CLINICAL RESEARCH STUDY

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Electronic Alerts, Comparative Practitioner Metrics, and Education Improves Thromboprophylaxis and Reduces Thrombosis

Scott C. Woller, MD,[a,b] Scott M. Stevens, MD,[a,b] R. Scott Evans, PhD,[c,d] Daniel G. Wray, MS, MBA,[e] John C. Christensen, MD,[a,b] Valerie T. Aston, BS,[a] Matthew H. Wayne, MBA,[f] James F. Lloyd, BS,[c] Emily L. Wilson, MS,[g] C. Gregory Elliott, MD[a,b]

[a]Intermountain Medical Center, Murray, Utah; [b]Department of Internal Medicine, University of Utah School of Medicine, Salt Lake City; [c]Department of Medical Informatics, Intermountain Healthcare, Murray, Utah; [d]Department of Biomedical Informatics, University of Utah, Salt Lake City; [e]Twine Clinical Consulting, LLC, Park City, Utah; [f]Medical Impact Ventures, LLC, Austin, Tex; [g]Division of Statistics, Intermountain Medical Center, Murray, Utah.

ABSTRACT

BACKGROUND: Venous thromboembolism chemoprophylaxis remains underutilized in hospitalized medical patients at high risk for venous thromboembolism. We assessed the effect of a health care quality-improvement initiative comprised of a targeted electronic alert, comparative practitioner metrics, and practitioner-specific continuing medical education on the rate of appropriate venous thromboembolism chemoprophylaxis provided to medical inpatients at high risk for venous thromboembolism.

METHODS: We performed a multicenter prospective observational cohort study in an urban Utah hospital system. All medical patients admitted to 1 of 2 participating hospitals from April 1, 2010 to December 31, 2012 were eligible. Patients were members of the "control" (April 1, 2010 to December 31, 2010), "intervention" (January 1, 2011 to December 31, 2011), or "subsequent year" (January 1, 2012 to December 31, 2012) group. The primary outcome was the rate of appropriate chemoprophylaxis among patients at high risk for venous thromboembolism. Secondary outcomes included rates of symptomatic venous thromboembolism, major bleeding, all-cause mortality, heparin-induced thrombocytopenia, physician satisfaction, and alert fatigue.

RESULTS: The rate of appropriate chemoprophylaxis among patients at high risk for venous thromboembolism increased (66.1% control period vs 81.0% intervention period vs 88.1% subsequent year; $P < .001$ for each comparison). A significant reduction of 90-day symptomatic venous thromboembolism accompanied the quality initiative (9.3% control period, 9.7% intervention period, 6.7% subsequent year; $P = .009$); 30-day venous thromboembolism rates also significantly decreased.

CONCLUSIONS: A multifaceted intervention was associated with increased appropriate venous thromboembolism chemoprophylaxis among medical inpatients at high risk for venous thromboembolism and reduced symptomatic venous thromboembolism. The effect of the intervention was sustained.

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KEYWORDS: Chemoprophylaxis medical patient; Prevention; Quality improvement; Venous thromboembolism

Without prophylaxis, up to 15% of hospitalized medical patients will develop venous thromboembolism (characterized as deep vein thrombosis or pulmonary embolism)[1-3] during hospitalization. Yet only about 40% of hospitalized medical patients at high risk for venous thromboembolism receive appropriate thromboprophylaxis, defined as chemoprophylaxis with low-molecular-weight heparin, unfractionated heparin, or fondaparinux.[4-6]

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Requests for reprints should be addressed to Scott C. Woller, MD, Eccles Outpatient Care Center, 5121 Cottonwood Street, PO Box 57700, Murray, UT 84157-7000.

E-mail address: scott.woller@imail.org

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Adoption of formalized venous thromboembolism risk assessment models has been recommended by guideline authors[7-12]; however, they have not been uniformly adopted.[13,14] Selective application of chemoprophylaxis avoids rare adverse events associated with chemoprophylaxis such as bleeding and heparin-induced thrombocytopenia,[15,16] that can be associated with substantial morbidity, mortality, and expense.[17,18] The importance of a reliable methodology to identify patients at high risk for hospital-associated venous thromboembolism and reduce that risk is highlighted by a recent Centers for Disease Control Hospital-Associated Venous Thromboembolism Reduction Challenge.[19]

Our primary objective was to report the rate of appropriate chemoprophylaxis among hospitalized medical patients at high risk for symptomatic venous thromboembolism following implementation of a multifaceted intervention including (a) targeted electronic alerts for high-risk patients, (b) comparative practitioner metrics, and (c) practitioner-specific continuing medical education. Appropriate venous thromboembolism prophylaxis rates were compared over a 3-year period. Secondarily we report 30- and 90-day rates of symptomatic venous thromboembolism, in-hospital major bleeding, in-hospital heparin-induced thrombocytopenia, in-hospital and 90-day all-cause mortality, practitioner response to electronic messaging, alert fatigue, and practitioner satisfaction with the intervention. We also evaluated outcomes in patients admitted to the medical service who were not at high risk for venous thromboembolism. These data are reported in the Appendix (online). The Intermountain Healthcare Institutional Review Board approved this study (Institutional Review Board #1019819).

