OPEN ACCESS

Practices to prevent venous thromboembolism: a brief review

Brandyn D Lau,[1,2] Elliott R Haut[1,3,4,5,6]

[1]Division of Acute Care Surgery, Department of Surgery, The Johns Hopkins University School of Medicine, Baltimore, Maryland, USA
[2]Division of General Internal Medicine, Department of Medicine, Evidence-based Practice Center, The Johns Hopkins University School of Medicine, Baltimore, Maryland, USA
[3]Department of Anesthesiology and Critical Care Medicine, The Johns Hopkins University School of Medicine, Baltimore, Maryland, USA
[4]Department of Emergency Medicine, The Johns Hopkins University School of Medicine, Baltimore, Maryland, USA
[5]The Armstrong Institute for Patient Safety and Quality, Johns Hopkins Medicine, Baltimore, Maryland, USA
[6]The Center for Surgical Trials and Outcomes Research (CSTOR), Johns Hopkins Medicine, Baltimore, Maryland, USA

Correspondence to
Dr E R Haut, Division of Acute Care Surgery, Department of Surgery, The Johns Hopkins Hospital, 1800 Orleans St, Sheikh Zayed 6107C, Baltimore, MD 21287, USA;
ehaut1@jhmi.edu

Received 21 December 2012
Revised 25 April 2013
Accepted 28 April 2013
Published Online First
24 May 2013

Open Access
Scan to access more free content

To cite: Lau BD, Haut ER. *BMJ Qual Saf* 2014;**23**: 187–195.

ABSTRACT

Background Venous thromboembolism (VTE) is a common cause of preventable harm for hospitalised patients. Over the past decade, numerous intervention types have been implemented in attempts to improve the prescription of VTE prophylaxis in hospitals, with varying degrees of success. We reviewed key articles to assess the efficacy of different types of interventions to improve prescription of VTE prophylaxis for hospitalised patients.

Methods We conducted a search of MEDLINE for key studies published between 2001 and 2012 of interventions employing education, paper based tools, computerised tools, real time audit and feedback, or combinations of intervention types to improve prescription of VTE prophylaxis for patients in hospital settings. Process outcomes of interest were prescription of any VTE prophylaxis and best practice VTE prophylaxis. Clinical outcomes of interest were any VTE and potentially preventable VTE, defined as VTE occurring in patients not prescribed appropriate prophylaxis.

Results 16 articles were included in this review. Two studies employed education only, four implemented paper based tools, four used computerised tools, two evaluated audit and feedback strategies, and four studies used combinations of intervention types. Individual modalities result in improved prescription of VTE prophylaxis; however, the greatest and most sustained improvements were those that combined education with computerised tools.

Conclusions Many intervention types have proven effective to different degrees in improving VTE prevention. Provider education is likely a required additional component and should be combined with other intervention types. Active mandatory tools are likely more effective than passive ones. Information technology tools that are well integrated into provider workflow, such as alerts and computerised clinical decision support, can improve best practice prophylaxis use and prevent patient harm resulting from VTE.

INTRODUCTION

Venous thromboembolism (VTE), comprised of deep vein thrombosis (DVT) and/or pulmonary embolism (PE), is estimated to account for 5–10% of all deaths among hospitalised patients.[1 2] In addition, non-fatal VTE events are associated with significant morbidities. In 2008, the US Surgeon General issued a Call to Action to Prevent DVT and PE. The report brings to light the huge numbers of patients afflicted by DVT (350 000–600 000) and killed by PE (>100 000) every year in the USA.[3]

Both pharmacological and mechanical prophylactic interventions have been demonstrated to be highly effective in preventing many, but not all, VTE.[1 4] It has been estimated that best practice prophylaxis may reduce the incidence of DVT by up to 70%.[1] The underlying pharmacological mechanism of all prophylaxis medications is to decrease clotting, and therefore they may increase the risk of bleeding. The balance between bleeding and clotting must be considered, and the harms and benefits must be weighed before administering these drugs.[5] Blanket approaches that give the same medication at the same dose and frequency to all patients may not be beneficial and may even cause more harm than benefit.[6–8] Therefore, individual patient risk assessment is paramount to ensure that all patients receive optimal prophylaxis.

Most hospitalised patients have one or more risk factors for VTE. Evidence based, best practice prophylaxis varies by individual patient risk factors (ie, cancer, advanced age, immobility, history of VTE) and primary clinical service (eg, medicine, surgery, trauma, orthopaedics).[1] Specialty specific guidelines are

