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The Johns Hopkins Venous Thromboembolism Collaborative: Multidisciplinary Team Approach to Achieve Perfect Prophylaxis

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Venous thromboembolism (VTE) 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

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 morbidity and mortality.¹ Each year it is estimated as many as 600,000 American's suffer VTE and as many as 100,000 die.² Consequently, patient safety and healthcare quality, accrediting organizations such as The Joint Commission, and federal agencies such as the Centers for Disease Control and Prevention and Agency for Healthcare Research and Quality (AHRQ) have made VTE prevention a priority.^{3–5}

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.⁶ 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,

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

Strategies to improve VTE prophylaxis ordering
Paper-based patient risk assessment forms (before computer order entry)
Mandatory evidence-based specialty-specific computer clinical decision support "smart order sets"
Group data and competitions
1-on-1 provider feedback
Pay for performance
Individualized feedback with resident scorecards
Strategies to improve VTE prophylaxis administration
Identification of missed doses as a major contributor to preventable VTE
Identification of physician, nurse and patient contributors to missed doses
Collaboration with patients to create patient-centered educational materials
Novel web-based module for nursing education
Real-time missed doses alert
Targeted 1-on-1 patient education

NOTE: Abbreviations: VTE, venous thromboembolism.

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/ μ L). 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 health-care 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% ($P < .001$) 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

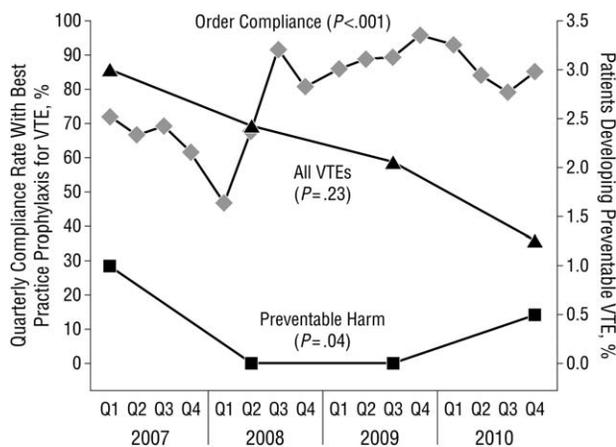


FIG. 1. The trauma CCDS order set increased prescription of risk appropriate VTE prophylaxis. Simultaneously, the order set led to a nonsignificant reduction in all symptomatic VTE and a significant reduction in preventable episodes of VTE (VTE that occur in the setting of suboptimal prophylaxis [ie, preventable harm]. Abbreviations: CCDS, Computerized Clinical Decision Support; 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 ≥ 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%, $P = 0.285$).¹³

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%, $P = 0.082$).¹⁴ These data indicate that standardizing care can potentially eliminate disparities in clinical practice.

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: 88–93). 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 $< 80\%$ = 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%).¹⁵ 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.¹⁶ 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 residents 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