CLINICAL SIGNIFICANCE

- Targeted electronic alerts for high-risk patients, comparative practitioner metrics, and practitioner-specific continuing medical education increased appropriate thromboprophylaxis from 66.1% to 88.1%, and it was sustained.
- Ninety-day venous thromboembolism decreased significantly from 9.3% (control period) to 6.7% (subsequent year) among high-risk patients.
- No increase in major bleeding or heparin-induced thrombocytopenia was observed with improved chemoprophylaxis.
- Hospitalists' response to the alerts increased from 19.5% (Q1) to 28.1% (Q4; $P = .006$), refuting alert fatigue.

METHODS

The multifaceted health care quality-improvement initiative, entitled the Venous Thromboembolism Reduction Initiative, was presented to all hospitalists of a multihospital urban health care hospitalist group at a Division meeting, and each hospitalist (100%) provided signed informed consent. The Venous Thromboembolism Reduction Initiative consisted of 4 components. First, an electronic venous thromboembolism risk assessment model[20,21] interrogated the electronic medical record daily and generated a venous thromboembolism risk score classifying each patient as being either high risk for venous thromboembolism (a venous thromboembolism risk score of ≥ 4 as defined by Kucher et al[20]) or not (a venous thromboembolism risk score <4 as defined by Kucher et al[20]). Second, another electronic tool interrogated the medical administration record for appropriate chemoprophylaxis as recommended by the American College of Chest Physicians[15]; or therapeutic anticoagulation (**Appendix Table 1**, online). Third, an audit-and-feedback assessment of each hospitalist's venous thromboembolism prophylaxis rates was developed that generated a monthly report of each hospitalist's performance in comparison with their de-identified peers. Fourth, a proprietary targeted online continuing medical education activity was provided (see below).

The Venous Thromboembolism Reduction Initiative began on April 1, 2010 with the prospective collection of data during the control period of 9 months. Beginning January 1, 2011 (intervention period), if a patient was: (a) high risk for venous thromboembolism and (b) not receiving appropriate chemoprophylaxis, then an electronic venous thromboembolism risk alert was sent to the attending hospitalist's pager. An electronic interface with the hospitalist billing program identified the attending hospitalist of record for each patient every day. In the intervention period and subsequent year, an electronic medical record electronic message was sent, which permitted the hospitalist to interface with the electronic alert system to document any reasons that prophylaxis was being withheld (eg, active bleeding, hospice). By doing so, the daily alert would be turned off for 5 days, and the hospitalist would be credited with having appropriately dispensed venous thromboembolism prophylaxis. At the end of the 5 days, if chemoprophylaxis had not yet been ordered, the alert would be resent.

Each hospitalist was provided a monthly e-mail link to a secure Web site where individual chemoprophylaxis performance metrics were presented along with the performance of the hospitalist's de-identified peers. Coincident with this calculation, proprietary software (Twine Clinical Consulting, LLC, Park City, Utah and Medical Impact Ventures, LLC, Austin, Texas) identified the characteristics of those patients cared for by the hospitalist that did not receive appropriate chemoprophylaxis. For example, if a given hospitalist's rate of chemoprophylaxis was 85% overall but only 35% among patients with cancer, then that hospitalist was invited to complete the continuing medical education activity entitled "Mitigating thrombosis risk

among patients with cancer." By the end of the intervention period as part of an annual Hospitalist Group incentive project, and with 100% of hospitalists participating (to avoid selection bias), each hospitalist completed a total of 6 continuing medical education offerings surrounding the importance of venous thromboembolism prophylaxis, which can be found at http://www.vte.physicianimprovement.com. During the subsequent year, no further formal interaction with the hospitalist group occurred, no further feedback was provided, and no further continuing medical education was administered. However, electronic alerts were continued and all outcomes were measured in the same fashion.

The primary outcome was prescription of appropriate venous thromboembolism chemoprophylaxis (or notation of a contraindication to prophylaxis), among medical patients identified as being at high risk for venous thrombosis. This was measured for each patient day. We used the same standards to measure appropriate prophylaxis during the control period, the intervention period, and the subsequent year.

Venous thrombosis was identified using natural language processing interrogation of the electronic medical record.[22] For a patient to be considered at high risk for venous thromboembolism, they must have spent >50% of the hospitalization classified at high risk.

