Venous thromboembolism (VTE) prevention. We developed novel strategies to improve provider VTE prevention ordering practices including face-to-face performance reviews, pay for performance, and provider VTE scorecards. When we discovered that prescription of risk-appropriate VTE prophylaxis does not ensure its administration, our multidisciplinary research team conducted in-depth surveys of patients, nurses, and physicians to design a multidisciplinary patient-centered educational intervention to eliminate missed doses of pharmacologic VTE prophylaxis that has been funded by the Patient Centered Outcomes Research Institute. We expect that the studies currently underway will bring us closer to the goal of perfect VTE prevention care for every patient. Our learning journey to eliminate harm from VTE can be applied to other types of harm. *Journal of Hospital Medicine* 2016;11:S8–S14. © 2016 Society of Hospital Medicine

Venous thromboembolism (VTE), which encompasses deep venous thrombosis and pulmonary embolism, is an important cause of preventable harm in hospitalized patients. The critical steps in delivery of optimal VTE prevention care include (1) assessment of VTE and bleeding risk for each patient, (2) prescription of risk-appropriate VTE prophylaxis, (3) administration of risk-appropriate VTE prophylaxis in a patient-centered manner, and (4) continuously monitoring outcomes to identify new opportunities for learning and performance improvement. To ensure that every hospitalized patient receives VTE prophylaxis consistent with their individual risk level and personal care preferences, we organized a multidisciplinary task force, the Johns Hopkins VTE Collaborative. To achieve the goal of perfect prophylaxis for every patient, we developed evidence-based, specialty-specific computerized clinical decision support VTE prophylaxis order sets that assist providers in ordering risk-appropriate Venous thromboembolism (VTE), which encompasses deep venous thrombosis and pulmonary embolism, is an important cause of preventable harm in hospitalized patients. The critical steps in delivery of optimal VTE prevention care include (1) assessment of VTE and bleeding risk for each patient, (2) prescription of risk-appropriate VTE prophylaxis, (3) administration of risk-appropriate VTE prophylaxis, and (4) continuously monitoring outcomes to identify new opportunities for learning and performance improvement. To ensure that every hospitalized patient receives VTE prophylaxis consistent with their individual risk level and personal care preferences, we organized a multidisciplinary task force, the Johns Hopkins VTE Collaborative. To achieve the goal of perfect prophylaxis for every patient, we developed evidence-based, specialty-specific computerized clinical decision support VTE prophylaxis order sets that assist providers in ordering risk-appropriate VTE prevention. Despite widespread recognition that VTE prophylaxis is an important patient safety measure, poor performance is common. The ENDORSE (Epidemiologic International Day for the Evaluation of Patients at Risk for Venous Thromboembolism in the Acute Hospital Care Setting) study of over 68,000 hospitalized patients in 32 countries noted only 58.5% of surgical patients and 39.5% medical patients received American College of Chest Physicians (ACCP) guideline-appropriate VTE prophylaxis. In 2005, an audit of the surgical services at The Johns Hopkins Hospital found that only 33% of 322 randomly selected patients were prescribed prophylaxis consistent with the ACCP guidelines.

Achieving defect-free VTE prevention requires attention to each step in the process: (1) assessment of both VTE and bleeding risk, (2) prescription of risk-appropriate VTE prophylaxis, and (3) administration of risk-appropriate VTE prophylaxis. In 2005, to improve our VTE prevention performance at Johns Hopkins Hospital, the Center for Innovations organized a VTE Collaborative of 2 physicians, 1 nurse,
and 1 pharmacist dedicated to VTE quality improvement. Since then, the group has grown dramatically, adding a clinical informatics expert and numerous other members and coming under the auspices of The Armstrong Institute for Patient Safety. Recognizing that many, though not all, VTEs are potentially preventable,7,8 the mission of the Johns Hopkins VTE Collaborative is to ensure that all hospitalized patients receive risk-appropriate, best-practice VTE prophylaxis. This article chronicles the innovative strategies that the Johns Hopkins VTE Collaborative has employed over the past decade to improve our hospital’s performance in VTE prevention (Table 1).