RANK	UID	CURRENT MONTH			RANK	UID	CURRENT MONTH			RANK	UID	CURRENT MONTH			
		September 2013					October 2013					November 2013			
		Compliant Orders	Number of Orders	Compliance			Compliant Orders	Number of Orders	Compliance			Compliant Orders	Number of Orders	Compliance	
1	A033	11	11	100%	1	A033	4	4	100%	1	A033	4	4	100%	
1	A111	12	12	100%	1	A111	7	7	100%	1	A111	5	5	100%	
1	A092	2	2	100%	1	A072	8	8	100%	1	A072	18	18	100%	
1	A112			n/a	1	A131	8	8	100%	1	A025	9	9	100%	
1	A072	14	14	100%	1	A025	13	13	100%	1	A161	7	7	100%	
1	A131	7	7	100%	1	A043	13	13	100%	1	A092	3	3	100%	
1	A053	2	2	100%	1	A092	3	3	100%	1	A131	2	2	100%	
1	A034	4	4	100%	1	A161	10	10	100%	1	A122	12	12	100%	
1	A024	8	8	100%	1	A034	8	8	100%	1				2	100%
1	A161	2	2	100%	1	A112	2	2	100%	1				7	100%
1	A045			n/a	1	A053	1	1	100%	1				10	100%
1	A025	5	5	100%	1	A055	5	5	100%	1				5	100%
1	A035			n/a	1	A122	8	8	100%	1				5	100%
1	A043	7	7	100%	1	A024				1				6	100%
1	A055	2	2	100%	1	A035	3	3	100%	1				5	100%
1	A004	1	1	100%	1	A004	2	2	100%	1				3	100%
1	A122			n/a	1	A082				1				14	100%
1	A121	1	1	100%	19	A012	7	7	100%	1				19	75.0%
1	A014			n/a	20	A102	7	7	100%	1				20	n/a
1	A082			n/a						19	A012	7	7	100%	
1	A062			n/a						20	A102	7	7	100%	
22	A012	4	4	100%										21	100%
23	A015	9	9	100%										22	100%
23	A071	8	8	100%										23	100%
25	A052	10	11	90.9%										23	100%
26	A091	11	12	91.7%										23	100%
26	A102	8	9	88.9%										23	100%
28	A032	4	4	100%										23	100%
29	A141	13	15	86.7%										23	100%
30	A005	9	9	100%										23	100%
31	A023	14	15	93.3%										23	100%
32	A051	2	2	100%										23	100%
32	A081	6	7	85.7%										23	100%
34	A042	7	8	87.5%										23	100%
				85.7%										23	100%
				0.0%										23	100%
				100%										23	100%
				85.7%										23	100%
				100%										23	100%
				83.3%										23	100%
				50.0%										23	100%
				50.0%										23	100%
				66.7%										23	100%
44	A021	5	12	41.7%										23	100%
45	A003	5	5	100%										23	100%
46	A013	1	4	25.0%										23	100%
OVERALL		235	268	87.7%	Overall		260	277	93.9%	Overall		260	270	96.3%	

96.3%
Nov

93.3%
Oct

87.7%
Sept

FIG. 2. A spreadsheet listing the percentage of VTE prophylaxis orders written by individual surgical residents that were risk appropriate for the months of September 2013 (baseline), October 2013, and November 2013 (first and second months of feedback) shows a significant improvement in prescription of risk-appropriate VTE prophylaxis. Abbreviations: VTE, venous thromboembolism.

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%, $P = 0.046$).¹⁷ 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 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 doses, 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.¹⁸ 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.¹⁹ Louis et al. noted that nonadministration of ≥ 1 dose of VTE prophylaxis was associated with a significant increase in risk for hospital acquired VTE.²⁰ 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.²¹ 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.²² 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%, $P < 0.0001$).²³ 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.²⁴ 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,²⁵ identify the weaknesses of current publicly reported VTE measures,²⁶⁻²⁹ identify opportunities to improve VTE prevention practices within clinical specialties,³⁰⁻³² define the role of surveillance bias in VTE outcomes reporting,³³⁻³⁵ discover and fully explore the important problem of missed doses of VTE prophylaxis,^{18,21-23,36} and summarize knowledge about VTE prevention via systematic reviews and meta-analyses.³⁷⁻³⁹ 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

