to prevent clots. High risk patients may be given a higher dose of a blood thinner or be prescribed compression boots in addition to medications. Accurate risk stratification needs to be trusted by providers and seamlessly support prophylaxis decisions.

There are two primary models for risk stratification: Caprini and Padua.[4] Both of the scoring systems use similar concepts of risk including age, malignancy, medications and immobility but the Caprini evaluates 40 variables compared to 11 in the Padua score. The sensitivity and predictive value of the Caprini was superior while the specificity was higher in the Padua score. Both scores were created in the pre-EHR era and are difficult to translate directly into automated systems.[4]

Baseline features	Score
Active cancer[a]	3
Previous VTE (with the exclusion of superficial vein thrombosis)	3
Reduced mobility[b]	3
Already known thrombophilic condition[c]	3
Recent (≤1 month) trauma and/or surgery	2
Elderly age (≥70 years)	1
Heart and/or respiratory failure	1
Acute myocardial infarction or ischaemic stroke	1
Acute infection and/or rheumatological disorder	1
Obesity (BMI ≥ 30)	1
Ongoing hormonal treatment	1

BMI: body mass index; VTE: venous thromboembolism.
[a]Patients with local or distant metastases and/or in whom chemotherapy or radiotherapy had been performed in the previous 6 months.
[b]Bed rest with bathroom privileges (either due to patient's limitations or on physician's order) for at least 3 days.
[c]Carriage of defects of antithrombin, protein C or S, factor V Leiden, G20210A prothrombin mutation, antiphospholipid syndrome.

Figure 1

Padua Risk Assessment[4]

Risk factors	Score
Age 41–60 years	1
Minor surgery planned	1
History of prior major surgery (<1 month)	1
Varicose veins	1
History of inflammatory bowel diseases	1
Swollen legs (current)	1
Obesity (BMI ≥ 25)	1
Acute myocardial infarction	1
Congestive heart failure (<1 month)	1
Sepsis (<1 month)	
Serious lung disease incl. pneumonia (<1 month)	1
Abnormal pulmonary function (COPD)	1
Medical patient currently at bed rest	1
Other risk factors ________________	1
Age 60–74 years	2
Arthroscopic surgery	2
Malignancy (present or previous)	2
Major surgery (>45 min)	2
Laparoscopic surgery (>45 min)	2
Patient confined to bed (>72 h)	2
Immobilizing plaster cast (<1 month)	2
Central venous access	2
Age over 75 years	3
History of DVT/PE	3
Family history of thrombosis[a]	3
Positive Factor V Leiden	3
Positive Prothrombin 20210A	3
Elevated serum homocysteine	3
Positive lupus anticoagulant	3
Elevated anticardiolipin antibodies	3
Heparin-induced thrombocytopenia (HIT)	3
Other congenital or acquired thrombophilia	3
If yes: Type ________________	
Elective major lower extremity arthroplasty	5
Hip, pelvis or leg fracture (<1 month)	5
Stroke (<1 month)	5
Multiple trauma (<1 month)	5
Acute spinal cord injury (paralysis) (<1 month)	5
For women only	
Oral contraceptives or hormone replacement therapy	1
Pregnancy or postpartum (<1 month)	1
History of unexplained stillborn infant, recurrent spontaneous abortions (≥3), premature birth with toxaemia or growth-restricted infant	1
Total risk factor score	

Figure 2

Caprini Risk Assessment[4]

Multiple authors describe the challenges of VTE risk stratification in EHRs as below. Some of the challenges described include manual versus automated scoring and the complexity of scoring models deployed. In addition, workflow issues around creation and review of the risk score will be described.

Maynard et al described validation of a simplified VTE risk model manually entered by the user.[5] The group described a prospective longitudinal study where they follow adult inpatients for three years between 2005 and 2007. Initial efforts at UC-San Diego rejected traditional points-based scoring systems in favor of a simplified model that could be completed by providers and quickly implemented in order sets. Attempts were made to keep the process as simple as possible to drive compliance. Patients at risk were given either unfractionated (UFH) or low molecular weight heparin (LMWH). Mechanical methods such as intermittent pneumatic compression (IPC) were ordered for those with contraindications to chemical prophylaxis or as an adjunct in those at highest risk.

This new protocol was then applied to each admission and transfer order set. VTE risk level selection was a required component of the order sets and once a risk level was selected only appropriate choices were presented. Upon later review of the tool only 4% were in the low risk category while 12% were highest risk with 84% in moderate risk category.

Outcomes demonstrated that adequate prophylaxis improved year over year from 58% at baseline to 78% in 2006 and 93% in 2007. Specifically, the change was most pronounced in the large moderate risk group that improved from 53% to 93% over 2 years. The largest jump in compliance was with the rollout of the order set in 2006. The first year after implementation of the order set showed a 39% relative risk reduction in HA-VTE. HA-VTE means that the VTE was not present on admission to the hospital but still diagnosed during the hospital stay. The authors attributed success to a simplified risk assessment strategy and required order set processes. This study demonstrated that a simple manually entered score can improve outcomes.

Elias et al studied potential automation of the Padua risk score using EHR data.[6] They note that the American College of Chest Physicians 9th edition guidelines recommend the Padua Prediction Score (PPS) as the best method to assess risk.[2] Previous studies noted that consistent use of the score can reduce mortality due to VTE after hospitalization. However, this score was difficult and time consuming to calculate manually.

Elias's group created an Automated Padua Prediction Score (APPS) that calculated the data based on prior encounters and the first 4 hours of the current encounter. The goal was to compare the performance of the automated score to a score created at admission by a provider. The APPS calculated a score between 0 and 20 based on lab results, orders, nursing flowsheets and claims data. APPS was compared with manual abstraction on 300 patients.

Designation of prophylaxis group by PPS or APPS was in agreement in 97.5% of cases. There was no significant difference in mean between PPS (5.1) and APPS (5.5). APPS had an AUC of 0.79 for prediction of hospital acquired events versus 0.76 for manual calculation.

They conclude that automated calculation of risk score was equivalent to manually created scoring in prediction of HA VTE. This had the potential to reduce the burden of VTE prophylaxis and increase compliance with correct and appropriate prophylaxis. Even though the accuracy for specific components of the Padua varied between the systems the overall accuracy was quite similar. The automated system was better at review of historical records, such as prior VTE, whereas the manual system was superior at determining whether a diagnosis was currently active.

In summary, risk scoring is needed to support VTE-P interventions based on either manual or automated processes. However, automated EHR processes improve efficiency and help support compliance better than manual data entry. Automated processes can realistically be deployed in EHRs and accepted by providers.

