Maintained effectiveness of an electronic alert system to prevent venous thromboembolism among hospitalized patients

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Summary

Despite current guidelines, venous thromboembolism (VTE) prophylaxis is underused. Computerized programs to encourage physicians to apply thromboprophylaxis have been shown to be effective in selected populations. Our aim was to analyze the impact of the implementation of a computer-alert system for VTE risk in all hospitalized patients of a teaching hospital. A computer program linked to the clinical record database was developed to assess all hospitalized patients' VTE risk daily. The physician responsible for patients at high risk was alerted, but remained free to order or withhold prophylaxis. Over 19,000 hospitalized, medical and surgical, adult patients between January to June 2005 (pre-intervention phase), January to June 2006 and January to June 2007 (post-intervention phase), were included. During the first semesters of 2006 and 2007, an electronic alert was sent to 32.8% and 32.2% of all hospitalized patients, respectively. Appropriate prophylaxis among alerted patients was ordered in 89.7% (2006) and 88.5% (2007) of surgical patients, and in 49.2% (2006) and 64.4% (2007) of medical patients. A sustained reduction of VTE during hospitalization was achieved, Odds ratio (OR): 0.53, 95% confidence interval (CI) (0.25–1.10) and OR: 0.51, 95%CI (0.24–1.05) during the first semesters of 2006 and 2007 respectively, the impact being significant ($p<0.05$) among medical patients in 2007, OR: 0.36, 95%CI (0.12–0.98). The implementation of a computer-alert program helps physicians to assess each patient's thrombotic risk, leading to a better use of thromboprophylaxis, and a reduction in the incidence of VTE among hospitalized patients. For the first time, an intervention aimed to improve VTE prophylaxis shows maintained effectiveness over time.

Keywords

Electronic alert, hospitalized patients, prophylaxis, venous thromboembolism

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Introduction

Venous thromboembolism (VTE), including deep vein thrombosis (DVT) and pulmonary embolism (PE), is a common cause of mortality and morbidity among hospitalized patients (1–3). Although VTE is more often considered to be associated with recent surgery or trauma, more than 50% of symptomatic thromboembolic events, and 70 to 80% of fatal PE, occur in nonsurgical illnesses (2,4). Hospitalization for an acute medical illness is independently associated with an eight-fold increase in relative risk of VTE (5).

Antithrombotic prophylaxis, either mechanical (graduated compression stockings or pneumatic compression devices) or pharmacological (mainly low-molecular-weight heparin [LMWH]), has been shown to be beneficial, safe and cost-effective in both surgical patients and those hospitalized for medical processes (6–8). In fact, current guidelines strongly recommend administration of antithrombotic prophylaxis in acutely ill hospitalized patients (9).

However, despite published evidence, current practice in most US and Europe hospitals is suboptimal, with very low rates of appropriate thromboprophylaxis (10–14). Recently the ENDORSE study, the most extensive registry study published so far, showed that 64.4 % of hospitalized surgical patients and 41.5% of medical patients were judged to be at risk for VTE. However, only 58.5% of the surgical patients at risk and 39.5% of at risk medical patients received the recommended VTE prophylaxis (15). Given the availability of effective VTE prophylaxis, many

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events and deaths could be prevented. Therefore, there is an urgent need to improve the implementation of existing evidence-based guidelines in this setting (16, 17). Different strategies have been proposed to achieve this aim, including continuous medical education, audit and feedback methods or use of reminders, with limited positive results (18, 19).

In a recent study, the use of a computer alert-program to remind the responsible physician about appropriate prophylaxis in high-risk patients, was associated with increased indication and a 41% reduction in VTE rates among selected hospitalized patients (20).

In the present study, we evaluated the impact of the implementation of an electronic alert system for the prevention of VTE among over 12,000 hospitalized patients from a single institution, focusing on effectiveness over time.

Material and methods

Study design

We developed a computer program that identified hospitalized patients at increased risk of VTE, linked to the computerized patient database of our institution, in order to acquire essential data to stratify the patients' thrombotic risk. The new program was installed in September 2005, and was fully operative in January 2006. All hospitalized patients between January to June 2006 and January to June 2007 aged 18 or over were included in the study, which was approved by the institutional ethics committee. Hospitalized patients between January to June 2005 served as historical controls.