Table 1 Characteristics of the included studies

Study	Design	Intervention type	Description
Scaglione (2005)	CBA	Education only	Hospital-wide VTE prophylaxis guideline implementation
Piazza (2012)	CBA	Education only	Pharmacist led patient education intervention to improve administration rates of VTE prophylaxis
Liu (2012)	CBA	Paper	Standardised paper based medication chart, was incorporated in Australian public hospitals
O'Connor (2009)	CBA	Paper	VTE prophylaxis order set for admitting medically ill patients
Fontaine (2006)	RCT	Paper	VTE prophylaxis prescription aids
Streiff (2012)	CBA	Paper	Paper based order set for admitting surgical patients
Lesselroth (2011)	CBA	Computerised	Clinical decision support order menu in computerised patient record system
Beeler (2011)	CCT	Computerised	Electronic alert displayed in chart of medically ill patients with documented risk but no prophylaxis order within 6 h of admission
Kucher (2005)	RCT	Computerised	Electronic alert to providers of patients at risk for developing VTE who were not prescribed prophylaxis
Haut (2012)	CBA	Computerised	Mandatory, computerised clinical decision support enabled VTE risk stratification order set was implemented in the computerised provider order entry system
Piazza (2009)	RCT	Real time audit and feedback	Real time alert to the attending physicians of patients at high risk of VTE who are not receiving prophylaxis
Mahan (2012)	CBA	Real time audit and feedback	Pharmacists prospectively reviewed patients' medical records to determine risk factors for VTE and the current prescribed prophylaxis. When the prophylaxis prescription was inadequate for their risk level, the pharmacist alerted the attending physician (in person or via telephone communication)
Clark (2011)	CBA	Combination	Clinical guideline implemented using a multidisciplinary team and multimodal strategy involving education, information technology, verbal and written reminders, and with frequent optimisation based on feedback from end users
Gallagher (2009)	CBA	Combination	Education and a printed hospital-wide risk assessment tool incorporated into routine clinical practice with VTE related feedback to clinicians
Stinnett (2005)	CBA	Combination	Education and a combination VTE prevention tool, including a VTE risk stratification scheme, and a standard admission order form that presented optimal VTE prevention regimens.
Maynard (2010)	CBA	Combination	Computerised risk assessment form linked to preferred VTE prophylaxis options with quarterly educational sessions, and feedback to the clinical staff when audits indicated that their patient was prescribed inadequate prophylaxis

CBA, controlled before/after; CCT, non-randomised controlled clinical trial; RCT, randomised controlled trial; VTE, venous thromboembolism.

often available in addition to general VTE prevention guidelines.[1 9 10]

Despite high quality, randomised controlled trials (RCTs) showing the clinical effectiveness of prophylactic medications and mechanical devices to reduce the risk of VTE,[1 11 12] numerous studies continue to show that many hospitalised patients are not prescribed risk appropriate VTE prophylaxis. One USA registry study found that only 42% of patients diagnosed with DVT during hospitalisation had received prophylaxis.[13] These findings are not localised; another recent study across 32 countries found that only 59% of at risk surgical and 40% of at risk medical patients received guideline recommended VTE prophylaxis.[14] Even as recently as Coagulation Day 2010, guideline adherence was reported to be 40% across Austrian intensive care units.[15]

In 2001, the Agency for Healthcare Research and Quality (AHRQ) 'Making health care safer' report called the delivery of appropriate prophylaxis against VTE "the number one patient safety practice"[16] and one that can prevent inhospital death.[17] The AHRQ has recently placed 'interventions to improve prophylaxis for VTE' on its top 10 list of strongly encouraged patient safety practices.[18 19]

Varied types of interventions aimed to improve adherence to VTE prophylaxis have been attempted. A systematic review of interventions to improve VTE prophylaxis use, based on literature searches from 1996 to 2003, found 30 eligible studies. Strategies included passive dissemination, which had little effect (50% compliance), single strategy studies (12 studies—audit and feedback, documentation aids and quality assurance activities all produced about 80% compliance) and clinical decision support systems (approached 100% compliance). Twelve studies incorporated two or more strategies, usually including an educational component, and all demonstrated improvements in the use of VTE prophylaxis. Most studies evaluated change in provider behaviour, not patient outcome, and no study that evaluated outcomes demonstrated a reduction in DVT or PE rates, often due to lack of adequate power.[20] As computerised provider order entry systems are increasingly adopted in hospitals, an opportunity exists to incorporate clinical decision support into these systems.

The purpose of this review is to provide an update on the most effective interventions aimed at improving adherence to guidelines on the use of VTE prevention strategies.

METHODS

As part of the AHRQ sponsored 'Making health care safer II' report,[18 21] we conducted a MEDLINE search to identify studies that assessed interventions designed to improve the use of VTE prophylaxis in hospitalised patients published between 2001 and October 2012. We selected articles to show a representative sample of the diversity in types of interventions. Interventions were classified as education only, paper based, computerised, real time audit and feedback, or combinations of interventions. Interventions were considered educational only if they involved retrospective audit and feedback, general guidelines, policies and protocols, and/or grand rounds type presentations. Because VTE prophylaxis is multifactorial, requiring risk assessment, prescription and administration, we liberally included a wide possible range of heterogeneous educational interventions, targeting both clinicians and patients. Paper based interventions were tangible, patient specific VTE risk assessment and prophylaxis recommendation tools, such as risk assessment forms or preprinted paper order sets. Computerised clinical decision support tools were intangible, patient specific VTE risk assessment and prophylaxis recommendation tools, such as electronic alerts, reminders or computerised order sets. Real time audit and feedback involved third party review, non-prescriber mediated intervention (eg, nurses or pharmacists risk stratifying and/or alerting prescribers). Combined interventions included multiple components from at least two categories. We included studies that employed three commonly used valid quality improvement designs: RCTs, non-randomised studies with concurrent controls or controlled before and after studies.[22]

Process outcomes of interest were the use of any VTE prophylaxis and best practice VTE prophylaxis defined within individual studies. Clinical outcomes of interest were both symptomatic and asymptomatic VTE and potentially preventable VTE, defined as VTE that occurs in patients not prescribed appropriate prophylaxis.[23]

RESULTS

Sixteen articles were included in this review. Two studies employed education only, four implemented paper based tools, four used computerised tools, two evaluated audit and feedback strategies, and four studies used combinations of intervention types (table 1).