Order Set Integration

Order sets are collections of orders in an electronic system designed to help facilitate a process. In the EHR setting, order sets can support an activity, such as admission, transfer or discharge or focus on a specific disease process. Often order sets can be combined such as when a user is admitting a patient for pneumonia. In this case the user may want to use an admission order set here and combine it with a pneumonia order set. The admission order set includes processes that must be evaluated with all hospital admissions such as VTE-P while the pneumonia order set contains orders such as antibiotics that are more specific to a specific disease.

First question is whether order sets can function as effective clinical decision support for VTE-P. Assuming the answer is yes based on studies described below, effective strategies to build these order sets will be described to maximize effectiveness. These strategies include medication suggestions based on risk level, support for all possible workflows, and mandatory order completion in order to proceed (also known as “hard stop” requirements). In addition, evidence exists that VTE-P CDS can also help close race and gender-based care gaps.[7]

O’Connor et al (2009) sought to establish the benefit of admission order sets to improve VTE-P compliance.[8] The group noted that at that point order sets had been used successfully to improve process measures for acute MI and asthma but the scope of such research was limited. The goal of the research group was to create paper-based order sets to increase compliance with VTE-P on admission. At that point most hospitals in North America had not yet implemented EHRs. The group created new order sets for common diagnoses such as pneumonia, chronic obstructive pulmonary disease, and urinary tract infection. Orders on these sets were either pre-checked (could be crossed out) or unchecked.

On rollout of the order sets they were suggested but not mandatory. Providers still had the option of creating admission orders on blank order sheets. There was no specific education on how to use the sets or about VTE-P in general. Chart abstraction was performed over three different time periods to assess VTE-P compliance and how consistently patients were covered during inpatient days.

Results indicated that order set use increased to 51.6% in the third period of measurement. VTE-P orders increased from 10.9% pre intervention to 44% post intervention. There was minimal difference in the control group. However, these changes only represented 25.8% of patient days covered. Finally, the group noted that despite no requirement to do so 92.6% of patients were admitted with order sets in the fourth and last phase of measurement.

They noted that order sets are better integrated into workflow than alerts and should be the preferred strategy to catch most cases. However, alerts may be needed to achieve the highest levels of compliance. Given the changing nature of a patient's clinical status over the period of an admission the alert must be capable of reevaluating VTE-P status on a regular basis over the course of the stay.

Maynard (2009) criticized this work on a number of levels. Initially noted was that the authors did not assess the appropriateness of VTE-P, just whether it was administered or not.[9] In addition, VTE outcomes and side effects of medications were not presented.

Dr. Maynard noted that there was no institution wide VTE protocol established by consensus based on risk stratification. This would include contraindications and recommendations based on risk level that did not exist here. In addition he suggested that order set based CDS is only successful when order sets are mandatory. In his opinion, if order sets are designed well clinicians will use them because they will save time. Additional recommendations included education plus audit and feedback.

Maynard presented his own work on order sets in 2010.[5] A standardized module for VTE-P was developed and integrated into multiple order sets. This included risk stratification, opt outs, and suggestions based on risk levels. The orders were mandatory. This strategy led to 93% of patients on adequate prophylaxis. They noted that multiple interventions were deployed but the biggest single intervention improvement was VTE-P integration into order sets, which increased compliance overnight to 80%. In addition, a 39% reduction in HA-VTE was noted in the year following the order set rollout.

Bhalla (2013) expanded the discussion on order sets by expanding workflow options and adding hard stops.[10] This research group created an order set including VTE chemoprophylaxis, opt outs for chemoprophylaxis, low risk status, and therapeutic anticoagulation. The goal was that all possible workflow steps for all risk levels could be documented from within the order set including a hard stop workflow. This meant that the order set could not be signed without filling out the VTE-P section. Mechanical options were offered if the patient was high risk but could not receive chemoprophylaxis. The authors concluded that a relatively simple automated solution with support for all workflows and hard stops improved compliance, and reduced HAV-VTE without an unacceptable increase in bleeding rate.

Lau (2017) evaluated the potential of CDS to reduce race-based disparities in VTE-P ordering.[7] The group at Johns Hopkins Hospital noted race-based disparities between black and white populations that they were unable to fully explain but mention the role of implicit bias. Specifically, they noted that black trauma patients at their institution were more likely to receive appropriate VTE-P than white trauma patients (70.1% appropriate versus 56.6% respectively).

The group developed order sets that required completion of checklists of VTE and bleeding risk factors. Based on the risk cohort the system suggested appropriate prophylaxis. This recommendation was not a hard stop. For internal medicine patients pre intervention VTE-P was more common in black than white patients (69.5% vs. 61.7%). After implementation compliance improved for both cohorts and performance aligned in black and white populations (91.8% and 88.0% respectively.)

Order sets are considered to be the cornerstone of VTE-P process improvement as they are well accepted by clinicians and can create correct initial orders rather than creating a correction process based on an alert later. Order sets best improve compliance combined with education but can still be effective without. Orders also need to include opt out reasons and suggestions based on level of risk. Order sets and order set sections need to be mandatory. Lastly, order sets can standardize care and mitigate race-based care disparities.

Alerts

Within EHRs, alerts are notifications to the end user, generally based on objective and patient specific criteria, that suggests a possible course of action based on the data evaluated. These alerts can be “passive” meaning that they are visible on the screen but do not interrupt workflow, or “active” which means they may pop-up and interrupt the originally intended workflow step. An example for VTE might be an alert that pops up if the patient has a high VTE risk score but is not on chemical prophylaxis.

Most clinicians prefer decision support in order sets rather than based on alerting due to the idea of getting the order correct initially versus fixing the order after placement when you may have moved on to a different task (local experience). Even though alerts are more bothersome than order sets they are still needed to catch incorrect initial orders or patients who have been discontinued from anticoagulation inappropriately or not restarted after a contraindication has passed. However, many clinicians find alerts burdensome as they often ask the user to perform a task that either the user does not agree with or is lower priority than the task that was originally intended by the user. The below examples provide different workflows but all of them provide a patient monitoring functionality that cannot be performed by admission order sets.

Piazza (2009) reviewed previous literature in cardiovascular medicine including CDS for VTE prophylaxis.[11] They conclude that VTE-P is a prime example of a clinical problem that can benefit from CDS. This is based on the idea that risk assessment and chemoprophylaxis has established consensus based guidelines that can be objectively recreated in an EHR. Evidence supports improvement in patient safety outcomes and reduction in costs with well-designed alerts.

Durieux (2000) created an early CDS system to create correct postoperative VTE-P orders and also provide alert based feedback if orders were incorrect.[12] The group created a standalone CDS system in the late 1990s to be used postoperatively to improve compliance and reduce postoperative VTE. This system combined patient specific factors with those specific to the procedure performed. All of the patient and procedure specific data needed to be entered into the system by the provider. Prophylaxis was then suggested by the system based on risk. If there was a discrepancy between the risk level and the orders the user was notified via an alert. The user could then continue or change the order.