ENSURING EVERY PATIENT IS PRESCRIBED RISK-APPROPRIATE PROPHYLAXIS

With the support of hospital leadership, the VTE Collaborative held a series of events in 2005 with medical and surgical providers to review the current evidence supporting VTE prophylaxis and achieve consensus on appropriate practice based upon the 2004 ACCP VTE Prophylaxis Guideline. The result was the development of 5 evidence-based, paper VTE prophylaxis order sets that guided the ordering provider on the assessment of VTE and bleeding risk and facilitated the selection of risk-appropriate VTE prophylaxis. Because there were no validated VTE or bleeding risk assessment tools at the time we developed our order sets, we used specialty-specific VTE risk factors derived from the 2004 ACCP Guideline. To identify patients inappropriate for pharmacologic prophylaxis, we used exclusion criteria derived from contemporary randomized clinical trials of pharmacologic prophylaxis in the target populations (ie, active bleeding, abnormal activated partial thromboplastin time not due to a lupus inhibitor) or mutually agreed upon thresholds after discussion with individual provider groups (platelet count <50,000/μL). On the Johns Hopkins Hospital inpatient acute rehabilitation unit, introduction of the paper order sets increased adherence with ACCP guidelines from 27% to 98% (P < 0.0001) and reduced symptomatic VTE from 49 per 1000 admissions to 8 per 1000 admissions (P = 0.0001).9 This study demonstrated that paper order sets used consistently by a dedicated group of providers can result in sustained improvements in practice. Paper order sets remain a low-tech, easy-to-implement strategy that can be applied in any healthcare setting. Other services also saw improvements in risk-appropriate prophylaxis prescription. In a follow-up cross-sectional analysis of the surgical services at Johns Hopkins, we found that appropriate VTE prophylaxis prescription improved from 33% to 62% in a sample of 226 patients. Unfortunately, paper order sets had several disadvantages including (1) the inherent difficulty of making them a mandatory part of the admission or transfer process, (2) their existence outside the usual clinical workflow, and (3) the labor- and time-intensive data collection that made it difficult to provide credible, timely performance reports to providers and leadership.

These disadvantages and our adoption of a computerized provider order entry system prompted us to pursue the development and implementation of mandatory, evidence-based, specialty-specific computerized clinical decision support (CCDS) VTE prophylaxis order sets. Using the Translating Research Into Practice approach to quality improvement,10 we collaborated with providers to design 16 different evidence-based specialty-specific CCDS VTE order sets. These CCDS VTE order sets, which are imbedded in the specialty-specific admission and transfer order sets, assist providers in assessing patients’ VTE and bleeding risk factors and provide evidence-based risk-appropriate VTE prophylaxis (see Supporting Figure 1 in the online version of this article). Individual patient data are saved in an administrative database and can be easily aggregated for research analyses and quality improvement/performance reporting. A detailed discussion of our strategy for change is discussed in Streiff et al.11 Because pharmacologic prophylaxis is not appropriate for every patient, and not all VTE are preventable, even with perfect prophylaxis, the goals of our collaborative are to ensure that every patient is ordered VTE prophylaxis consistent with their risk profile (risk-appropriate prophylaxis) and to eliminate preventable episodes of VTE (VTE that occurs in the setting of suboptimal prophylaxis). In a pre–post quasi-experimental study of 1599 trauma patients, the CCDS VTE order set increased risk-appropriate prophylaxis prescription from 66.2% to 84.4% (P < 0.001) and reduced the incidence of potentially preventable harm from VTE from 1% to 0.17% (P = 0.04) (Figure 1).12 On the medical service, the CCDS VTE order set improved risk-appropriate VTE prophylaxis prescription from 65.6% to 90.1% (P < 0.0001) and reduced the incidence of potentially

---

### TABLE 1. Johns Hopkins Venous Thromboembolism Collaborative Innovations in VTE Prevention

<table>
<thead>
<tr>
<th>Strategies to improve VTE prophylaxis ordering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper-based patient risk assessment forms (before computer order entry)</td>
</tr>
<tr>
<td>Mandatory evidence-based specialty-specific computer clinical decision support “smart order sets”</td>
</tr>
<tr>
<td>Group data and competitions</td>
</tr>
<tr>
<td>1-on-1 provider feedback</td>
</tr>
<tr>
<td>Pay for performance</td>
</tr>
<tr>
<td>Individualized feedback with resident scorecards</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategies to improve VTE prophylaxis administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of missed doses as a major contributor to preventable VTE</td>
</tr>
<tr>
<td>Identification of physician, nurse and patient contributors to missed doses</td>
</tr>
<tr>
<td>Collaboration with patients to create patient-centered educational materials</td>
</tr>
<tr>
<td>Novel web-based module for nursing education</td>
</tr>
<tr>
<td>Real-time missed doses alert</td>
</tr>
<tr>
<td>Targeted 1-on-1 patient education</td>
</tr>
</tbody>
</table>