Education only interventions

Scaglione *et al* evaluated the impact of implementing a hospital guideline on the appropriateness of VTE prophylaxis prescription for hospitalised patients. They sampled the medical records of two cohorts of patients, one before and the other after implementation of the guideline. The authors found that after implementation, prescription of appropriate prophylaxis in those at high risk for VTE improved for both medical (42% vs 25%, p=0.0075) and surgical (97% vs 64%, p=0.0004) hospitalised patients. The authors also reported a significant decrease in VTE in the 2 years after implementation (adjusted OR 0.68, 95% CI 0.62 to 0.75) (table 2).[24]

In an effort to address a recently discovered cause of suboptimal prophylaxis,[25] patient refusal,[26] Piazza *et al* launched a pharmacist mediated intervention to individually educate hospitalised patients on the importance of VTE prophylaxis. They targeted all hospitalised patients prescribed pharmacological VTE prophylaxis during their study period (n=528) and evaluated medication adherence. Patient education sessions were conducted within 24 h of the initial prescription for VTE prophylaxis. Compared with their pre-implementation group, administration of prescribed pharmacological VTE prophylaxis was higher after the patient education intervention (94.4% vs 89.9%, p<0.0001), and documentation of patient refusal significantly decreased (29.3% vs 43.7%, p<0.001) (table 2).[27]

Paper based interventions

As part of an effort to reduce prescription errors, the National Inpatient Medication Chart, a standardised paper based medication chart, was incorporated in Australian public hospitals. Liu *et al* evaluated a National Inpatient Medication Chart based VTE risk stratification and prophylaxis guidance tool on improving the quality of VTE prophylaxis. They followed consecutive medical and surgical patients

Table 2 Summary of studies implementing education only interventions

Study	Outcomes measured	Results
Scaglione (2005)	Appropriate prophylaxis prescription	Appropriate VTE prophylaxis prescription significantly improved for medical (42% vs 25%, p=0.0075) and surgical (97% vs 64%, p=0.0004) patients
	VTE	VTE significantly decreased (adjusted OR 0.68, 95% CI 0.62 to 0.75)
Piazza (2012)	Prophylaxis administration	Administration of prescribed pharmacological VTE prophylaxis was higher after the patient education intervention (94.4% vs 89.9%, p<0.0001)
	Documented patient refusal of prophylaxis	Patient refusal significantly decreased (29.3% vs 43.7%, p<0.001)

VTE, venous thromboembolism.

(n=2371) before and after implementation of the tool. VTE prophylaxis prescription increased from 52.7% to 66.5% for medical patients and from 77.5% to 89.1% in surgical patients (p<0.001). Adherence rates to recommended guidelines increased from 55.6% to 71.0% in medical patients and from 53.6% to 75.6% in surgical patients (p<0.01) although the authors found that improved quality of prophylaxis did not significantly reduce VTE (risk ratio (RR) 0.88, 95% CI 0.48 to 1.62) (table 3).[28]

O'Connor *et al* made an optional paper based VTE prophylaxis order set available for prescribers when admitting medically ill patients. The order set was located near order sheets used by admitting physicians in the emergency department and no formal education regarding use of the order set was done. The authors reported that patients admitted with the VTE prophylaxis order set were more likely to be prescribed prophylaxis against VTE than patients admitted with free text orders (44.0% vs 20.6%, p<0.0001).[29] Although this intervention doubled the proportion of patients prescribed VTE prophylaxis, the absolute rate remained quite low (table 3), highlighting one of the notable flaws of optional interventions.

Fontaine *et al* evaluated the impact of providing prescribers with paper based VTE prophylaxis prescription aids. Prescribers randomised to the intervention group were required to use specific prophylaxis prescription forms. The authors found that use of the prescription aids did not improve VTE prophylaxis for those patients at risk before and after implementation (OR 0.7, 95% CI 0.2 to 1.8, p=0.44) (table 3).[30]

Streiff *et al* reported significant improvement (26% to 68%, p<0.0001) in the proportion of surgical patients prescribed risk appropriate VTE prophylaxis after implementation of a paper based order set at the Johns Hopkins Hospital. This paper based order set has now been replaced entirely with a computerised approach (table 3).[31]

Computerised interventions

Lesselroth *et al* developed a clinical decision support enabled order menu in their computerised patient record system to recommend appropriate VTE prophylaxis at the time medications are prescribed at the Portland Oregon VA Medical Center. After identifying and addressing some key initial limitations (providers could unintentionally or intentionally bypass the order menu and recommended guidelines), use of the order menu increased from 20% to 80%. This study underscores the need for interventions to integrate well into provider workflow and ideally be mandatory without any possibility of ignoring or bypassing the VTE algorithm. Alerts and systems are only effective if they consistently reach their intended target.[32] These findings also highlight the fact that even 'mandatory' tools do not result in 100% prophylaxis prescription compliance for all patients (table 4).