The authors note that the computer system was used in 100% of patients who had surgery during the study period. VTE-P guideline compliance improved during the intervention period from 82.8% to 94.9%. They note that three VTE events were noted during the control period but none during the intervention period. The overall conclusion in this pre EHR study was that well designed CDS alerts can improve compliance and outcomes after initial ordering.

Sobieraj (2008) at Hartford Hospital created a system to remind providers to use VTE-P in patients at risk but this time embedded in the native EHR.[13] Starting at a baseline compliance of 49%, the goal was that patients without contraindications and at least 1 risk factor would be on chemoprophylaxis and others with contraindication and risk would be on mechanical. The message created would display post admission if a patient was not ordered for prophylaxis and suggest the need for risk stratification based on at least one known risk factor.

VTE-P improved from 49% to 93% post-intervention. Rates of inappropriate mechanical prophylaxis decreased from 11% to 3%. Also patients with contraindications to chemoprophylaxis received mechanical prophylaxis 100% of the time after. This study demonstrated that even a simple reminder can improve compliance even without complex support for risk stratification in the EHR setting.

Mathers et al (2017) noted an increase in VTE-P compliance with alerting in inflammatory bowel disease (IBD) patients, a high risk population.[14] The authors initially note that IBD patients have a 2-3x higher risk of IBD than patients without the disease. The goal of the study was to improve VTE-P in this population.

The alert devised by the group was designed to establish VTE risk based on the Caprini scoring system with low, medium and high risk levels. Pharmacological and mechanical prophylaxis were required for patients at medium or high risk. In the setting of a clinical contraindication the system can be overridden. The alert did not re-fire after admission.

The VTE-P compliance rate increased significantly from 60 to 81.2% ($p<0.001$). The authors supported the idea that this simple intervention is a promising quality improvement strategy. The authors also commented that missed doses need to be considered concurrently to this initiative. An appropriate conclusion would be that VTE alerts are effective in specific subpopulations but outcomes may be driven by other factors such as nursing and patient education.

Alerts are clearly an important component of the CDS toolkit for VTE-P but need to be carefully deployed in concert with order sets to maximize effectiveness. Alerts are best deployed after risk stratification and admission order sets are complete. The alerts must be able to account for all possible workflow possibilities. At that point improvements in VTE-P compliance and reduction on HA-VTE are possible.

Comprehensive IT Quality Models

More recently several prestigious academic medical centers have published comprehensive multifaceted IT driven models to improve VTE prophylaxis and reduce HA-VTE. These publications emphasize all of the people, technology, and change management techniques required to drive sustainable change. They emphasize the idea that IT changes are necessary but not sufficient to drive and sustain improved VTE-P.

Morganthaler et al (2016) created a system to support VTE-P and scaled the process improvement to 22 hospitals in the Mayo Clinic System.[15] The goal was to develop systems based on evidence and consensus that could be scaled across hospitals with heterogeneous populations and IT systems. At this point Mayo Clinic Rochester was using the GE Centricity EHR and the rest were using different versions of the Cerner EHR.

Mayo spread these changes through a diffusion of innovation team. Generally a best practice process was defined and optimized at one institution first. Following this success the team evaluated the readiness for change of other institutions. Subsequently this best practice was supported to diffuse across the entire system.

Starting with Mayo Rochester, defect rates (errors in VTE-P orders) were reduced to less than 10%. The key findings included that most patients needed prophylaxis and that if the providers were walked through an evaluation process at admission correct decisions were generally made. In addition, alerts were required to accommodate changes in patient status over an admission.

The key change was creation of this required VTE-P section at admission that required all services to create a VTE-P plan on all patients. This was included on all admission, transfer, and postoperative order sets. These designs were tested in a usability lab prior to use to make sure they were easy to use.

In addition to order sets, alerts were created if a patient did not have prophylaxis or an opt-out or low risk status for 24 hours. Also if a patient was designated as low risk at admission but stayed more than 3 days this status would need reevaluation. These alerts would present to any member of the provider team until firing conditions were resolved. When the alert fired the provider would have access to the same orders as on admission. At that point the options included: restate low risk, add or resume a VTE-P order, or define a reason why prophylaxis was contraindicated.

Monitoring for success was based on several measures. These included patients with risk who were on prophylaxis, patients with low risk who were not on chemoprophylaxis, and CDS firing rates to determine which patients did not have a VTE-P plan. Diffusion teams included physicians, nursing, project managers, and pharmacy. Strong institutional support from the highest levels was emphasized.

Results indicated >=97% hospital wide VTE-P compliance at Mayo and the decision was made to diffuse to all member hospitals. Best practices for diffusion were as follows: (1) all order sets will have the required hard stops, (2) 95% of patients at any point in time need to have a valid VTE-P plan and (3) compliance needs to be automated and not require chart review. It was noted in the evaluation that 1 EHR vendor system was better at order set hard stops while another was better at custom CDS for monitoring.

Metrics were based on the CDS firing frequency and the CMS VTE core measures. The CDS firing frequency was used as a proxy measure for patients without a valid VTE-P plan. As plans changed and patients were moved to and from operative settings, a decision was made to shoot for 95% compliance with a valid VTE-P at any given time.

The CMS core measures (VTE-1 and VTE-2) were used for chart abstraction as process measures to determine the percentage of non ICU and ICU patients respectively that are on prophylaxis or determined to be low risk. VTE-6 was an outcome measure as the percentage of patients with HA-VTE who did not receive adequate prophylaxis. Both VTE-1 and VTE-2 increased to >95% within the project and VTE-6 declined from 12% to 0%. See figure below for an image of the required pediatric VTE-P section.

Name:Pediatric VTE Prophylaxis

Select Order	Order Description
	Note: Presence of one or more risk factors can increase the risk for thrombosis
	such as: central venous catheter (used 7 or more days), high risk orthopedic
	surgery or complex fracture of pelvis or lower extremity, projected immobility
	7 or more days, history of clot or thrombophilia, ECMO, malignancy, multiple
	body trauma, use of hormonal therapy, obesity (BMI greater than 95th percentile)
	continuous BPAP/CPAP or mechanical ventilation, or severe inflammatory bowel
	disease (colitis).
	Pharmacologic Prophylaxis is generally not utilized in spine and neurosurgery
	patients:
☐	Pediatric VTE Prophylaxis (mech and pharm) Is Not Indicated Due To:
☐	Pediatric Mechanical Prophylaxis (Pharmacologic Contraindicated):
☐	Pediatric Pharmacologic Prophylaxis and mechanical prophylaxis
☐	Pediatric Pharmacologic Prophylaxis
	Other:
☐	High Risk - Hematology Consult- Coagulation

Figure 3

VTE-P Order Set Section

Morganthaler 2016[15]

Some limitations of the work were described and visible from the screenshot above. Notably, even though the system defines risk factors it did not precisely define which patients are low, intermediate, and high risk. Specifically this did not define which patients should additionally receive mechanical prophylaxis. Despite this simplification of the risk process at admission the workflow supported increased utilization of chemoprophylaxis and led to impressive reduction in preventable HA-VTE.