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References

- Streiff MB, Lau BD. Thromboprophylaxis in nonsurgical patients. *Hematology Am Soc Hematol Educ Program*. 2012;2012:631–637.
- Office of the Surgeon General (US); National Heart, Lung, and Blood Institute (US). The Surgeon General’s Call to Action to Prevent Deep Vein Thrombosis and Pulmonary Embolism. Rockville, MD: Office of the Surgeon General; 2008.
- Haut ER, Lau BD. Prevention of venous thromboembolism: brief update review. In: *Making Health Care Safer II: An Updated Critical Analysis of the Evidence for Patient Safety Practices*. Rockville, MD: Agency for Healthcare Research and Quality; 2013.
- Shekelle PG, Pronovost PJ, Wachter RM, et al. The top patient safety strategies that can be encouraged for adoption now. *Ann Intern Med*. 2013;158:365–368.
- Lau BD, Haut ER. Practices to prevent venous thromboembolism: a brief review. *BMJ Qual Saf*. 2014;23:187–195.
- Cohen AT, Tapson VF, Bergmann JF, et al. Venous thromboembolism risk and prophylaxis in the acute hospital care setting (ENDORSE study): a multinational cross-sectional study. *Lancet*. 2008;371:387–394.
- Streiff MB, Haut ER. The CMS ruling on venous thromboembolism after total knee or hip arthroplasty: weighing risks and benefits. *JAMA*. 2009;301:1063–1065.
- Lau BD, Haut ER, Hobson DB, et al. ICD-9 code-based venous thromboembolism performance targets fail to measure up. *Am J Med Qual*. 2016;31(5):448–453.
- Mayer RS, Streiff MB, Hobson DB, Halpern DE, Berenholtz SM. Evidence-based venous thromboembolism prophylaxis is associated with a six-fold decrease in numbers of symptomatic venous thromboembolisms in rehabilitation inpatients. *PM R*. 2011;3:1111–1115.e1.

- Pronovost PJ, Berenholtz SM, Needham DM. Translating evidence into practice: a model for large scale knowledge translation. *BMJ*. 2008;337:a1714.
- Streiff MB, Carolan HT, Hobson DB, et al. Lessons from the Johns Hopkins Multi-Disciplinary Venous Thromboembolism (VTE) Prevention Collaborative. *BMJ*. 2012;344:e3935.
- Haut ER, Lau BD, Kraenzlin FS, et al. Improved prophylaxis and decreased rates of preventable harm with the use of a mandatory computerized clinical decision support tool for prophylaxis for venous thromboembolism in trauma. *Arch Surg*. 2012;147:901–907.
- Zeidan AM, Streiff MB, Lau BD, et al. Impact of a venous thromboembolism prophylaxis “smart order set”: improved compliance, fewer events. *Am J Hematol*. 2013;88(7):545–549.
- Lau BD, Haider AH, Streiff MB, et al. Eliminating health care disparities with mandatory clinical decision support: the venous thromboembolism (VTE) example. *Med Care*. 2015;53:18–24.
- Michtalik HJ, Carolan HT, Haut ER, et al. Use of provider-level dashboards and pay-for-performance in venous thromboembolism prophylaxis. *J Hosp Med*. 2015;10:172–178.
- Lau BD, Streiff MB, Pronovost PJ, Haider AH, Efron DT, Haut ER. Attending physician performance measure scores and resident physicians’ ordering practices. *JAMA Surg*. 2015;150:813–814.
- Lau BD, Arnaoutakis GJ, Streiff MB, et al. Individualized performance feedback to surgical residents improves appropriate venous thromboembolism prophylaxis prescription and reduces potentially preventable VTE: a prospective cohort study [published online November 25, 2015]. *Ann Surg*. doi: 10.1097/SLA.0000000000001512.
- Shermock KM, Lau BD, Haut ER, et al. Patterns of non-administration of ordered doses of venous thromboembolism prophylaxis: implications for novel intervention strategies. *PLoS One*. 2013;8:e66311.
- Haut ER, Lau BD, Kraus PS, et al. Preventability of hospital-acquired venous thromboembolism. *JAMA Surg*. 2015;150(9):912–915.
- Louis SG, Sato M, Geraci T, et al. Correlation of missed doses of enoxaparin with increased incidence of deep vein thrombosis in trauma and general surgery patients. *JAMA Surg*. 2014;149:365–370.
- Piechowski KL, Elder S, Efron DT, et al. Prescriber knowledge and attitudes regarding non-administration of prescribed pharmacologic venous thromboembolism prophylaxis [published online May 21, 2016]. *J Thromb Thrombolysis*. doi:10.1007/s11239-016-1378-8.
- Elder S, Hobson DB, Rand CS, et al. Hidden barriers to delivery of pharmacological venous thromboembolism prophylaxis: the role of nursing beliefs and practices. *J Patient Saf*. 2016;12:63–68.
- Wong A, Kraus PS, Lau BD, et al. Patient preferences regarding pharmacologic venous thromboembolism prophylaxis. *J Hosp Med*. 2015;10:108–111.
- Popoola VO, Lau BD, Shihab HM, et al. Patient preferences for receiving education on venous thromboembolism prevention—a survey of stakeholder organizations. *PLoS One*. 2016;11:e0152084.
- Boelig MM, Streiff MB, Hobson DB, Kraus PS, Pronovost PJ, Haut ER. Are sequential compression devices commonly associated with in-hospital falls? A myth-busters review using the patient safety net database. *J Patient Saf*. 2011;7:77–79.
- Johnbull EA, Lau BD, Schneider EB, Streiff MB, Haut ER. No association between hospital-reported perioperative venous thromboembolism prophylaxis and outcome rates in publicly reported data. *JAMA Surg*. 2014;149:400–401.
- Aboagye JK, Lau BD, Schneider EB, Streiff MB, Haut ER. Linking processes and outcomes: a key strategy to prevent and report harm from venous thromboembolism in surgical patients. *JAMA Surg*. 2013;148:299–300.
- Kardooni S, Haut ER, Chang DC, et al. Hazards of benchmarking complications with the National Trauma Data Bank: numerators in search of denominators. *J Trauma*. 2008;64:273–277; discussion 277–279.
- Farrow NE, Lau BD, JohnBull EA, et al. Is the meaningful use venous thromboembolism VTE-6 measure meaningful? A retrospective analysis of one hospital’s VTE-6 cases. *Jt Comm J Qual Patient Saf*. 2016;42(9):410–416.
- Monn MF, Haut ER, Lau BD, et al. Is venous thromboembolism in colorectal surgery patients preventable or inevitable? One institution’s experience. *J Am Coll Surg*. 2013;216:395–401.e1.
- Weiss MJ, Kim Y, Ejaz A, et al. Venous thromboembolic prophylaxis after a hepatic resection: patterns of care among liver surgeons. *HPB (Oxford)*. 2014;16:892–898.
- Ejaz A, Spolverato G, Kim Y, et al. Defining incidence and risk factors of venous thromboembolism after hepatectomy. *J Gastrointest Surg*. 2014;18:1116–1124.
- Haut ER, Noll K, Efron DT, et al. Can increased incidence of deep vein thrombosis (DVT) be used as a marker of quality of care in the absence of standardized screening? The potential effect of surveillance bias on reported DVT rates after trauma. *J Trauma*. 2007;63:1132–1135; discussion 1135–1137.
- Haut ER, Pronovost PJ. Surveillance bias in outcomes reporting. *JAMA*. 2011;305:2462–2463.