**NOTE:** Abbreviations: VTE, venous thromboembolism.
preventable harm attributable to VTE from 1.1% to 0% ($P = 0.001$). There was no increase in major bleeding (International Society of Thrombosis and Hemostasis definition: hemoglobin decline of $\geq 2$ grams/dL or transfusion of 2 or more units of blood or bleeding into a critical organ such as brain, gastrointestinal tract, or eye) post–order set implementation ($0.3\%$ vs $0.1\%$, $P = 0.625$) or all-cause mortality ($1.3\%$ vs $2.0\%$, $P = 0.285$).

These order sets demonstrated that CCDS tools can lead to significant improvements in prescribing practices and reductions in preventable harm from VTE without increasing the risk of major bleeding complications. In addition to improving the quality of care, the order sets also improved the consistency of care. In a retrospective analysis, we found that implementation of CCDS VTE order sets eliminated racial disparities in prescribing practices. In the preimplementation group, risk-appropriate VTE prophylaxis was prescribed for $70.1\%$ of black patients and $56.6\%$ of white patients on the trauma service ($P = 0.025$) and $69.5\%$ of black patients and $61.7\%$ of white patients on the medical service ($P = 0.015$). After implementation of the CCDS VTE order sets, care improved for all patients such that the previously observed disparities were eliminated (trauma service $84.5\%$ vs $85.5\%$, $P = 0.99$ and medical service $91.8\%$ vs $88.0\%$, $P = 0.082$).

Although implementation of mandatory evidence-based, specialty-specific CDSS VTE order sets led to substantial improvements in VTE prophylaxis ordering, high performance was not uniform across our institution. On the medical service, substantial disparities in adherence to order set recommendations existed. On the housestaff services, over $90\%$ of patients consistently received risk-appropriate VTE prophylaxis compared with only $85\%$ on the hospitalist service. Examination of individual provider performance found that some providers only ordered risk-appropriate prophylaxis $50\%$ of the time, whereas others were doing so $98\%$ of the time. To address this disparity, we conducted a retrospective analysis of a prospective performance improvement project conducted on the Johns Hopkins Hospitalist service studying the impact of individualized hospitalist attending feedback on VTE prevention practices. During the preintervention period (January 2009–December 2010), guideline-adherent VTE prophylaxis was ordered for $86\%$ ($95\%$ confidence interval [CI]: $85\%$-$88\%$) of patients. Six months after initiation of direct face-to-face provider feedback (January 2011–June 2011), guideline-adherent VTE prophylaxis rates rose to $90\%$ ($95\%$ CI: $88.9$-$93$). Subsequently (July 2011–December 2012), a pay-for-performance (P4P) initiative was added to direct face-to-face provider feedback. During the P4P initiative, provider incentive per relative value unit (RVU) was progressively increased with increasing performance on provision of risk-appropriate VTE prophylaxis (adherence $\leq 80\%$ = no bonus to $0.50$ per RVU for adherence $\geq 95\%$). During this period, prescription of guideline-adherent prophylaxis rose to $94\%$ ($95\%$ CI: $93\%$-$96\%$). These initiatives transformed the hospitalist unit from a consistently low-performance unit to a high-performance unit.