In a study by Beeler *et al*, an electronic alert was displayed in the chart of every hospitalised medical patient who did not have pharmacological or

Table 3 Summary of studies implementing paper based interventions

Study	Outcomes measured	Results
Liu (2012)	Prophylaxis prescription	Prophylaxis prescription improved for medical (66.5% vs 52.7%) and surgical (89.1% vs 77.5%) patients (p<0.001)
	Appropriate prophylaxis	Appropriate VTE prophylaxis prescription significantly improved for medical (71.0% vs 55.6%) and surgical (75.6% vs 53.6%) patients (p<0.01)
	VTE	No significant change in VTE (risk ratio 0.88, 95% CI 0.48 to 1.62)
O'Connor (2009)	Prophylaxis prescription	Patients more likely to be prescribed VTE prophylaxis with order set than free text orders (44.0% vs 20.6%, p<0.0001).
Fontaine (2006)	Prophylaxis prescription	Prescription aids did not improve VTE prophylaxis prescription (OR 0.7, 95% CI 0.2 to 1.8, p=0.44)
Streiff (2012)	Appropriate prophylaxis prescription	Appropriate prophylaxis prescription significantly improved for surgical patients (26% to 68%, p<0.0001).

VTE, venous thromboembolism.

Table 4 Summary of studies implementing computerised interventions

Study	Outcomes measured	Results
Lesselroth (2011)	Order set utilisation	Use of the order set increased from 20% to 80% after switch from optional to mandatory completion
Beeler (2011)	Prophylaxis prescription	Prophylaxis prescription improved for medical patients from 43.4% to 66.7% (p<0.0001) to 73.6% (p=0.011).
Kucher (2005)	Prophylaxis prescription	Patients were more likely to be prescribed mechanical prophylaxis (p<0.001) or unfractionated heparin (p<0.001) in the intervention arm. There was no significant difference in prescription of enoxaparin (p=0.18) or warfarin (p=0.11) between intervention and control arms
	VTE	Significantly more patients in the intervention arm were free from DVT or PE after 90 days (p<0.001)
Haut (2012)	Appropriate prophylaxis	Appropriate prophylaxis prescription significantly improved for trauma patients (84.4% vs 66.2%, p<0.001).
	Preventable VTE	Preventable VTE significantly decreased (1.0% vs 0.17%, p=0.04).

DVT, deep vein thrombosis; PE, pulmonary embolism; VTE, venous thromboembolism.

mechanical VTE prophylaxis prescribed within 6 h after admission and had documented VTE risk. This system, which reacts to a lack of prescription for VTE prophylaxis, made improvements but may not be optimal as more proactive systems that prompt the appropriate care on admission. Rates of VTE prophylaxis orders among medical patients significantly increased from pre-implementation rates of 43.4% to 66.7% (p<0.0001) during the 4 months after implementation. The following year, VTE prophylaxis orders increased further to 73.6% (p=0.011).[33] The rates of prophylaxis among these medical patients still did not reach those for surgical patients (approximately 90%) who were used as the control arm (table 4).

Kucher *et al* actively searched for hospitalised patients at risk for developing VTE who were not prescribed prophylaxis (pharmacological or mechanical). In this randomised trial, electronic alerts that the patient was at risk for VTE were sent to providers of patients in the intervention group. Patients in this intervention group were significantly more likely to receive mechanical prophylaxis (p<0.001) and significantly more likely to receive prophylactic doses of unfractionated heparin (p<0.001). There were no significant changes to orders of enoxaparin (p=0.18) or warfarin (p=0.11) between intervention and control groups. In addition, patients in the intervention group were significantly more likely to be free from DVT or PE after 90 days (p<0.001) (table 4). This computerised approach is effective, but is also reactive—it identifies patients who were not initially ordered prophylaxis and then attempts to correct the patient safety problem, rather than proactively suggesting appropriate prophylaxis at the time of initial treatment.[34]

In 2008, a mandatory, computerised, decision support enabled VTE risk stratification order set was implemented in the computerised provider order entry system at the Johns Hopkins Hospital to recommend guideline appropriate, service specific (eg, medicine, general surgery, trauma, etc) prophylaxis for an individual patient's risk stratum.[31] This system requires proactive risk stratification during the completion of the admission order set for all admitted patients and therefore is nearly 100% effective at forcing providers to assign a risk stratum to all patients within 24 h of hospital arrival. Within the first year, adherence to guideline appropriate VTE prophylaxis increased significantly hospital-wide and rates of VTE have been on a decreasing trend. Within the trauma service, prescription compliance increased from 66.2% to 84.4% (p<0.001) and preventable harm (defined as VTE in patients not ordered appropriate prophylaxis)[23 35] significantly decreased from 1.0% to 0.17% (p=0.04) and was eliminated for 2 full years after implementation (table 4).[36] However, this system remains fallible as the guideline suggested VTE prophylaxis is merely a recommendation; it is not required and may be overridden by the ordering clinician.