Schleyer et al (2016) presented an additional model for IT Quality for VTE-P. Harborview Medical Center in Washington State, a tertiary care referral center, noted high rates of VTE-P but VTE continued to be the most common Hospital Acquired Condition (HAC) at the institution.[16] This implied that the VTE-P prescribed may have been inappropriate or incomplete. Project goals included: (1) incorporating best evidence into clinical workflows, (2) structured quality review of all HAVTE events, (3) support process improvement through IT and reporting processes and (4) transparently share performance across the institution.

In addition to creation of a multidisciplinary team, the team created a tool called the Harborview VTE tool that facilitated efficient review of all HA-VTE cases on a monthly basis. Using the summarized clinical data, the task force could easily assess the quality of the VTE risk assessment and prophylaxis medication given plus treatment of the VTE itself. This data was fed back to the additional committees for continuous process improvement. Patient lists were also created for daily hospital wide review of real-time prophylaxis including an anticoagulation summary report. The work included some updates to VTE-P in order sets.

Process measures indicated 96% performance on VTE-1 and 98% on VTE-2 (prophylaxis given in acute care and critical care respectively). The hospital has had 0 VTE-6 events since the inception of the measure in 2013. This was a model not only for IT but also all aspects of how a multidisciplinary team could affect change. The difference between this study and Morganthaler was the focus on reporting and feedback rather than front end workflow modification.

Streiff (2016) spearheaded a similar project at Johns Hopkins in parallel to the projects above.[17] The paper documents the multidisciplinary interventions that the team deployed to perfect VTE-P over 10 years. Success was based on order set changes combined with provider education and financial incentives.

The team started with the introduction of paper order sets that improved compliance with ACCP guidelines from 27% to 98%. In this setting, symptomatic VTEs decreased from 49 per 1000 admissions to 8 per 1000. However, paper order sets were difficult to deploy in a mandatory fashion and data collection became laborious. Later order sets were translated into CPOE with 16 different VTE-P order sets based on specialty.

The goal of these changes was not to eliminate all HA-VTE but to support appropriate VTE-P in all patients and eliminate preventable cases. These changes resulted in improvements in compliance from 65.6 to 90.1% and reduced preventable VTE on medical services from 1.1% to 0%. There was no change in major bleeding or all-cause mortality.

Review of individual performance on the hospitalist service indicated vast variability in VTE-P rates. Direct provider feedback increased compliance from 86% to 90%. In addition a pay for performance initiative based on RVUs increased compliance to 94%. Resident performance on surgical services was evaluated with scorecards in a similar way. Primarily the work directly with physicians demonstrated the power of showing providers their own data. Even though IT changes were made here, the focus was on education and incentives, similar to the work from Schleyer.

The articles in this section are demonstrative of the labor intensive journey to reduce harm from preventable VTE. IT changes such as order sets and alerts must be configured currently to impact change but are only one ingredient of the change process.

Other elements are just as crucial including creation of a multidisciplinary team, effective reporting and analytics, and direct feedback to providers.

20 Commandments of VTE Prophylaxis

In order to assist with VTE-P implementation in EHRs, the following suggestions are provided. These are common to many types of CDS implementations with more specificity to VTE-P. These include suggestions for project success including creating the workgroup and creation of guidelines before build. The commandments continue with suggestions for risk stratification in EHRs, order sets, alerts, and reporting.

Table 1

20 Commandments of VTE-P

Number	Category	Summary
1	General	EHRs are the most appropriate place to do VTE-P CDS, not on paper or external CDS systems
2	Project management	Multidisciplinary team required including medicine, nursing, pharmacy, IT and QI staff
3	Guidelines	Guidelines need to be agreed upon prior to any changes to the EHR

4	Guidelines	Education is required to not only the EHR changes but also the underlying guidelines
5	Guidelines	CDS must also provide link to guidelines in those who were not educated to initial changes such as new staff
6	Risk stratification	Automated risk stratification can be done in most EHRs and shows comparable performance to provider data entry with more convenience
7	Order sets	Admission and transfer order sets are the best location in EHRs to design CDS including risk stratification
8	Order sets	Order sets should be set up to prevent most VTE-P noncompliance with alerts playing a more limited role afterwards
9	Order sets	Within order sets interventions should be defined based on risk level

10	Order sets	Modular order set sections should be used to standardize workflows across services with similar needs
11	Order sets	Hard stops for VTE workflows improve the effectiveness of order sets
12	Order sets	Order sets need to include opt outs, low risk status and comment if already on anticoagulation
13	Alerts	Alerts are required to catch noncompliance after admission either based on initial errors or changes in patient status especially peri-procedural
14	Alerts	Even simple alerts in more basic EHRs have proven effective
15	Alerts	Alerts need to include same functionality as order sets including risk level, medications suggestions, opt outs, low risk and already on anticoagulation

16	Alerts	Alerts should re-fire after short intervals if patient no longer meets VTE-P compliance criteria
17	Reporting	Metrics including process and outcome need to be determined ahead of intervention and measured continuously
18	Reporting	Real time reporting required to identify deficits in currently admitted patients
19	Reporting	Reporting needs to be set up at the hospital floor, medical division, and individual provider level
20	Reporting	Continuous monitoring required to make sure compliance does not diminish with time

Local VTE-P Project

Introduction

Lahey Hospital and Medical Center (LHMC) is a 335 bed academic medical center affiliated with Tufts University School of Medicine. In July 2017, the Chief Patient Safety Officer (CPSO) approached the EHR team with concerns about high rates of hospital acquired VTE. There had been 22 events over the last 12 months, predominantly in surgical patients. Based on root-cause analysis of the cases, anticoagulation interruption was felt to be a contributing factor. The CSPO asked the EPIC team to reevaluate VTE-P tools in order to improve VTE-P daily compliance and reduce HA-VTE.

The VTE task force presented the EPIC team with problems to solve in a collaborative manner. In addition to the CPSO, the task force included representatives from Vascular Medicine, nursing leadership, pharmacy, quality, and anesthesia. In addition to a clinical informaticist, the EPIC team included analysts from clinical documentation, orders, and reporting. The EPIC team would create solutions that would be brought back to the VTE task force for review. At that point the solution would go to system levels meetings for final discussion prior to go-live. The EPIC team would continue to be involved in maintenance and modification of current solutions along with reporting on the outcomes of the specified interventions.