Similar findings were noted on the trauma service. Although the original plan was to provide feedback to attending trauma surgeons, that plan changed when we found that performance was driven entirely by resident practice; residents write the VTE prophylaxis orders, which is then attributed to attending performance. Resident performance varied widely; $42$ of $75$ ($56\%$) residents on the trauma service ordered risk-appropriate prophylaxis for $100\%$ of their patients. In contrast, $7$ ($9.3\%$) residents never ordered optimal prophylaxis for any of their patients. To motivate all residents to prescribe optimal prophylaxis, we developed an individualized resident VTE prophylaxis scorecard (Figure 2). This prospective cohort study of $2420$ patients and $49$ general surgery residents compared resident VTE prophylaxis performance on the general surgery service during $3$ periods: period 1 (baseline, July 2013–September 2013), period 2 (surgery resident scorecard, October 2013–December 2013), period 3 (resident scorecard plus individualized 1-on-1 coaching, January 2014–March 2014). At baseline, $89.4\%$ of patients were prescribed appropriate VTE prophylaxis, and only $45\%$ of patients prescribed risk-appropriate prophylaxis for all their patients. During the scorecard period, $95.4\%$ of patients were prescribed risk-appropriate VTE prophylaxis ($P < 0.001$). During the scorecard plus coaching period, risk-appropriate prophylaxis rose to $96.4\%$. These prescribing practice changes were
durable. During the 15 months prior to issuing scorecards, 88.0% of patients (3718/4226) were prescribed risk-appropriate prophylaxis. After implementation, 95.8% of patients (3799/3966) were prescribed risk-appropriate prophylaxis ($P < 0.001$) (see Supporting Figure 2 in the online version of this article). During the baseline period, 7 of 865 patients (0.81%) had a VTE during their hospital stay, of which 3 (0.35%) were potentially preventable. In contrast, none of the 3 of 784 patients who suffered VTE during the post-implementation period had a potentially preventable event (0.35% vs 0%, $P = 0.046$). These studies demonstrate that providing physicians with their own specific data can be a powerful tool for performance improvement that may be applicable to many other quality and safety measures. Our group recently received funding from the AHRQ to scale this work to other residents, nurse practitioners, physician assistants, and attending physicians (1R01HS024547, Individualized Performance Feedback on Venous Thromboembolism Prevention Practice).

**IMPROVING VTE PROPHYLAXIS ADMINISTRATION**

Ordering VTE prophylaxis does not ensure its administration. We conducted a retrospective review of electronic administration records of 10,526 consecutive patients admitted over a 7-month period at The Johns Hopkins VTE Collaborative | Streiff et al. An Official Publication of the Society of Hospital Medicine Journal of Hospital Medicine Vol 11 | No S2 | December 2016 S11
Hopkins Hospital. Twelve percent of the over 100,000 ordered doses of VTE prophylaxis were not administered, and the proportion of nonadministered doses on individual floors varied 5-fold from 5.4% to 26.9%. The proportion of nonadministered doses was significantly higher on medical floors compared with all other services (17.5% vs 8.1%, odds ratio [OR]: 2.1 [95% CI: 2.0-2.2]). Patient or family member refusal was the most common cause for nonadministered doses of VTE prophylaxis accounting for 59% of all missed doses. Eight percent of patients missed more than half their prescribed does, and 5% of patients missed over 75% of ordered doses of VTE prophylaxis. Consistent with the Pareto principle, over 80% of the missed doses of prophylaxis were accounted for by just 20% of the patients. A retrospective analysis of hospital-acquired VTE at Johns Hopkins found that 39% of events occurred in patients who missed 1 or more doses of appropriate VTE prophylaxis. Louis et al. noted that nonadministration of ≥1 dose of VTE prophylaxis was associated with a significant increase in risk for hospital acquired VTE. These data indicate the need for more aggressive interventions to reduce missed doses to improve VTE prevention.

To fully understand the root causes of VTE prophylaxis non-administration, we conducted a series of studies examining each of the participants in the VTE prevention care pathway, physicians, nurses, and patients. In a survey of 122 resident physicians, we found significant differences in clinical practice between medicine and surgery residents. Medicine residents were more likely to believe that VTE prophylaxis was overprescribed, and that it was appropriate for nurses to make judgement calls about whether patients needed the prophylaxis that was prescribed. In a mixed methods study that included a written survey and qualitative observations of nursing practice, we found that some nurses presented pharmacologic VTE prophylaxis injections as optional to patients. Furthermore, nurses on units where nonadministration was higher were more likely to believe that VTE prophylaxis was prescribed for patients unnecessarily, and that they could use their clinical judgement to determine when it was appropriate to omit doses of pharmacologic prophylaxis. Our team also examined patient preferences in regard to VTE prophylaxis. In a survey of 227 consecutive medical and surgical inpatients, we found that 60% of patients would prefer an oral route of administration if available. Patients with a preference for a parenteral route of administration (27.5%) were less likely to refuse prophylaxis (37.5% vs 51.3%, P < 0.0001). These findings underscore the fact that unit culture, nursing attitudes and beliefs, and patient preferences have an important influence on medication administration, and that nurse–patient communication is an important target for modifying adherence.