Hospital-associated major bleeding was identified by electronic medical record interrogation, as we have previously performed.[23,24] We defined major bleeding by International Classification of Diseases, Ninth Revision code as bleeding into a critical space including the spinal cord, brain, eye, retroperitoneum, or pericardium; or clinically overt bleeding that was associated with the transfusion of ≥2 units of packed red blood cells. We reported major bleeding rates stratified for patients that received ≥1 dose of venous thromboembolism chemoprophylaxis compared with those who did not, after first excluding all patients with an admission diagnosis for major bleeding defined by the presence of any International Classification of Diseases, Ninth Revision code reported in Appendix Table 2 (online). Death was identified upon interrogation of the electronic medical record for a flag that denoted death, or in the Intermountain Healthcare mortality database, which incorporates an interface with state-wide mortality data. Heparin-induced thrombocytopenia was considered present if the International Classification of Diseases, Ninth Revision code of 289.84 was associated with the hospitalization. Heparin-induced thrombocytopenia was stratified for patients that received ≥1 dose of venous thromboembolism chemoprophylaxis compared with those who did not. Ninety-day electronic follow-up was completed for 100% of patients.

Alert fatigue is described as the observation that interruptive alerts, if they occur too frequently or are felt to be clinically irrelevant in some instances, are associated with physicians ignoring the alert.[25,26] In an attempt to measure if the hospitalists' experienced alert fatigue over the course of the study, the hospitalist response to the alert was captured. To report hospitalists' response to alerts, we calculated the percent of patients for whom an alert was generated that subsequently had prophylaxis ordered, or contraindication for prophylaxis entered, within 24 hours.

Statistical Analysis

Demographic information was summarized overall, as well as for the high- and low-risk groups (**Table 1**). The rates for all primary and secondary outcomes from the study period, intervention period, and subsequent year were formally compared using chi-squared tests for proportions, or Fisher's exact test when appropriate. A significance level of 0.05 was used for all comparisons, and multiple comparisons were controlled for using a false discovery rate of 5%.[27] Ninety-five percent exact confidence intervals (CIs) were also calculated for all primary and secondary outcomes. All analyses were conducted using the R Statistical Package.[28]

RESULTS

Appropriate Prophylaxis

There were 63,717 patient-days that occurred during the study; 18,043 patient-days in the control period (30.8% high risk; n = 5558 patient days), 22,843 patient-days in the intervention period (34.1% high risk; n = 7788 patient days), and 22,831 patient-days (24.4% high risk; n = 5577 patient days) during the subsequent year. The primary outcome, rate of appropriate venous thromboembolism chemoprophylaxis among patients at high risk for venous thromboembolism, increased significantly from 66.1% (95% CI, 64.8%-67.3%) during the control period to 81.0% (95% CI, 80.1%-81.8%) during the study period to 88.1% (95% CI, 87.2%-88.9%) during the subsequent year, with $P < .001$ for all comparisons (**Figure 1**). Hospitalists indicated a contraindication to venous thromboembolism chemoprophylaxis for 222 of 2303 (9.6%) high-risk patient encounters during the intervention period. After excluding days when venous thromboembolism chemoprophylaxis was identified by the hospitalist as contraindicated during the intervention period, to allow for a direct comparison with the control period, the rate of appropriate venous thromboembolism chemoprophylaxis was 75.2% (95% CI, 74.2%-76.2%); significantly higher than during the control period (66.1%; 95% CI 64.8-67.3%); $P < .001$. Hospitalists indicated a contraindication to venous thromboembolism chemoprophylaxis for 274 of 1767 (15.5%) high-risk patient encounters during the subsequent period; significantly greater than the intervention period ($P < .001$). After excluding days when venous thromboembolism chemoprophylaxis was identified by the hospitalist as contraindicated during the subsequent period to allow for a direct comparison with the control period, the rate of appropriate venous thromboembolism chemoprophylaxis was 76.8% (95% CI, 75.6%-77.9%), significantly higher than during the intervention period ($P = .039$). The rate of prescription of appropriate venous thromboembolism chemoprophylaxis by each individual hospitalist is represented in **Figure 2**.