Table 5 Summary of studies implementing real time audit and feedback interventions

Study	Outcomes measured	Results
Piazza (2009)	Prophylaxis prescription	Physicians who were alerted were more likely to prescribe VTE prophylaxis (46.0% vs 20.6%, p<0.0001)
	VTE	VTE was not significantly different (2.7% vs 3.4%, HR 0.79; 95% CI 0.50 to 1.25)
Mahan (2012)	Appropriate prophylaxis prescription	Appropriate prophylaxis prescription significantly improved (37.9% vs 23.8%, OR 1.8, 95% CI 1.6 to 2.1, p<0.0001)
	Preventable VTE	Preventable VTE decreased by 74% (95% CI 44% to 88%, p=0.0006)

VTE, venous thromboembolism.

Real time audit and feedback interventions

Piazza *et al* conducted a multicentre RCT to study a real time alert to the attending physicians of patients at high risk of VTE who are not receiving prophylaxis. Patients whose physicians were alerted were more likely to receive VTE prophylaxis than control subjects (46.0% vs 20.6%, p<0.0001); however, the rate of VTE was not significantly different between the two groups (2.7% vs 3.4%, HR 0.79; 95% CI 0.50 to 1.25) (table 5).[37]

In a study by Mahan *et al*, pharmacists prospectively reviewed patients' medical records to determine risk factors for VTE and the current prescribed prophylaxis. When the prophylaxis prescription was inadequate for their risk level, the pharmacist alerted the attending physician (in person or via telephone communication). After implementation of this intervention, the proportion of patients prescribed appropriate prophylaxis increased from 23.8% in 2006 to 37.9% (OR 1.8, 95% CI 1.6 to 2.1, p<0.0001), and preventable VTE decreased by 74% (95% CI 44% to 88%, p=0.0006) (table 5).[38]

Combinations of interventions

In response to poor documentation of VTE risk and inadequate use of appropriate prophylaxis, a clinical guideline was implemented at one hospital in the UK to enhance the culture of documenting VTE risk and prescribing VTE prophylaxis. The guideline was implemented using a multidisciplinary team and multimodal strategy involving education, information technology, verbal and written reminders, and with frequent optimisation based on feedback from end users. An immediate post-implementation review found that adherence to VTE prophylaxis guidelines increased from 56% to 96%.[39] Unfortunately, there was a significant drop-off over time in adherence

noted in a follow-up analysis, with only a 69% compliance rate reported (table 6). The authors suggest the cause may be due to over prophylaxis of patients who, on retrospective chart review, did not have indications for pharmacological prophylaxis.

Gallagher *et al* evaluated the impact of several interventions implemented over a 3 year period to improve the use of VTE prophylaxis at one hospital in Australia. Interventions included educating providers on the burden of VTE, the failure to apply guidelines and the development of a printed hospital-wide risk assessment tool incorporated into routine clinical practice with VTE related feedback to clinicians. Comparing the first three quarters with the final three quarters, the authors found a statistically significant increase in VTE prophylaxis use (48% to 74%, p=0.01) accompanied by a significant reduction in VTE after implementation (RR 0.68, 95% CI 0.47 to 0.99, p=0.04) over the 3 year study period (table 6).[40]

Stinnett *et al* found that 75% of patients admitted to the medical service were at increased risk for VTE yet only 43% of those patients received any type of VTE prophylaxis. The authors designed an intervention that consisted of education and a combination VTE prevention tool, which included a VTE risk stratification scheme, a standard admission order form that presented optimal VTE prevention regimens. After implementation of this intervention, the authors found that 71% of patients at high risk for VTE received prophylaxis (table 6).[41]

Maynard *et al* implemented a computerised risk assessment form linked to preferred VTE prophylaxis options. In addition, approximately one educational session was held per quarter, and feedback was provided to the clinical staff when audits indicated that their patient was prescribed inadequate prophylaxis. Prescription of appropriate VTE prophylaxis increased each year after implementation of the intervention, from 58% at baseline in year 1 to 78% and 93% during study years 2 and 3, respectively (p<0.001). Overall, the risk of developing hospital acquired VTE decreased significantly after implementation (RR 0.69, 95% CI 0.47 to 0.79) while the risk of developing preventable VTE decreased by 86% (95% CI 0.06 to 0.31) (table 6).[42]

Table 6 Summary of studies implementing combination interventions

Study	Outcomes measured	Results
Clark (2011)	Appropriate prophylaxis prescription	After implementation, appropriate VTE prophylaxis prescription increased from 56% to 96%, but waned over time to 69%
Gallagher (2009)	Prophylaxis prescription VTE	Prophylaxis prescription significantly increased (74% vs 48%, p=0.01) VTE events significantly decreased (risk ratio 0.68, 95% CI 0.47 to 0.99, p=0.04)
Stinnett (2005)	Prophylaxis prescription	Prophylaxis prescription increased after implementation (71% vs 43%)
Maynard (2010)	Prophylaxis prescription	VTE prophylaxis prescription significantly increased each year for 3 years from 58% at baseline to 78% to 93% (p<0.001)
	VTE	Hospital acquired VTE decreased significantly (risk ratio 0.69, 95% CI 0.47 to 0.79)
	Preventable VTE	Preventable VTE decreased significantly by 86% (95% CI 0.06 to 0.31)

VTE, venous thromboembolism.