Identification of patients at risk for venous thromboembolism

The risk of VTE in medical patients was determined according to a modified national PRETEMED scale. To create this scale, risk factors for VTE were identified and ponderated following current published scientific evidence. Nine experts from different specialities involved in VTE management analyzed and reached consensus on the indication of prophylaxis in every scenario using the RAND appropriateness method (21). Briefly, on this point scale major risk factors, such as active cancer, previous VTE, acute myocardial infarction, ischemic stroke with limb paralysis, decompensated chronic obstructive pulmonary disease and thrombophilia, were assigned a score of 3; congestive heart failure, chronic renal insufficiency/nephrotic syndrome, severe acute infection, lower limb cast or prolonged bed rest were assigned a score of 2; pregnancy/postpartum period, recent prolonged flight, lower limb paresia, estrogen therapy, thalidomide administration, use of central vein catheter, obesity, age >60 years or smoking were assigned a score of 1. High risk of VTE was defined as a cumulative risk score of at least four points.

In surgical patients, the thrombotic risk was estimated following the stratification recommended by the American College of Chest Physicians (ACCP) (9).

Daily screening of the thrombotic risk of all hospitalized patients was performed using the alert software by a member of the Hematology Service, and an electronic alert was sent to those at high-risk. A symbol "VTE!" indicating that a patient had received the alert appeared on the screen of the responsible physician, who was free to order or withhold prophylaxis. Moreover, the program was linked to the hospital VTE prevention guidelines allowing clinicians to review the indications of different thromboprophylaxis measures. Basically, prophylactic LMWH is recommended in at risk hospitalized patients, with the exception of high bleeding risk patients (thrombocytopenia <50,000/mm^3, known bleeding diathesis or active bleeding), who are encouraged to receive mechanical prophylaxis, i.e. elastic stockings or pneumatic compression devices.

Study endpoints and data collection

The primary endpoint was objective VTE, either DVT (diagnosed by ultrasonography or contrast venography) or PE (diagnosed by computed tomography of the chest, ventilation-perfusion scanning or pulmonary angiography) during hospitalization. Events were adjudicated by three researchers who were unaware of the patients' risk stratification. The number of patients hospitalized and the incidence of VTE during hospitalization were obtained from the registries of the Documentation Service of our institution. The incidence of DVT and PE among hospitalized patients who were at least 18 years old was determined by evaluation of the Hospital Discharge Minimum Basic Data Set (MBDS) which includes clinical and administrative data of each hospital discharge. The clinical information was coded using the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM), as stated by the Spanish Ministry of Health (22). Medical records of in-patients with DVT and/or PE secondary diagnosis codes were checked to exclude those incidents due to comorbidity. Final selected cases were those with established diagnosis of DVT and/or PE 24 hours after admission until discharge date. The corresponding diagnosis-related groups were incorporated to identify medical or surgical discharge. MBDS was checked to record age, active neoplasm and average length of hospital stay. Other secondary variables were the total number of electronic alerts sent and the percentage of alerted patients who received appropriate thromboprophylaxis, provided by the computer alert-program itself.

Statistical analysis

Categorical variables were expressed as frequencies and percentages, and quantitative variables either as mean and standard deviation or median and interquartile range, depending on the distribution. Differences in baseline characteristics for patients in the preintervention and postintervention groups were compared using mid-P exact value for categorical variables and the Wilcoxon rank sum test as a nonparametric approach for quantitative variables. The odds ratio (OR) and 95% confidence interval (OR, 95% CI) of any VTE, for patients in the postintervention phase compared with the preintervention phase were estimated. The study protocol stated the performance of separate analysis for medical and surgical patients. An OR lower than 1 meant that patients in the postintervention groups were at decreased risk for any VTE. Type I error was set at 0.05. Analyses were performed using WinPepi 4.8 (BioMed Central Ltd, open on-line access) and SPSS 14.0 (Chicago, IL, USA) software.

Table 1: Baseline characteristics of the patients.

	2005* (N=6441)	2006* (N=6312)	2007* (N=6585)	P#
Age – years, mean (SD)	54.8 (16.1)	55.2 (16.3)	55.3 (16.7)	n.s.
Age > 70 years, n (%)	1198 (18.6)	1238 (19.6)	1356 (20.6)	0.01
Male sex, n (%)	3528 (54.8)	3403 (53.9)	3500 (53.2)	n.s.
Lengh of stay – days, median (IQR)	4 (2 – 7)	4 (2 – 7)	3 (2 – 7)	n.s.
Patients with stay > 15 days, n (%)	487 (7.6)	432 (6.8)	475 (7.2)	n.s.
Surgical patients, n (%)	3051 (47.4)	3175 (50.3)	3262 (49.5)	<0.01
Surgery > 1 hour, n (%)	2450 (38.0)	2556 (40.5)	2686 (40.8)	<0.01
Knee/Hip replacement, n (%)	80 (1.2)	139 (2.2)	164 (2.5)	<0.001
Medical patients, n (%)	3390 (52.6)	3137 (49.7)	3323 (50.5)	<0.01
Cancer, n (%)	2382 (37.0)	2016 (31.9)	1955 (29.7)	<0.001
Chronic lung disease, n (%)	273 (4.2)	294 (4.7)	387 (5.9)	<0.001
Congestive heart failure /ischemic cardiopathy, n (%)	449 (7.0)	444 (7.0)	587 (8.9)	<0.001
Diabetes mellitus, n (%)	537 (8.3)	590 (9.3)	637 (9.7)	<0.05
Immobility >3 days (not due to surgery), n (%)	44 (0.7)	38 (0.6)	54 (0.8)	n.s.
Central vein lines, n (%)	1233 (19.1)	1014 (16.0)	919 (14.0)	<0.001
Previous VTE history	102 (1.6)	205 (3.2)	231 (3.5)	<0.001