Table 1 Patient Demographics

Characteristic	Overall (n = 20,186)	High Risk* (n = 5338)	Non-High Risk† (n = 14,848)
Demographic			
Age:‡ median (IQR)	62 (46-77)	71 (57-80)	59 (42-74)
Female: n (%)	11,439 (57)	3170 (59)	8269 (56)
Comorbidities: n (%)			
Cancer‡	1745 (9)	1582 (30)	163 (1)
Obesity‡	6038 (30)	2785 (52)	3253 (22)
Hypercoagulability‡	710 (4)	686 (13)	24 (1)
Prior VTE‡	3508 (17)	3262 (61)	246 (2)
Hormone replacement therapy‡	855 (4)	397 (7)	458 (3)
Congestive heart failure	5273 (26)	2167 (41)	3106 (21)
Diabetes	6366 (32)	2095 (39)	4271 (29)
Current tobacco use	6013 (30)	1265 (24)	4748 (32)
Hospital detail: n (%)			
Bed rest‡	6713 (33)	3277 (61)	3436 (23)
Surgery (in the past month)‡	1672 (8)	1270 (24)	402 (3)
Central venous catheter	1329 (7)	518 (10)	811 (6)
Infection	6049 (30)	1840 (34)	4209 (28)
PICC line	1928 (10)	786 (15)	1142 (8)
Sepsis	4101 (20)	1195 (22)	2906 (20)
ICU admission	3428 (17)	1073 (20)	2355 (16)
Length of stay: median (IQR)	2.7 (1.6-4.2)	3.1 (1.9-5.2)	2.5 (1.6-3.9)

ICU = intensive care unit; IQR = interquartile range; PICC = peripherally inserted central catheter; VTE = venous thromboembolism.
*Patients at high risk for at least 50% of their hospital stay were classified as high risk overall.
†See Appendix for outcomes among non-high-risk patients.
‡Component of the risk-stratification score.

All secondary outcomes are reported in **Table 2**. **Appendix Figure 1** and **appendix Figure 2** demonstrate the rate of appropriate chemoprophylaxis by individual hospital and among non-high risk patients, respectively. **Appendix Figure 3** and **Figure 4** demonstrate the rate of venous thromboembolism by individual hospital, and clinically important outcomes among non-high risk patients, respectively.

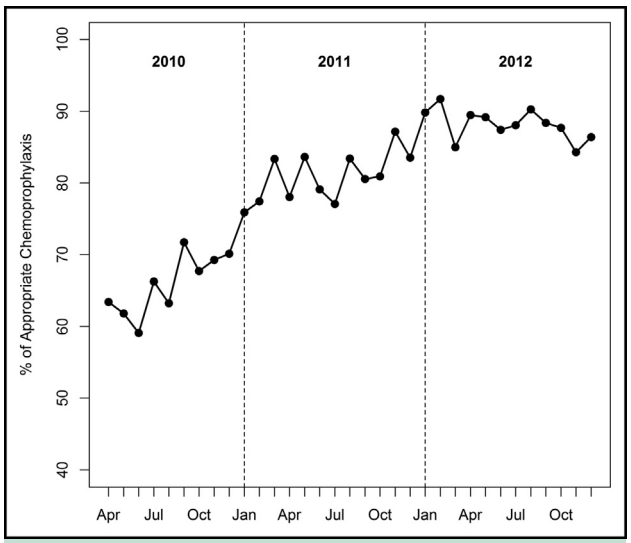

Figure 1 Each dot represents the average rate of appropriate chemoprophylaxis for the month represented.

Symptomatic Venous Thromboembolism

The 90-day rate of symptomatic venous thromboembolism among high-risk patients during the control period, the intervention period, and the subsequent year was 9.3%, 9.7%, and 6.7%, respectively, and decreased significantly ($P = .009$). The 30-day rate of symptomatic venous thromboembolism among high-risk patients during the control period, the intervention period, and the subsequent year was 7.3%, 7.9%, and 4.9%, respectively, and decreased significantly ($P = .003$).

Major Bleeding

Less major bleeding was observed among high-risk patients that received ≥1 dose of chemoprophylaxis and those that did not (control: 0.8% vs 1.8%; $P = .183$; intervention: 0.8% vs 2.0%; $P = .049$; subsequent year: 1.1% vs 2.1%; $P = .139$). No difference existed upon comparing sequential years. No difference was observed in the rate of major bleeding among patients that either did or did not receive chemoprophylaxis upon comparing sequential years.

Heparin-Induced Thrombocytopenia

Among high-risk patients that received ≥1 dose of chemoprophylaxis, in-hospital heparin-induced thrombocytopenia was identified in 1 of 1077 (0.1%) in control; 3 of 1830 (0.2%) in intervention; and 1 of 1428 (0.1%) in the subsequent year. The rate of in-hospital heparin-induced