DISCUSSION

Numerous interventions have been implemented in attempts to improve the use of VTE prophylaxis for hospitalised patients with varying degrees of success. The most successful interventions are those that integrate well into the prescriber workflow and, as demonstrated in numerous quality improvement interventions,[20 43 44] should be coupled with ongoing education to re-emphasise the importance of VTE prophylaxis for hospitalised patients.[31]

Public reporting of VTE prophylaxis processes and outcomes is another possible approach to improve VTE prophylaxis, through feedback and public reporting or the financial incentive of non-payment for VTE events. The Centres of Medicare and Medicaid Services placed VTE after orthopaedic hip/knee replacement on their list of 'never events' for which providers will not be reimbursed. However, as has been seen in numerous clinical trials, even with best practice prophylaxis, not all VTE events can be prevented,[5 45] especially in the orthopaedic patient population.[35]

Another potential limitation to the use of VTE rates alone to measure quality is the significant problem caused by surveillance bias; many DVTs are clinically silent and therefore go undetected without routine screening which is differentially applied to various patient populations and hosptials.[23] For example, in the field of trauma surgery, clinical ambiguity persists regarding the clinical and cost effectiveness of screening high risk asymptomatic trauma patients for DVT with duplex ultrasound.[23] As a result, certain providers and hospitals report higher DVT rates due entirely to higher rates of diagnostic testing—a classic example of surveillance bias.[46–48] Because of these issues—and variation in patient risk—unadjusted VTE rates alone are likely not appropriate for public reporting as they may be more misleading than helpful.

The updated evidence for VTE prophylaxis in selected patients has been well described in a variety of recent evidence based clinical guidelines and systematic reviews.[1 7 9] The evidence for clinical interventions for VTE prophylaxis remains strong for

hospitalised patients, and prophylaxis is recommended by practice guidelines for specific populations, although it should not be applied universally. As the availability of medications and condition specific evidence is rapidly evolving and these guidelines are regularly updated, we did not evaluate specific regimens within this review.

When evaluating preventable harm from VTE, we agree that the ideal definition should combine an outcome and process measure rather than relying on clinical VTE outcomes alone. It has been suggested that only VTE events occurring in patients who did not receive adequate prophylaxis should be labelled a 'preventable VTE'.[23] This approach and specific definition has been incorporated as one of the six meaningful use quality measures related to VTE.[16] Although there is not yet national consensus on the use of this definition, preventable harm from VTE has been shown to be a useful quality improvement measure in several single centre studies.[36 38 42 49–51] We advocate including this measure in future clinical research studies that evaluate the impact of interventions to prevent VTE.

CONCLUSION

Strong evidence from numerous high quality trials supports the effectiveness of VTE prophylaxis for specific populations. However, there are significant potential harms and risk stratification is necessary to ensure that prophylaxis is targeted to appropriate patients. Unfortunately, rates of VTE prophylaxis remain suboptimal, and VTE continues to be a difficult and elusive crisis in patient safety. Relatively little evidence exists on which specific interventions are effective for increasing rates of VTE prophylaxis in appropriate populations. As with other patient safety interventions, educating providers on the benefits of appropriate VTE prophylaxis alone is not an effective strategy to improve use of appropriate VTE prophylaxis. Evidence, although mostly low quality (non-randomised studies without concurrent controls), supports that education combined with other quality improvement strategies and information technology approaches such as alerts and mandatory computerised clinical decision support, appear to offer the most effective approaches to promote best practice prophylaxis use and prevent patient harm resulting from VTE.

Funding This project was funded under contract No HHSA-290-2007-10062-I from the Agency for Healthcare Research and Quality, US Department of Health and Human Services. The authors are responsible for its content. Statements in the report should not be construed as endorsement by the Agency for Healthcare Research and Quality or the US Department of Health and Human Services.

Contributors BDL conducted the search, reviewed relevant articles, analysed the results and drafted the paper. ERH planned the concept of the paper, developed the framework for conducting the review and is the guarantor of the paper.