This project review will consist of three main components: (1) modifications to EPIC tools including risk stratification, order sets, alerts and reporting, (2) analytics including internal process measures and internal and external outcome measures, and (3) interpretation based on the 20 Commandments VTE guidelines.

Current State of EHR tools

LHMC had gone live with EPIC 2 years prior with standard foundation tools for VTE. This included 5 components: Caprini risk tool, admission order sets with VTE-P sections, patient list and reporting columns, and a Best Practice Advisory (BPA) that would fire if the patient was not prescribed VTE-P or did not have an opt-out reason on admission. As part of this project all VTE-P tools were systematically reevaluated and updated over the course of 2 years from July 2017 to August 2019.

Caprini risk tool

The EPIC foundation from the 2015 go-live included a Caprini risk model. However, the components of this model were not evaluated for accuracy of data capture and alignment with the original intentions of the risk tool. The tool would also need to be aligned with other aspects of local build including diagnosis groupers, medications, and lab data.

There was originally concern expressed locally that perhaps the Caprini model installed in 2015 needed to be updated to improve sensitivity for high risk. However, initial analysis locally demonstrated that 95% of inpatients were considered high risk so there may have been other issues at play in high VTE-P rates. These included reduced visibility of the score at order entry or perhaps lack of trust in the score as so many patients were considered high risk.

There were a number of issues that may have impacted the performance of the score. The first was the ability to differentiate between acute and chronic problems. This is often a challenge with EHRs particularly around acute events such as ischemic stroke. We made changes so that this would only be considered acute if on the hospital problem list. This likely improved the accuracy but does not account for the situation where a chronic problem may be on the hospital problem list (eg as an anticoagulation reminder).

In addition, groupers were updated and several clinical problems were modified to reduce false positive scoring. Specifically, hip/knee replacement, hip/pelvis/leg fracture, and acute spinal cord injury were limited to hospital problems or a surgical case request from the current admission to prevent bringing in old problems or surgical history. DVT/PE was only considered an active problem if on the hospital problem list. See grouper changes summary below (table 2).

Table 2

Grouper Changes for Caprini Score

Type	Specific Diagnosis/Procedure/Medication
diagnosis	Stroke
diagnosis	Spinal cord injury
diagnosis	Cancer
diagnosis	DVT
diagnosis	Femur fracture
diagnosis	Pulmonary embolism
diagnosis	Thrombophilia
diagnosis	Trauma
diagnosis	CHF
diagnosis	Chronic pulmonary diseases
diagnosis	Acute myocardial infarction
diagnosis	Sepsis
diagnosis	Inflammatory bowel disease
diagnosis	Pregnancy
procedure	Hip replacement

medication	Oral contraceptives
medication	Estrogen

Immobility risk factors were updated to prevent scoring based on “up independently” and prevent orders from coming in based on previous encounters. In addition, dialysis catheters were added to the central line risk factor.   Scoring based on medications was only included if the medication was active.

See below for summary of final completed risk score. Despite the changes to promote accuracy, the % of patients considered high risk did not decrease from 95%. The conclusion that the majority of the inpatient census was high risk was unchanged but perhaps the low risk population would be better identified by these changes to improve accuracy.

See below (figure 4) for local implementation of the Caprini score. Note that there are only two risk levels (high and low) and that high risk patients are recommended to get both chemical and mechanical prophylaxis. Note that the highest scoring elements are based on specific current active hospital problems and/or ICU admission.

VTE Prophylaxis Risk Assessment

High Risk (scores ≥ 4) Pharmacologic and mechanical prophylaxis is warranted (unless contraindication exists)
Low Risk (scores ≤ 3) No pharmacologic or mechanical prophylaxis needed

Risk Factor	Point Score
Admitted to critical care	4
Acute ischemic stroke in previous 30 days	4
Hip/Knee replacement – current or within previous 30 days	4
Hip/Pelvis/Leg fracture within previous 30 days	4
Acute spinal cord injury in previous 30 days	4
Active cancer - patients with dx and/or receiving chemo/radiation in previous 6 months	3
Previous DVT/PE	3
Anticipated bed rest or inability to independently ambulate in the hallway for 48 hours	3
Known thrombophilic condition (Factor V Leiden, prothrombin G20210A, protein C/S deficiency, antiphospholipid syndrome, Antithrombin deficiency)	3
Recent trauma or surgery within previous 30 days	2
Morbid Obesity (BMI > 40)	2
Surgery anticipated during current admission	2
Surgery lasting > 45 minutes	2
Central venous access	2
Age > 70	1
Congestive heart failure – systolic or diastolic in previous 30 days	1
Abnormal pulmonary function (COPD, asthma, pulmonary fibrosis)	1
Acute myocardial infarction within previous 30 days	1
Sepsis - current diagnosis or within previous 30 days	1
History of inflammatory bowel disease (Crohn's or ulcerative colitis)	1
Obesity (BMI > 30)	1
Pregnancy/post-partum within previous 30 days	1
Receiving estrogen/progesterone hormone replacement therapy or birth control	1
Total	

Figure 4

Local Implementation of Caprini Score

Order Set Changes

Order sets included VTE prophylaxis sections when the system went live in 2015. However, two primary modifications needed to be made to better support VTE-P in the setting of this initiative. The first step was to make an evaluation of VTE-P required at admission. This meant that in order to admit a patient the provider would need to order chemical or mechanical VTE-P or document a reason why not. There would be separate reasons why not for mechanical or chemical.

In addition the opt-out reasons needed to be modified and set up in alignment with the BPA that was to be modified afterwards. Conventional opt-outs included active bleeding, high bleeding risk procedure or low platelets. Non evidence based options were removed such as liver patients with INR>1.5. One of the primary differences between the initial order set and the BPA was that the BPA could evaluate active orders while the order set was placed prior to order signing so additional opt out options were required such as patient is comfort measures only, active order for anticoagulation or low risk were added given that these were situations in which the BPA would not fire.

Patient List and Reporting Changes

Patient list columns and real time reports are key components in a comprehensive VTE-P improvement plan. Patient list columns allow visibility of VTE-P status directly within a front-line provider’s workflow. Real-time reports can be run to establish VTE-P status in real time based on service or hospital location.

The existing patient list columns and report templates were built for meaningful use (regulatory) requirements and not suitable for real time review of VTE-P status. Specific services such as orthopedics requested the ability to look at VTE-P status in real time for entire services. The existing functionality was set up to determine if the patient met the initial admission VTE-P measure with a yes or no answer, clearly inadequate for real time review of status.