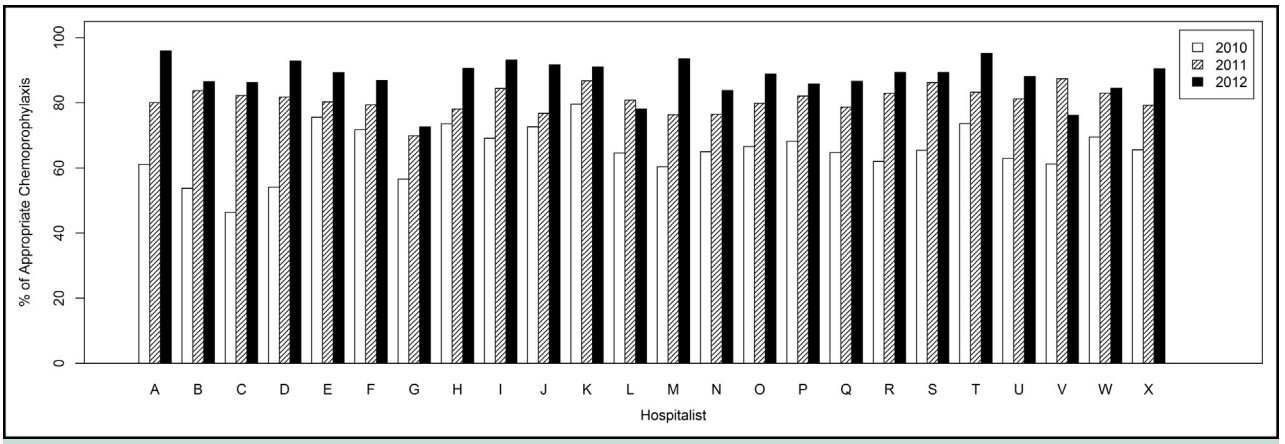

Figure 2 Each bar represents the annual rate of appropriate chemoprophylaxis ordered by each hospitalist (A-X) for the years 2010, 2011, and 2012.

thrombocytopenia was not significantly different from year to year ($P = .96$).

Mortality

Among high-risk patients, neither the rate of in-hospital mortality (control: 2.4%; intervention: 2.1%; subsequent year: 1.6%); nor the 90-day mortality rate (control: 13.0%; intervention: 12.7%; subsequent year: 12.5%) differed significantly.

Hospitalist Satisfaction

Hospitalist satisfaction surveys were completed by 18 hospitalists 1 month after initiation of the Venous Thromboembolism Reduction Initiative, and by 16 hospitalists after the intervention period. The Venous Thromboembolism Reduction Initiative was broadly well received, and Hospitalist survey results are found in **Appendix Table 5** (online).

Alert Fatigue

There were 1619 alerts sent during the intervention period. Hospitalist behavior was considered changed if within 24 hours of an alert, appropriate chemoprophylaxis was ordered, or if a contraindication to chemoprophylaxis was recorded. Of the 1619 alerts sent during the intervention period, 387 (23.9%) were associated with a behavioral change. Hospitalist response to an alert increased significantly, comparing the first with the last quarter of the intervention period from 19.5% to 28.1% ($P = .006$).

DISCUSSION

The Venous Thromboembolism Reduction Initiative was associated with an increased rate of appropriate venous thromboembolism prophylaxis and reduced rates of symptomatic venous thromboembolism in medical inpatients with a high risk for the development of venous thromboembolism.

Table 2 Rate of Venous Thromboembolism, Mortality, Major Bleeding, and Heparin-Induced Thrombocytopenia Among High-Risk Patients Stratified by Year

% (95% Confidence Interval)	2010	2011	2012	*P* Value
90-day VTE, %	9.3 (7.8-10.9)	9.7 (8.5-11.0)	6.7 (5.6-8.0)	.009
30-day VTE, %	7.3 (6.0-8.8)	7.9 (6.8-9.1)	4.9 (3.9-6.0)	.003
90-day all-cause mortality, %	13.0 (11.2-14.9)	12.7 (11.3-14.1)	12.5 (10.9-14.1)	.96
In-hospital mortality, %	2.4 (1.7-3.4)	2.1 (1.5-2.7)	1.6 (1.0-2.3)	.43
Alerted, %	61.1* (58.5-63.7)	41.2 (39.2-43.3)	35.3 (33.0-37.6)	<.001
Yes: 90-day VTE, %	8.4* (6.6-10.5)	9.7 (7.9-11.8)	7.3 (5.4-9.7)	.43
No: 90-day VTE, %	10.6 (8.1-13.6)	9.6 (8.1-11.4)	6.4 (5.0-8.0)	.009
Thromboprophylaxis				
Yes: in-hospital HIT,† %	0.1 (0.0-0.5)	0.2 (0.0-0.5)	0.1 (0.0-0.4)	.96
Yes: Major bleeding,† %	0.8 (0.4-1.6)	0.8 (0.5-1.3)	1.1 (0.6-1.7)	.96
No: Major bleeding,† %	1.8 (0.6-4.1)	2.0 (0.9-3.9)	2.1 (0.8-4.6)	.96

The *P*-value is from an overall hypothesis test exploring whether any difference exists for the parameter across all 3 years, controlled for a false discovery rate of 5%.

HIT = heparin-induced thrombocytopenia; VTE = venous thromboembolism.

*In the control period (2010) no alert was sent, however it would have been given the criteria applied during the study period and subsequent year.

†Thromboprophylaxis is defined as ever receiving a dose of chemoprophylaxis.