Competing interests ERH is the primary investigator of a Mentored Clinician Scientist Development Award K08 1K08HS017952-01 from the Agency for Healthcare Research and Quality entitled 'Does screening variability make DVT an unreliable quality measure of trauma care?' ERH receives royalties from Lippincott, Williams and Wilkins for a book *Avoiding common ICU errors*, and has given expert witness testimony in various medical malpractice cases.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1 Guyatt GH, Akl EA, Crowther M, *et al*. Antithrombotic therapy and prevention of thrombosis, 9th ed: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest* 2012;141:7S–47S.
2 Anderson FA Jr, Zayaruzny M, Heit JA, *et al*. Estimated annual numbers of US acute-care hospital patients at risk for venous thromboembolism. *Am J Hematol* 2007;82:777–82.
3 US Department of Health and Human Services. The surgeon general's call to action to prevent deep vein thrombosis and pulmonary embolism. 2008. http://www.surgeongeneral.gov/topics/deepvein/ (accessed 30 Aug 2011).
4 Cushman JG, Agarwal N, Fabian TC, *et al*. Practice management guidelines for the management of mild traumatic brain injury: the EAST practice management guidelines work group. *J Trauma* 2001;51:1016–26.
5 Haut ER, Lau BD, Streiff MB. New oral anticoagulants for preventing venous thromboembolism. *BMJ* 2012;344:e3820.
6 Goldhaber SZ, Leizorovicz A, Kakkar AK, *et al*. Apixaban versus enoxaparin for thromboprophylaxis in medically ill patients. *N Engl J Med* 2011;365:2167–77.
7 Qaseem A, Chou R, Humphrey L, *et al*. Venous thromboembolism prophylaxis in hospitalized patients: a clinical practice guideline from the American College of Physicians. *Ann Intern Med* 2011;155:625–32.
8 Lederle FA, Zylla D, MacDonald R, *et al*. Venous thromboembolism prophylaxis in hospitalized medical patients and those with stroke: a background review for an American College of Physicians Clinical Practice Guideline. *Ann Intern Med* 2011;155:602–15.
9 Rogers FB, Cipolle MD, Velmahos G, *et al*. Practice management guidelines for the prevention of venous thromboembolism in trauma patients: the EAST practice management guidelines work group. *J Trauma* 2002;53:142–64.
10 Mont MA, Jacobs JJ, Boggio LN, *et al*. Preventing venous thromboembolic disease in patients undergoing elective hip and knee arthroplasty. *J Am Acad Orthop Surg* 2011;19:768–76.
11 Samama MM, Cohen AT, Darmon JY, *et al*. A comparison of enoxaparin with placebo for the prevention of venous thromboembolism in acutely ill medical patients. Prophylaxis in Medical Patients with Enoxaparin Study Group. *N Engl J Med* 1999;341:793–800.
12 Streiff MB, Lau BD. Thromboprophylaxis in nonsurgical patients. *Hematol Am Soc Hematol Educ Program* 2012;2012:631–7.