* First semester; # 2005 vs 2006 and 2007; IQR,: interquartile range; n.s. not significant, SD, standard deviation; VTE, venous thromboembolism.

Results

Between January 1st and June 30th 2006, and January to June 2007, 6,312 and 6,585 adult patients were hospitalized in our institution, respectively (12,897 in total). Both groups had similar baseline characteristics (Table 1). Mean age was 55 years old and mean stay was six days. Half of the patients (6,460 individuals) were hospitalized due to medical illnesses, while 6,437 were surgical patients. Nearly 30% of patients in both groups suffered from active cancer, while more than 3% refered previous VTE history.

The control group (hospitalized patients during the first semester of 2005) included 6,441 patients, with a mean age of 55 years. Regarding VTE risk factors, there were fewer hospitalized patients with cancer in the post-intervention groups, but more patients older than 70 years with previous VTE history or undergoing orthopaedic replacement surgery (Table 1).

First period post-intervention: January to June 2006

An electronic alert indicating high thrombotic risk was sent to 2,073/6,312 patients (32.8%): 1,770 (55.7%) surgical patients and 303 (9.7%) medical patients. Appropriate prophylaxis according to current protocols in the alerted patients was 89.7% (1,588/1,770) in surgical patients and 49.2% (149/303) in those hospitalized for medical reasons (Table 2).

The incidence of in-hospital VTE during the first semester of 2006 was 1.74/1000 (11 episodes in 6,312 codified patients). Medical patients developed seven VTE episodes during hospitalization (2.2/1000), while objective VTE was diagnosed in four surgical patients (1.3/1000).

Among medical patients, one VTE episode developed despite adequate thromboprophylaxis, another event ocurred in a patient with low thrombotic risk, and five in high-risk patients but without electronic alert sent because some clinical data were missing in the computerized clinical record. In surgical patients, two out of four VTE episodes developed despite an electronic alert having been adequately sent and LMWH prophylaxis used; two episodes occurred in patients with a low estimated risk of thrombosis, and therefore, without risk warning.

Second period post-intervention: January to June 2007

An electronic alert indicating high thrombotic risk was sent to 2,121/6,585 patients (32.2%): 1,736 (53.2%) surgical and 385 (11.6%) medical patients. Appropriate prophylaxis in alerted patients was 88.5% (1,536/1,736) in surgical, and 64.4% (248/385) in those hospitalized for medical reasons (Table 2).

The rate of VTE among hospitalized patients in this period was 1.67/1000 (11 episodes in 6,585 codified patients). Medical patients developed five VTE episodes during hospitalization (1.5/1000), while objective VTE was diagnosed in six surgical patients (1.8/1000).

Regarding medical patients, one VTE episode developed despite adequate thromboprophylaxis; another event occurred in a patient with low-estimated thrombotic risk, and three in high-risk patients without electronic alert sent because of insufficient computerized clinical record data. In surgical patients, three out of six VTE episodes developed despite the fact that an electronic alert had been sent and adequate LMWH prophylaxis used, and three episodes occurred in patients with an underestimated risk of thrombosis due to lack of clinical data.

Overall population	2006*	2007*	P
Alerts sent	2073/6312 (32.8%)	2121/6585 (32.2%)	n.s.
Appropriate prophylaxis	1737/2073 (83.8%)	1684/2121 (84.1%)	n.s.
Medical patients			
Alerts sent	303/3137 (9.7%)	385/3262 (11.6%)	<0.05
Appropriate prophylaxis	149/303 (49.2%)	248/385 (64.4%)	<0.01
Surgical patients			
Alerts sent	1770/3175 (55.7%)	1736/3262 (53.2%)	<0.05
Appropriate prophylaxis	1588/1770 (89.7%)	1536/1736 (88.5%)	n.s.