The rate of major bleeding and the rate of heparin-induced thrombocytopenia did not increase significantly, even as the rates of anticoagulant prophylaxis increased. These observations are consistent with reports of prior randomized controlled trials of venous thromboembolism prophylaxis[1-3] and electronic alerts.[9,13,20] The increased rate of venous thromboembolism prophylaxis and reduced rates of symptomatic venous thromboembolism were sustained for more than 1 year after we initiated the Venous Thromboembolism Reduction Initiative. We demonstrated that alerts sent only about those patients thought to benefit most from the application of venous thromboembolism chemoprophylaxis were well received, with no indication of alert fatigue.

Our study is unique given that, compared with former studies that presented a sampling of inpatients over a similar duration of time,[29] and those enrolling fewer patients,[30,31] ours is the largest prospective study of hospitalized medical patients over the longest duration of time reported to date.

Our study design allows us to report an association between the outcomes measured and the Venous Thromboembolism Reduction Initiative, but does not allow us to prove causation. We do, however, further validate the role of venous thrombosis risk stratification and electronic alert adoption established by others.[20] We acknowledge that concomitant secular trends may have influenced hospitalist application of chemoprophylaxis.[13,32,33] Nonetheless, the association between the Venous Thromboembolism Reduction Initiative implementation and the change in outcomes, and the rate at which hospitalist physicians responded to alerts with a behavior change, suggests a strong effect from the Venous Thromboembolism Reduction Initiative.

Our observation that significantly fewer alerts were sent during the year subsequent to the intervention period yet, the rate of appropriate chemoprophylaxis increased, is additionally supportive of the Venous Thromboembolism Reduction Initiative facilitating hospitalists' learning. In fact, the hospitalist response to the alerts increased over time, which refutes concern surrounding alert fatigue. This observation suggests that over time, the hospitalists' perceived increased value associated with the alerts. This conclusion is also supported by the favorable ratings observed in the hospitalist satisfaction survey. Research assessing the variables that effect hospitalists' prescriptive behavior may improve the efficiency of future alerting.

We believe that the higher rate of major bleeding observed among those patients for whom chemoprophylaxis was withheld was because hospitalists refrained from prescribing chemoprophylaxis among patients that were at an increased risk for bleeding. The overall rate of heparin-induced thrombocytopenia we observed was low and analogous to previously reported rates.[17,30,34,35] Similar to others,[29,30] we did not observe an increase in heparin-induced thrombocytopenia or major bleeding rates as chemoprophylaxis rates improved. In-hospital and 90-day all-cause mortality did not differ between years.

Strengths of our study included that we perform this intervention at 2 large metropolitan teaching hospitals with one hospitalist group and with 100% of hospitalists participating. We report nearly 3 years of data capture and follow-up and describe in detail an initiative that was associated with a sustained change in physician behavior that improved thromboprophylaxis, was accompanied by reduced rates of symptomatic venous thromboembolism over time, and was well received. We achieved 100% electronic follow-up for the secondary outcomes reported.

Limitations of our study include those attributable to performing this prospective interventional study in the setting of routine clinical practice. These include the secular influences surrounding venous thromboembolism prophylaxis, and those attributable to clinical care. We were not able to report the prescription or utilization of mechanical prophylactic devices. Additionally, our study is limited by the constraints of defining thrombosis outcomes using natural language processing and an inability to capture patient events that occurred outside our hospital system. However, we have reported a high degree of accuracy in the utility of this approach to identify patients with thrombosis.[22,36]

In conclusion, the Venous Thromboembolism Reduction Initiative was associated with a significant increase in appropriate venous thromboembolism chemoprophylaxis of medical inpatients, a reduction in hospital-acquired symptomatic venous thromboembolism, and was well received by clinicians. Intermountain Healthcare was awarded a 2015 Centers for Disease Control and Prevention Hospital-Associated Venous Thromboembolism Reduction Champion award for the outcomes reported in this manuscript.[37]

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Appendix Table 1 Definition of Appropriate Chemoprophylaxis and Active Anticoagulation

Drug	Dose	Frequency
Enoxaparin	40 mg	Daily
Enoxaparin	30 mg	Twice daily
Enoxaparin	30 mg	Daily
Fondaparinux	2.5 mg	Daily
Unfractionated heparin	5000 IU	Twice daily
Unfractionated heparin	5000 IU	Thrice daily
Dalteparin	5000 units	Daily
Active anticoagulation		
Enoxaparin	1 mg/kg	Twice daily
Enoxaparin	1.5 mg/kg	Daily
Heparin	Pre-mix	Drip
Fondaparinux	5 mg	Daily
Fondaparinux	7.5 mg	Daily
Fondaparinux	10 mg	Daily
Dalteparin	>5000 units	Daily
Argatroban	Pre-mix	Drip
Bivalirudin	Pre-mix	Drip
Lepirudin	Pre-mix	Drip
Tirofiban	Pre-mix	Drip
Rivaroxaban*	Tablet	Twice daily
Apixaban*	Tablet	Daily or twice daily
COAG study drug (warfarin)	Tablet any dose	Daily
ADOPT study drug (apixaban)	Tablet any dose	Daily or twice daily
dabigatran	Tablet any dose	Daily or twice daily
	or	
Warfarin managed by pharmacist ordered		
	or	
INR ≥1.8†		

INR = international normalized ratio.
*These were study drugs without an indication for thromboprophylaxis.
†INR ≥identified upon interrogation of the electronic medical record current laboratory results.