New columns were required to support presentation of risk scoring, VTE chemical and mechanical status, plus whether the patient had an anticoagulation opt-out reason. Medication groupers needed to be modified to exclude anticoagulants that were not appropriate for VTE-P such as hemodialysis and line flushes. Aspirin was included in the VTE-P column given extensive use by orthopedics.

Given that the VTE-P column only showed active medications, daily one time dosing or warfarin did not display and required correction. In addition, home medications were excluded and free text opt out reasons were added to the display. The real time reports described above were set up similarly using the same columns as patient lists.

Alert Modifications

At EPIC go-live the alert was originally set up to drive VTE-P at admission. Based on the original build a high risk patient that was not prescribed prophylaxis at admission or designated with an opt-out reason would prompt an alert. In addition, if anticoagulation was discontinued later in the admission the alert would fire requiring prophylaxis or an opt-out.

Several problems were discovered with the original build. First of all, any time an opt-out reason was selected (at admission or later), the opt-out reason would last the duration of the admission. So if a patient was opted out for bleeding at the start of an admission with no further bleeding after the first day, the user would not be prompted to resume anticoagulation. See table 3 for opt out reasons with the original settings and new settings for duration. In addition, mechanical prophylaxis would never be considered a viable substitute for chemoprophylaxis in a high risk patient as this would prevent the original BPA from firing. Aspirin (ASA) was also excluded from the chemoprophylaxis grouper as this was not considered adequate in high risk patients so would prompt an alert. After seven months of logic changes the BPA was set up to run in the background for 6 months given concern about the complexity of the BPA and potential for alert fatigue.

Table 3

Opt-out reasons for order sets and BPA

Indication for VTE-P hold	**Old duration**	**New duration**
Risk <=3	Only applies to admission order set for encounter	24 hours
Already on anticoag	Only applies to admission order set for encounter	24 hours
Active bleeding	encounter	24 hours

High risk procedure	encounter	24 hours
LP within 24 hours	encounter	24 hours
CNS bleed	encounter	48 hours
TPA within 24 hours	encounter	24 hours
PLT <50	encounter	24 hours
CMO (new)	Only applies to admission order set for encounter	encounter

Orthopedics was considered a unique stakeholder in the VTE-P discussion. They did not follow American College of Chest Physicians guidelines for risk stratification and chemoprophylaxis and use ASA for prophylaxis on many joint replacement and some fracture patients. However, we could not set up ASA as viable prophylaxis for all patients as many high risk medical patients were on ASA due to CAD and this would not be adequate to prevent VTE in this population. We were able to solve this problem by setting up rule logic to determine if ASA was ordered off an appropriate orthopedic order set. This would prevent BPA firing on orthopedic patients and allow firing on high risk medical patients.

After more than a year of redesign the BPA was set to go-live in redesigned form. Initial feedback from users was positive noting that many appreciated the daily reminder to reevaluate VTE-P to make sure that decisions made days ago were not adversely impacting patient care on the day of evaluation.

Best Practice Alert Analytics

The VTE BPA was evaluated 5 months later to determine user response to the alert. Across three separate hospitals the alert had fired 14, 302 times over 3 months. This means that the alert is firing roughly 53 times per day in each of three hospitals. This means the alert would potentially fire on 20% of inpatients daily. This was considered initially reasonable. More than 75% of the alerts triggered to Hospital Medicine and Internal Medicine providers but the alert was also firing to surgical services. The response rate at the time was an average of 5% if response was considered based on opening the VTE-P order set to order prophylaxis or designate an opt-out reason. The alert fired much less frequently to general surgery and urology but response rates were much higher at 12% and 15% respectively while Hospital Medicine was at 4%.

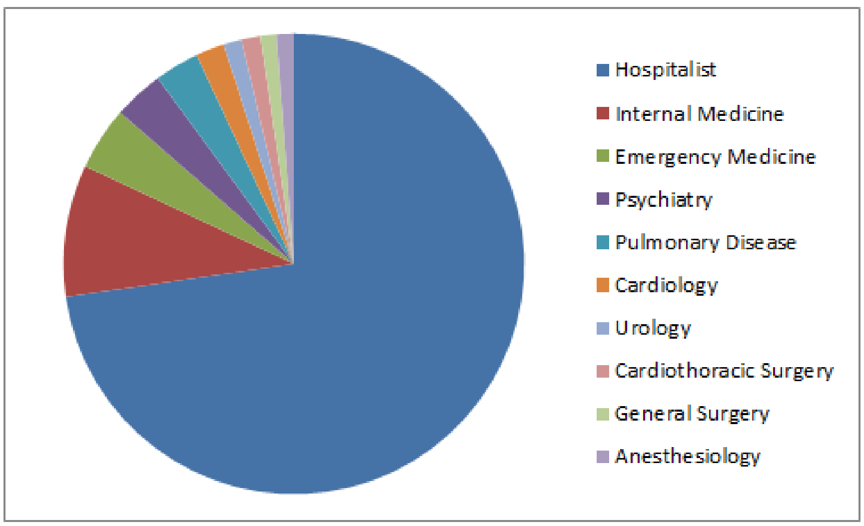

Figure 5

VTE BPA firing by service

Table 4

Alert response rate of opening order

Row Label	Cancel BPA	Open Order	Grand Total	percentage
Hospitalist	9321	430	9751	4
Internal M	1186	60	1246	5
Emergency	569	31	600	5
Psychiatry	452	6	458	1
Pulmonary	401	41	442	9
Cardiology	257	9	266	3
Urology	163	23	186	12
Cardiothor	172	2	174	1
General Su	142	26	168	15
Anesthesic	156	7	163	4
	12819	635	13454	

Based on the data above, a modification of the triggering mechanism was considered to potentially improve compliance. The BPA was set to “chart open” meaning that even if the chart was being opened for a different urgent reason or the provider needed to review the chart first that the BPA would be dismissed. Instead the BPA could be set to “sign orders” which would mean that the acute issue may have been resolved and the chart reviewed before decisions about VTE-P needed to be made. In addition, given daily dosing of warfarin, the BPA was set up to look back 24 hours for any administered warfarin order.

3 months of data were reevaluated 12 months after the evaluation above to determine continued impact. Interestingly the firing rate fell from roughly 150 times per day to 110 per day across the system. We found that the alert fired roughly 8-9 times per patient relative to the response deemed correct (open VTE-P order set). This 9% response rate improved from 5% a year prior, possibly due to the corrections designated above. The vast majority of alerts were going to Hospital Medicine (HM) / Internal Medicine (78%) with compliance in HM increasing from 4% to 7% over the period. Given the process measures described above the BPA was considered successful.