*, First semester; n.s., not significant.

Table 2: Electronic alerts sent and appropriateness of prophylaxis.

Comparison with pre-intervention period

Compared with the first semester of 2005, before implementing the computer-alert program, the overall rate of VTE during hospitalization was reduced from 3.26/1,000 (21 episodes in 6,441 patients) to 1.74/1,000 patients, (relative reduction 46.6%) in 2006, OR: 0.53, 95%CI (0.25–1.10). Similar reductions rates were observed when medical and surgical patients were considered separately, OR: 0.54, 95%CI (0.20–1.33) and OR: 0.55, 95%CI (0.14–1.90), respectively (Table 3).

Most importantly, the positive impact observed with the use of the electronic alert was maintained over time (Fig. 1). During the first semester of 2007, the rate of VTE during hospitalization was 1.67/1,000 (11 episodes in 6,585 patients), OR: 0.51, 95% CI (0.24–1.05); 1.5/1,000 medical patients (five episodes in 3,323 patients), OR: 0.36, 95%CI (0.12–0.98) ($p<0.05$); and 1.84/1000 surgical patients (6 episodes in 3,262 patients), OR: 0.80, 95%CI (0.25–2.148) (Table 3).

Discussion

The implementation of an electronic alert system can help clinicians to identify hospitalized patients at increased risk of VTE. We present the results in a single institution of a computerized alert program that was associated with a marked reduction of VTE episodes during hospitalization, especially in medical patients. Overall, 32% of all hospitalized patients were considered at risk of VTE, resulting in an electronic alert, in accordance with a recent survey of US inpatients (23), although lower than the proportion observed in the ENDORSE study (15). The reduced number of alerts sent to medical patients (around 10%) is surprisingly low. This may be explained by the fact that to estimate every medical patient's thrombotic risk, the reason for hospitalization and previous history of VTE were essential data. The electronic alert software obtained these items from a very simple electronic questionnaire that had to be fulfilled by the physician at admission. Unfortunately, some medical patients lacked this questionnaire, so their risk was underestimated. On the contrary, in surgical patients, these data could also be obtained from the surgery registries (nearly always fulfilled), so their risk estimation was more accurate. However, despite this potential shortcoming effect that would reduce the impact of the electronic alert system, our results showed a major reduction in the rate of VTE, especially in medical patients.

The percentage of alerted medical patients who received adequate prophylaxis was low (49% in 2006 and 64% in 2007), compared with almost 90% of surgical patients. A survey of discharged patients at our institution in the control population, before the implementation of the electronic alert program, showed

Overall population	2005*	2006*	OR (95% CI)#	2007*	OR (95% CI)#
N	6441	6312		6585	
VTE events	21	11		11	
Incidence (/1,000 patients)	3.26	1.74	0.53 (0.25–1.10)	1.67	0.51 (0.24–1.05)
Medical patients					
N	3390	3137		3323	
VTE events	14	7		5	
Incidence (/1,000 patients)	4.13	2.23	0.54 (0.20–1.33)	1.50	0.36 (0.12–0.98)
Surgical patients					
N	3051	3175		3262	
VTE events	7	4		6	
Incidence (/1,000 patients)	2.29	1.26	0.55 (0.14–1.90)	1.84	0.80 (0.25–2.48)

*, First semester; #2005 corresponds to the reference group.

Table 3: Cumulative incidence of VTE during hospitalization.

that the rate of appropriate thromboprophylaxis in at-risk medical patients was only 27%, similar to previous reports (12, 13). Recent data from the RIETE registry showed that only 28% of acutely ill medical patients had received thromboprophylaxis, compared with 67% of surgical patients (24). Therefore, although it must still be improved, the implementation of prophylaxis in up to 64% and 89% in medical and surgical patients, respectively, had a great clinical impact, leading to a marked reduction in in-hospital VTE incidence.

Evidence-based educational programs can be successful in increasing the use of prophylaxis by clinicians. Computerized tools for patient risk assessment can also improve physicians' use of different preventive therapies (25–27). In a recent randomized trial that assessed the effects of a computerized reminder system among 2,501 in-patients identified at high-risk of VTE, the intervention group received more prophylaxis than the control group (34% vs. 15%, p<0.001), and also had a lower incidence of clinically-diagnosed, objectively-confirmed DVT or PE at 90 days (4.9% vs. 8.2%, p<0.001) (20). In addition, the use of electronic alerts in a cohort study of hospitalized high-risk patients was associated with increased prophylaxis rates (37.7% of alerted patients), although the majority of physicians failed to order prophylaxis (28).