Appendix Table 2 Definition of Major Bleeding

Major Bleeding Was Considered Present if Either of the Below Criteria Were Fulfilled
The presence of any of the following ICD9 codes associated with the hospitalization:
'430', '431', '432', '4320', '4321', '4329', '8520', '8521', '8522', '8523', '8524', '8525', '8002', '8012', '8013', '8017', '8018', '8032', '8033', '8037', '8038', '8042', '8043', '8047', '8048', '853', '36281', '37632', '37923', '7191', '56881', '4230'
OR
The presence of one of the following ICD9 codes in conjunction with a transfusion of ≥2 units of packed red blood cells:
'4552', '4555', '4558', '4590', '4560', '4562', '5307', '5308', '5310', '5312', '5314', '5316', '5320', '5322', '5324', '5326', '5330', '5332', '5334', '5336', '5340', '5342', '5344', '5346', '5350', '5351', '5352', '5353', '5354', '5355', '5356', '5378', '5620', '5621', '5688', '5693', '56985', '578', '5938', '5997', '6238', '6262', '6266', '7847', '7863'

ICD9 = International Classification of Diseases, Ninth Revision.

Appendix Table 3 Outcome Rate of Venous Thromboembolism and Mortality by Hospital Stratified by Year

	IMC				LDS			
	2010	2011	2012	*P* Value	2010	2011	2012	*P* Value
High-risk patients:								
90-day VTE, %	8.8	10.5	6.8	.005	10.9	7.2	6.6	.171
30-day VTE, %	7.0	8.8	5.1	.002	8.3	5.3	4.1	.162
90-day all-cause mortality, %	13.3	13.8	13.0	.82	11.9	9.3	10.7	.55
In-hospital mortality, %	2.7	2.0	1.7	.30	1.6	2.1	1.2	.55
Alerted, %	58.8*	39.7	34.4	<.001	68.9*	45.6	38.1	<.001
Yes: 90 day VTE, %	7.6	10.8	7.6	.115	10.7	6.9	6.4	.38
No: 90 day VTE, %	10.4	10.3	6.3	.009	11.3	7.5	6.7	.46
Non-high-risk patients:								
90-day VTE, %	3.1	2.6	2.5	.52	2.8	1.8	2.5	.41
30-day VTE, %	2.3	1.9	1.8	.52	2.2	1.2	1.7	.35
90-day all-cause mortality, %	5.9	5.9	7.1	.28	5.1	4.5	4.9	.77
In-hospital mortality, %	1.3	0.9	0.9	.52	1.2	0.9	0.5	.35
Thromboprophylaxis†								
Yes: 90-day VTE, %	3.4	2.7	2.7	.53	3.0	2.4	2.3	.77
No: 90-day VTE, %	2.9	2.4	2.3	.53	2.6	0.8	2.8	.24

IMC = Intermountain Medical Center; LDS = LDS Hospital; VTE = venous thromboembolism.

*In the control period (2010) no alert was sent, however it would have been given the criteria.

†Thromboprophylaxis defined as chemoprophylaxis for ≥75% of hospitalized.

Appendix Table 4 Outcome Rate of Venous Thromboembolism, Mortality, Major Bleeding, and Heparin-Induced Thrombocytopenia Among Non-High-Risk Patients Stratified by Year

	2010 % (95% CI)	2011 % (95% CI)	2012 % (95% CI)	*P* Value
90-day VTE, %	3.0 (2.5-3.6)	2.4 (2.0-2.8)	2.5 (2.1-3.0)	.29
30-day VTE, %	2.3 (1.8-2.8)	1.7 (1.4-2.1)	1.8 (1.5-2.2)	.29
90-day all-cause mortality, %	5.7 (5.0-6.5)	5.5 (4.9-6.2)	6.5 (5.9-7.2)	.29
In-hospital all-cause mortality, %	1.3 (0.9-1.7)	0.9 (0.7-1.2)	0.8 (0.6-1.1)	.29
Thromboprophylaxis				
Yes: 90-day VTE,* %	3.3 (2.4-4.3)	2.6 (2.1-3.2)	2.6 (2.1-3.2)	.44
No: 90-day VTE,* %	2.8 (2.1-3.6)	1.9 (1.3-2.7)	2.4 (1.8-3.1)	.29
Yes: in-hospital HIT,† %	0.1 (0.0-0.3)	0.0 (0.0-0.1)	0.1 (0.0-0.2)	.29
Yes: major bleeding,† %	0.5 (0.2-0.8)	0.4 (0.2-0.7)	0.3 (0.2-0.5)	.54
No: major bleeding,† %	1.6 (0.9-2.6)	1.4 (0.8-2.2)	1.5 (1.0-2.2)	.96