VTE Process Measures

An internal report was requested to add additional metrics to the discussion. Demographics were requested to determine the population of interest and whether the population changed before and after intervention. Days covered by chemoprophylaxis was a simplified process measure to determine if rates of chemoprophylaxis increased. Rates of Heparin Induced Thrombocytopenia (HIT) were considered a balancing measure to see if more chemoprophylaxis increased unintended side effects.

Comparison Groups

Most of the EPIC changes were complete by October 2018. Therefore we set up a comparison between 2018 and 2019 as before and after completed changes. The two cohorts were very similar (see table 5).

Table 5

Demographics

	2018 (Jan-Dec)	**2019 (Jan-Dec)**
N inpatient encounters	54202	58661
gender	45% male/55% female	45% male/55% female
Marital status	44% married/56% other	44% married/56% other

Days Covered by Chemoprophylaxis

As a simplified process measure we decided to focus on days covered by chemoprophylaxis. We were making the assumption that not all patients are appropriately given opt outs but that the % covered was low and would increase with the CDS deployed. For each encounter the number of days chemoprophylaxis was given was divided by length of stay to determine % of admission covered by chemoprophylaxis. We noted that 74.5% of inpatient days were covered in 2018 and 73.5% were covered in 2019, essentially no difference.

VTE-P Outcome Measures

Heparin Induced Thrombocytopenia

Heparin Induced Thrombocytopenia (HIT) is a potential complication of heparin administration for VTE prophylaxis. You would expect that this might rise with additional chemoprophylaxis as a balancing measure to reduce HA-VTE. In this case HIT rates were essentially unchanged from 12 in 2018 to 11 cases in 2019.

Hospital Acquired VTE

During the project Vizient™ data was reviewed to determine impact of the changes The project started with 22 patients with HA-VTE over 12 months in FY2017. Based on reevaluation in FY2018 the rate had fallen to 17. However, a more detailed evaluation using EPIC reporting was later undertaken to better determine the relationship between the EPIC changes and the improved outcomes. These changes were off in timing from the process measures above as requirements for measurement changed during 2018 to focus more on surgical rather than entire hospital populations.

Conclusions

Project Discussion

The process measures in this local project were unchanged yet we say some early improvement in HA-VTE rates without an increase in HA-VTE. There are possible explanations for this: We may not have measured the correct process measures. With more sophisticated reporting we could have looked at inpatient days that the patient did not have an active opt out. This would have given us a better sense of the days in which the patient should have been given prophylaxis that actually received it. There may have been an independent initiative that had an impact on HA-VTE rates but there were no known additional initiatives at the time.

Compliance with 20 Commandments

The VTE-P best practices described in the first section of this paper are transcribed below along with a discussion of our local compliance with such guidelines.

Table 6

Compliance with 20 Commandments

Number	Category	Summary	Compliance	Notes
1	General	EHRs are the most appropriate place to do VTE-P CDS, not on paper or external CDS systems	Yes	Relevance is EHR versus external apps
2	Project management	Multidisciplinary team required including medicine, nursing, pharmacy, IT and QI staff	Yes	Present
3	Guidelines	Guidelines need to be agreed upon prior to any changes to the EHR	No	EHR team asked to solve problems without guidelines
4	Guidelines	Education is required to not only the EHR changes but also the underlying guidelines	No	Minimal Education in this project
5	Guidelines	CDS must also provide link to	No	Not present

		guidelines in those who were not educated to initial changes such as new staff		
6	Risk stratification	Automated risk stratification can be done in most EHRs and shows comparable performance to provider data entry with more convenience	Yes	Initially present with EHR but required heavy modification
7	Order sets	Admission and transfer order sets are the best location in EHRs to design CDS including risk stratification	Yes	Present
8	Order sets	Order sets should be set up to prevent most VTE-P	Yes	Present

		noncompliance with alerts playing a more limited role afterwards		
9	Order sets	Within order sets interventions should be defined based on displayed risk level	No	Absent
10	Order sets	Modular order set sections should be used to standardize workflows across services with similar needs	Yes	Present
11	Order sets	Hard stops for VTE workflows improve the effectiveness of order sets	Yes	Present
12	Order sets	Order sets need to include opt outs,	Yes	Present

		low risk status and comment if already on anticoagulation		
13	Alerts	Alerts are required to catch noncompliance after admission either based on initial errors or changes in patient status especially per-procedural	Yes	Primary QI objective to increase perioperative VTE-P
14	Alerts	Even simple alerts in more basic EHRs have proven effective	Yes	Increased complexity with time
15	Alerts	Alerts need to include same functionality as order sets including risk level, medications suggestions, opt	Yes	Present

		outs, low risk and already on anticoagulation		
16	Alerts	Alerts should re-fire after short intervals if patient no longer meets VTE-P compliance criteria	Yes	Present
17	Reporting	Metrics including process and outcome need to be determined ahead of intervention and measured continuously	No	Measures were not defined for internal reporting only external outcome measures
18	Reporting	Real time reporting required to identify deficits in currently admitted patients	Yes	Present in a report but not a dashboard
19	Reporting	Reporting needs to be set up at the	No	Not present

		hospital floor, medical division, and individual provider level		

Limitations/Criticisms/Future Directions

Based on the analysis above, the current project does not meet all of the 20 Commandments for VTE prophylaxis. The categories involved include guidelines creation and education, order set build, and metrics and dashboards for reporting. This does not mean that the underlying project was not successful but that potential for improvement exists.

Optimally, local guidelines will be created by subject matter experts prior to creation of the clinical decision support. The fact that these guidelines were not created leads to some potential problems later in the project. The process of guideline production requires clinical consensus. Once this is achieved, the clinical decision support is only reminding the provider to perform a task that he or she already agrees to. Otherwise some providers may disagree with content as built therefore increasing non-compliance. Not all providers will be involved in the guideline process as well so those clinical champions must educate other providers on the decisions made. Lastly, a link to guidelines must be present for those less familiar for review at the point of care.

The commandments include order sets that display automated risk scores within the order entry process. This means that the risk score can be reviewed and acted on within the order set. In addition, interventions are set up based on scoring levels so providers will clearly see the connection between risk status and proposed interventions. The lack of this functionality increases the possibility that the provider places orders on the patient assuming a risk level that is not consistent with objective data.   This could mean that compliance with VTE-P might be high but incorrect prophylaxis orders may mean some high risk patients are not covered optimally and low risk patients may be given prophylaxis in- appropriately. This could lead to high process measures for use of chemoprophylaxis but less improvement in HA-VTE or increased bleeding. We were told that system limitations prevented the score from displaying within the order set itself. The score is currently displayed in a sidebar report that the provider needs to navigate to during order entry.