35. Pierce CA, Haut ER, Kardooni S, et al. Surveillance bias and deep vein thrombosis in the national trauma data bank: the more we look, the more we find. *J Trauma*. 2008;64:932–936; discussion 936–937.
36. Newman MJ, Kraus PS, Shermock KM, et al. Nonadministration of thromboprophylaxis in hospitalized patients with HIV: a missed opportunity for prevention? *J Hosp Med*. 2014;9:215–220.
37. Singh S, Haut ER, Brotman DJ, et al. Pharmacologic and mechanical prophylaxis of venous thromboembolism among special populations. Comparative effectiveness review No. 116. Prepared by the Johns Hopkins University Evidence-based Practice Center under Contract No. 290-2007-10061-L.) AHRQ Publication No. 13-EHC082–1. Rockville, MD: Agency for Healthcare Research and Quality; 2013.
38. Brotman DJ, Shihab HM, Prakasa KR, et al. Pharmacologic and mechanical strategies for preventing venous thromboembolism after bariatric surgery: a systematic review and meta-analysis. *JAMA Surg*. 2013;148:675–686.
39. Haut ER, Garcia LJ, Shihab HM, et al. The effectiveness of prophylactic inferior vena cava filters in trauma patients: a systematic review and meta-analysis. *JAMA Surg*. 2014;149:194–202.