CI = confidence interval; HIT = heparin-induced thrombocytopenia; VTE = venous thromboembolism.

The *P* value is from an overall hypothesis test exploring whether any difference exists for the parameter across all 3 years, controlled for a false discovery rate of 5%.

*Thromboprophylaxis defined as chemoprophylaxis for ≥75% of hospitalized days.

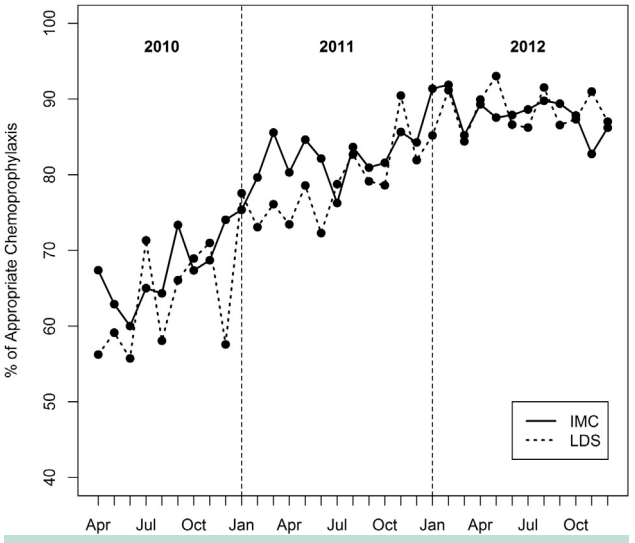
†Thromboprophylaxis is defined as ever receiving a dose of chemoprophylaxis.

Appendix Table 5 Hospitalist Satisfaction Survey Results of the VTE Reduction Initiative*

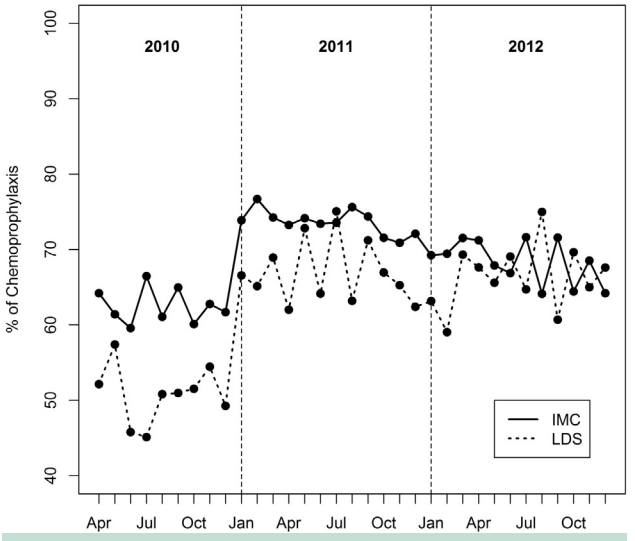
Question	Overall Mean (SD)	Pre Mean (SD)	Post Mean (SD)	*P* Value
Positively impacted the way that I approach VTE prophylaxis	5.2 (0.6)	5.1 (0.6)	5.3 (0.6)	.25
Positively impacted outcomes in my patients	4.9 (0.7)	4.7 (0.6)	5.2 (0.8)	.039
Overall, has been valuable	5.2 (0.7)	5.1 (0.7)	5.3 (0.7)	.38
I would be supportive of continuing the initiative for another year	5.2 (0.8)	5.1 (0.8)	5.3 (0.8)	.48
I would be supportive of extending the initiative to additional IHC hospitals	5.6 (0.6)	5.4 (0.5)	5.7 (0.6)	.161

IHC = Intermountain Healthcare; VTE = venous thromboembolism.

*Administered at the time of introduction to the intervention period, and at the end of the intervention period. Responses were measured on a Likert scale where 1 is strongly disagree and 6 is strongly agree.



Appendix Figure 1 Each dot represents the average rate of appropriate chemoprophylaxis for the month represented. IMC = Intermountain Medical Center; LDS = LDS Hospital.



Appendix Figure 2 Each dot represents the average rate of chemoprophylaxis for the month represented. IMC = Intermountain Medical Center, LDS = LDS Hospital.