The commandments include process and outcome metrics defined from EHR data and displayed within the EHR. The current project relied on data derived from chart abstraction and collated by an outside entity (Vizient™) and returned after comparison to outside benchmarks. This is helpful for benchmarking but is delayed by months and does not allow comparison of process. Addition of timely process measures is critical to understand what changes may have contributed to improved outcomes. In addition, timelier reporting allows for changes to be made in a more timely fashion for any identified defects.

There were no dashboards set up for VTE prophylaxis. Ideally you would have a dashboard of VTE process and outcome measures that could be filtered from the patient and provider level to the department and hospital level. If this is monitored on a regular basis this allows the ability to identify quality problems early on based on provider or system factors and intervene early to prevent problems from worsening. Going without this type of functionality means that you are generally looking only at historical data and waiting long periods of time for measurement of the impact of process improvement changes made. Sites may be limited in resources to manage this resource even if built.

It may be unrealistic to think that any individual clinical site would have the resources to apply all 20 commandments. This implies local control over IT and resources in order sets, alerts and reporting. In addition, local subject matter expertise is not always present. However, the goal is to adhere to as many components as possible to help ensure project success.

Final Conclusion

This project met the primary objective of 29% reduction in HA-VTE over 1 year of measurement. This was done through an IT driven improvement in orders sets, patient lists, and a pop-up alert. However, a HA-VTE is considered a never event and further reductions are necessary based on future directions above, many of which are not IT-centric. Not only technical resources but human resources are required to update guidelines, educate providers, and staff dashboards.

The goals of this toolkit are as follows: (1) review literature around IT driven VTE-P quality improvement, (2) create recommendations based on literature review combined with local experience, and (3) present a case study of how the 20 Commandments can help a local project achieve improved outcomes. This information would be helpful to review prior to initiation of a VTE-P project or for optimization of an existing project. Given that the 20 Commandments encompass IT and non-IT components the best lesson is that full integration of IT, quality, and provider engagement are needed to ensure project success.

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1-17

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Appendix

Summary of VTE-P Toolkit Studies

Title	Author	Year	Summary	Primary Conclusion
Interventions for Implementation of thromboprophylaxis in hospitalized patients at risk for venous thromboembolism	Kahn SR	2018	Meta Analysis of RCTs to determine successful interventions to increase VTE-P	Multifaceted interventions in combination with alerts most effective at increasing VTE-P. EAlerts reduced symptomatic VTE at 3 months.
Antithrombotic Therapy for VTE Disease: CHEST Guideline and Expert Panel Report	Kearon C	2016	Update of American College of Chest Physicians Guidelines for VTE-P	20 strong guidelines were generated but none based on strong evidence
American Society of Hematology 2018 guidelines for management of	Schunemann HJ	2018	Guidelines for VTE-P in hospitalized or medically ill	19 recommendations made

venous thromboembolism : prophylaxis for hospitalized and nonhospitalized medical patients			outpatients	
Comparison between Caprini and Padua risk assessment models for hospitalized medical patients at risk for venous thromboembolism: a retrospective study	Liu	2016	Retrospective comparison of VTE risk scores	Caprini, the higher complexity score, has better ability to predict VTE than Padua score
Optimizing Prevention of Hospital-acquired Venous Thromboembolism (VTE): Prospective Validation of a VTE	Maynard	2010	Evaluation of new VTE risk model with provider data entry	Manually entered model integrated into order sets can reduce HA-VTE

Risk Assessment Model				
Automating Venous Thromboembolism Risk Calculation Using Electronic Health Record Data Upon Hospital Admission: The Automated Padua Prediction Score	Elias	2017	Comparison of manual versus automated calculation of Padua risk score	Automated calculation is non-inferior to manual and more efficient
Medical Admission Order Sets to Improve Deep Vein Thrombosis Prophylaxis Rates and Other Outcomes	O'Connor	2009	Do admission order sets improve compliance with VTE-P?	Order set can improve many different quality outcomes including VTE-P
Medical Admission Order Sets to Improve Deep Vein Thrombosis Prevention: A Model	Maynard	2009	Editorial on how to best support VTE-P with order sets	More organizational buy-in and education would improve

for Others or a Prescription for Mediocrity?				compliance even further than study above
Improving Hospital Venous Thromboembolism Prophylaxis With Electronic Decision Support	Bhalla	2013	Cohort study looking at VTE-P CDS to improve outcomes with workflow enhancements and hard stops	VTE CDS can improve process and outcome measures
Eliminating Healthcare Disparities Via Mandatory Clinical Decision Support: The Venous Thromboembolism (VTE) Example	Lau	2017	Use of VTE-P CDS driven process improvement to reduce race and gender based care gaps	Health IT can not only improve outcomes but also reduce race and gender based care gaps
Computerized Decision Support for the Cardiovascular Clinician:	Piazza and Goldhaber	2009 (Sept)	Review article on benefits of CDS for VTE and other clinical quality outcomes	Improvement in patient safety, disease specific outcomes and healthcare costs

Applications for Venous Thromboembolism Prevention and Beyond				
A Clinical Decision Support System for Prevention of Venous Thromboembolism	Durieux	2000	Evaluation of a post ordering messaging system to improve compliance with ordering based on risk	CDS alerts improved compliance with VTE-P compliance process measures outside of EHR
Development and implementation of a program to assess medical patients' need for venous thromboembolism prophylaxis	Sobieraj	2008	Creation of an alert based on VTE risk in patients without prophylaxis in EHR	VTE prophylaxis compliance improved from 49-93% with simple EHR based alerting
An Electronic Alert System Is Associated With a	Mathers	2017	VTE prophylaxis alert created specifically	VTE prophylaxis improved from 60 to 81.2% but

Significant Increase in Pharmacologic Venous Thromboembolism Prophylaxis Rates Among Hospitalized Inflammatory Bowel Disease Patients			focused on inflammatory bowel disease population based on much higher than baseline risk	16% of doses not administered and majority of those due to patient refusal
Preventing Acute Care–Associated Venous Thromboembolism in Adult and Pediatric Patients Across a Large Healthcare System	Morgenthaler	2016	Creation of comprehensive VTE-P health IT workflow and diffusion to 22 member hospitals	VTE process measures improved to 97-100% and no preventable VTE events
Preventing Hospital-Acquired Venous Thromboembolism: Improving Patient Safety With Interdisciplinary Teamwork, Quality	Schleyer	2016	Creation of VTE task force focused on event review without chart abstraction and comparison of	Improvement in process and outcome driven by committee using EHR reporting mechanisms

Improvement Analytics, and Data Transparency			VTE practice to evidence	
The Johns Hopkins Venous Thromboembolism Collaborative: Multidisciplinary Team Approach to Achieve Perfect Prophylaxis	Streiff	2016	VTE Collaborative Task Force improved order sets and alerts for missed doses plus , supported education and set up pay for performance	Improvement in VTE-P and preventable VTE supported by IT, education, and incentives