PATIENT-CENTERED APPROACHES TO IMPROVE VTE PROPHYLAXIS ADMINISTRATION

To address nurse- and patient-related factors that influence VTE prophylaxis administration, we applied for and received a Patient Centered Outcomes Research Institute contract to develop patient-centered interventions to engage and empower patients to take an active role in their preventive care. To achieve these aims, we partnered with 3 national patient advocacy organizations, the National Blood Clot Alliance, the North American Thrombosis Forum, and ClotCare, as well as our local Johns Hopkins Patient and Family Advisory Council. Using a modified Delphi method, we engaged patient stakeholders from the 4 collaborating organizations to build consensus on patient-centered VTE education methods. Input from this Delphi assessment was used to build educational materials including paper brochures published in 8 different languages and a 10-minute educational video filmed by an Oscar-winning documentary director featuring both clinicians and patients relating their VTE experience and the importance of VTE prevention. These educational materials are available for public use (http://www.hopkinsmedicine.org/armstrong_institute/improvement_projects/VTE/) and are being used in a trial of a patient-centered intervention bundle to reduce rates of VTE prophylaxis nonadministration. We also conducted a cluster-randomized trial to compare different approaches to nurse education (https://clinicaltrials.gov/ct2/show/NCT02301793).

ENGAGING TRAINEES IN MULTIDISCIPLINARY PATIENT SAFETY/QUALITY IMPROVEMENT INITIATIVES

Trainees from many healthcare-related disciplines have played a critical role in our quest to improve VTE prevention. Over the past 10 years, we have mentored countless medical students, public health graduate students, nursing students, residents, and postdoctoral fellows in research projects that have resulted in numerous high-quality publications. Trainees have helped to dispel staff concerns about patient falls in connection of intermittent pneumatic compression devices, identify the weaknesses of current publicly reported VTE measures, identify opportunities to improve VTE prevention practices within clinical specialties, define the role of surveillance bias in VTE outcomes reporting, discover and fully explore the important problem of missed doses of VTE prophylaxis, and summarize knowledge about VTE prevention via systematic reviews and meta-analyses. These collaborations have been a classic win-win. The mentees learn critical skills while growing their curriculum vitae with contributions to the literature, allowing them to progress in their careers (ie, obtain a residency match, faculty positions). The faculty have leveraged this work to obtain
over $3 million in extramural funding to develop interventions to study and improve the quality of VTE preventive care for hospitalized patients.

In healthcare, we have not yet achieved defect-free VTE prevention; however, we have a better understanding of the path to accomplishing this goal. In this article we describe our goal of zero harm from VTE and our learning journey to realize that goal. Although the journey never ends, a critical ingredient to the success of our program has been the multidisciplinary nature of our VTE collaborative team. The combination of expertise from medicine, surgery, nursing, pharmacy, clinical informatics, and public health has facilitated the development of innovative strategies to improve VTE prevention that integrate seamlessly into clinical workflow. The approach used for VTE can be applied to eliminate other types of harms.

Disclosures
Mr. Lau, Dr. Streiff, and Dr. Haut are supported by a grant from the Agency for Healthcare Research and Quality (1R01HS024547) titled “Individualized Performance Feedback on Venous Thromboembolism Prevention Practice” and a contract from the Patient-Centered Outcomes Research Institute titled “Preventing Venous Thromboembolism: Empowering Patients and Enabling Patient-Centered Care via Health Information Technology” (CE-12-11-4489). Mr. Lau is supported by the Institute for Excellence in Education Berkerimer Faculty Education Scholarship Grant and a contract (AD-1306-05980) from the Patient-Centered Outcomes Research Institute titled “Patient Centered Approaches to Collect Sexual Orientation/Gender Identity Information in the Emergency Department.” Ms. Hobson has given expert witness testimony in various medical malpractice cases. Dr. Streiff has received research funding from Portola and Janssen; consulted for Bio2Medical, CSL Behring, Merck, and Janssen HealthCare; and has given expert witness testimony in various medical malpractice cases. Dr. Haut receives royalties from Lippincott, Williams, and Wilkins for a book titled Avoiding Common ICU Errors. Dr. Haut is a paid consultant and speaker for the “Preventing Avoidable Venous Thromboembolism—Every Patient, Every Time” VHA/Vizient IMPERATIV Advantage Performance Improvement Collaborative. Dr. Haut is a paid consultant and speaker for the Illinois Surgical Quality Improvement Collaborative. All other authors report no disclosures.

References