13 Goldhaber SZ, Tapson VF, DVT FREE Steering Committee. A prospective registry of 5451 patients with ultrasound-confirmed deep vein thrombosis. *Am J Cardiol* 2004;93:259–62.
14 Cohen AT, Tapson VF, Bergmann J, *et al*. Venous thromboembolism risk and prophylaxis in the acute hospital care setting (ENDORSE study): a multinational cross-sectional study. *Lancet* 2008;371:387–94.
15 Schaden E, Metnitz PG, Pfanner G, *et al*. Coagulation Day 2010: an Austrian survey on the routine of thromboprophylaxis in intensive care. *Intensive Care Med* 2012;38:984–90.
16 Shojania KG, Duncan BW, McDonald KM, *et al*. Making health care safer: a critical analysis of patient safety practices. Rockville, MD: Agency for Healthcare Research and Quality. 2001:43.
17 Maynard G, Stein J. Preventing hospital-acquired venous thromboembolism: a guide for effective quality improvement. Rockville, MD: Agency for Healthcare Research and Quality. 2008.
18 Shekelle PG, Wachter RM, Pronovost PJ, *et al*. Making health care safer II: an updated critical analysis of the evidence for patient safety practices. Comparative Effectiveness Review No. 211. (Prepared by the Southern California-RAND Evidence-based Practice Center under Contract No. 290–2007-10062-I.) AHRQ Publication No. 13-E001-EF. Rockville, MD: Agency for Healthcare Research and Quality, March 2013.
19 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(5 Part 2):365–8.
20 Tooher R, Middleton P, Pham C, *et al*. A systematic review of strategies to improve prophylaxis for venous thromboembolism in hospitals. *Ann Surg* 2005;241:397–415.
21 Haut ER, Lau BD. *Chapter 28: prevention of venous thromboembolism (VTE)*. Rockville, MD: Agency for Healthcare Research and Quality. Making Health Care Safer II: An Updated Critical Analysis of the Evidence for Patient Safety Practices. Comparative Effectiveness Review No. 211. (Prepared by the Southern California-RAND Evidence-based Practice Center under Contract No. 290-2007-10062-I.) AHRQ Publication No. 13-E001-EF. Rockville, MD: Agency for Healthcare Research and Quality, March 2013.
22 Fan E, Laupacis A, Pronovost PJ, *et al*. How to use an article about quality improvement. *JAMA* 2010;304:2279–87.
23 Haut ER, Pronovost PJ. Surveillance bias in outcomes reporting. *JAMA* 2011;305:2462–3.
24 Scaglione L, Piobbici M, Pagano E, *et al*. Implementing guidelines for venous thromboembolism prophylaxis in a large Italian teaching hospital: lights and shadows. *Haematologica* 2005;90:678–84.
25 Fanikos J, Stevens LA, Labreche M, *et al*. Adherence to pharmacological thromboprophylaxis orders in hospitalized patients. *Am J Med* 2010;123:536–41.
26 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*. (in press)
27 Piazza G, Nguyen TN, Morrison R, *et al*. Patient education program for venous thromboembolism prevention in hospitalized patients. *Am J Med* 2012;125:258–64.
28 Liu DS, Lee MM, Spelman T, *et al*. Medication chart intervention improves inpatient thromboembolism prophylaxis. *Chest* 2012;141:632–41.
29 O'Connor C, Adhikari NKJ, DeCaire K, *et al*. Medical admission order sets to improve deep vein thrombosis prophylaxis rates and other outcomes. *J Hosp Med* 2009;4:81–9.
30 Fontaine A, Mahe I, Bergmann JF, *et al*. Effectiveness of written guidelines on the appropriateness of thromboprophylaxis prescriptions for medical patients: a prospective randomized study. *J Intern Med* 2006;260:369–76.
31 Streiff MB, Carolan H, Hobson DB, *et al*. Lessons from the John Hopkins multi-disciplinary Venous Thromboembolism (VTE) Prevention Collaborative. *BMJ* 2012;344:e3935.
32 Lesselroth BJ, Yang J, McConnachie J, *et al*. Addressing the sociotechnical drivers of quality improvement: a case study of post-operative DVT prophylaxis computerised decision support. *BMJ Qual Saf* 2011;20:381–9.
33 Beeler PE, Kucher N, Blaser J. Sustained impact of electronic alerts on rate of prophylaxis against venous thromboembolism. *Thromb Haemost* 2011;106:734–8.
34 Kucher N, Tapson VF, Goldhaber SZ, *et al*. Risk factors associated with symptomatic pulmonary embolism in a large cohort of deep vein thrombosis patients. *Thromb Haemost* 2005;93:494–8.
35 Streiff MB, Haut ER. The CMS ruling on venous thromboembolism after total knee or hip arthroplasty: weighing risks and benefits. *JAMA* 2009;301:1063–5.
36 Haut ER, Lau BD, Kraenzlin FS, *et al*. Improved prophylaxis and decreased preventable harm with a mandatory computerized clinical decision support tool for venous thromboembolism (VTE) prophylaxis in trauma patients. *Arch Surg* 2012;10:901–7.
37 Piazza G, Rosenbaum EJ, Pendergast W, *et al*. Physician alerts to prevent symptomatic venous thromboembolism in hospitalized patients. *Circulation* 2009;119:2196–201.
38 Mahan CE, Hussein MA, Amin AN, *et al*. Venous thromboembolism pharmacy intervention management program with an active, multifaceted approach reduces preventable venous thromboembolism and increases appropriate prophylaxis. *Clin Appl Thromb Hemost* 2012;18:45–58.
39 Clark BM, d'Ancona G, Kinirons M, *et al*. Effective quality improvement of thromboprophylaxis in acute medicine. *BMJ Qual Saf* 2011;20:460–4.
40 Gallagher M, Oliver K, Hurwitz M. Improving the use of venous thromboembolism prophylaxis in an Australian teaching hospital. *Qual Saf Health Care* 2009;18:408–12.
41 Stinnett JM, Pendleton R, Skordos L, *et al*. Venous thromboembolism prophylaxis in medically ill patients and the development of strategies to improve prophylaxis rates. *Am J Hematol* 2005;78:167–72.
42 Maynard GA, Morris TA, Jenkins IH, *et al*. Optimizing prevention of hospital-acquired venous thromboembolism (VTE): prospective validation of a VTE risk assessment model. *J Hosp Med* 2010;5:10–18.
43 Anderson FA Jr, Wheeler HB, Goldberg RJ, *et al*. Changing clinical practice. Prospective study of the impact of continuing medical education and quality assurance programs on use of prophylaxis for venous thromboembolism. *Arch Intern Med* 1994;154:669–77.
44 Roumie CL, Elasy TA, Greevy R, *et al*. Improving blood pressure control through provider education, provider alerts, and patient education: a cluster randomized trial. *Ann Intern Med* 2006;145:165–75.

45 Gómez-Outes A, Terleira-Fernández A, Suárez-Gea M, *et al*. Dabigatran, rivaroxaban or apixaban versus enoxaparin for thromboprophylaxis after total hip or knee replacement: systematic review, meta-analysis and indirect treatment comparisons. *BMJ* 2012;344:e3675.
46 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;63:1132–5.
47 Haut ER, Chang DC, Pierce CA, *et al*. Predictors of posttraumatic deep vein thrombosis (DVT): hospital practice versus patient factors-an analysis of the National Trauma Data Bank (NTDB). *J Trauma* 2009;66:994–9.
48 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;64:932–6.
49 Zeidan AM, Streiff MB, Lau BD, *et al*. Impact of a venous thromboembolism (VTE) prophylaxis 'smart order set': improved compliance, fewer events. *Am J Hematol* 2013.
50 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.
51 Aboagye JK, Lau BD, Schneider EB, *et al*. Linking processes and outcomes: a key strategy to prevent and report harm from venous thromboembolism in surgical patients. *JAMA Surg* 2013;148:299–300.