Whereas a temporary limited benefit after different interventions, owing to progressive loss of motivation of clinicians, has been observed in clinical practice (29), the use of this computerized reminder system had a prolonged positive impact, since VTE reduction was maintained for two years. Moreover, the rate of appropriate thromboprophylaxis in medical patients improved from 49% in 2006 to 64% in 2007. A possible explanation for this improvement is that acceptance of the alert program by physicians increased over time as they became more familiar with it.

Some limitations of the study should be recognized. First, the benefit of the electronic alert was based on comparison with historical controls. Indeed, the performance of a randomized study would have provided higher evidence, but some ethics concerns arose when the study was designed. To minimize the risk of bias, patients hospitalized in the first semester of 2005, just before the new alert system was implemented, were used as controls. The characteristics of hospitalized patients were not exactly similar in the two periods analyzed. For example, the percentage of cancer patients was higher in the first semester of 2005 than in the two post-intervention periods. However, its impact on the incidence of VTE among hospitalized patients during the study periods would be counteracted by the higher rates of elderly patients, previous VTE or subjects urdergoing orthopaedic surgery in 2006 and 2007. Importantly, in-hospital stay was similar in all groups and the same thromboprophylaxis protocol was active. Second, only the incidence of VTE during the hospitalization period was evaluated and it is possible that the effect was not maintained after hospital discharge (30). There is a link between outpatient and inpatient cases of VTE (31), and it seems reasonable to believe that a more appropriate use of thromboprophylaxis during hospitalization should be associated with better prophylaxis indications at discharge, both in high-risk medical and surgical patients. However, the optimum duration of thromboprophylaxis in medical patients is currently under evaluation (32). Unfortunately, follow-up of patients after discharge was not performed. Third, the risk assessment method used for medical patients (the modified PRETEMED scale) has not yet been validated in prospective studies. Hence, this study would also represent the first implementation and validation of this potentially important risk assessment method in clinical practice. Finally, data regarding the incidence of major bleeding complications secondary to thromboprohylaxis or thrombosis-related death before and after implementation of the electronic alerts are lacking. The incidence of major bleeding associated with prophylactic doses of LMWH has been shown to be low in clinical trials (6). In our thromboprophylaxis protocol, patients with high bleeding risk were encouraged to receive mechanical rather than pharmacological prophylaxis. In addition, no significant increase in blood units consumption has been observed.

No other intervention, neither local nor national campaign for VTE prevention, was started at the time this study was conducted, so the possibility that the changes seen were a result of a general increase in awareness of VTE rather than an effect of the electronic alert program is unlikely.

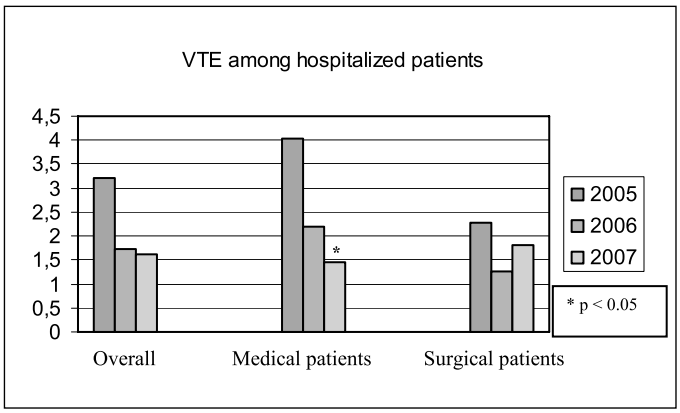

Figure 1: Rates of VTE among hospitalized patients (incidence/ 1,000 patients) in the pre-intervention (year 2005) and post-intervention periods (years 2006 and 2007). *p<0.05 as compared with 2005.

What is known about this topic?

- VTE prophylaxis is underused, especially in medical patients.
- Individual VTE risk assessment is complex and may lead to suboptimal prophylaxis compliance.
- Computer decision-support systems have been shown to increase thromboprophylaxis adherence and reduce three-month VTE incidence in high-risk patients.

What does this paper add?

- The implementation of a computer-alert program helped to reduce the incidence of VTE during hospitalization.
- For the first time, an intervention aimed to improve VTE prophylaxis has shown a maintained effectiveness over time.

In order to implement the electronic-alert program a complete computerized clinical record system is mandatory. Physicians and other care providers must accept and clearly understand the objective of electronic alerts, which are useful tools to evaluate each patient's thrombotic risk. Our results confirm that the implementation of an electronic alert program for the prevention of VTE among hospitalized patients facilitates the appropriate indication of thromboprophylaxis among clinicians and reduces the rates of VTE during hospitalization. However, clinical alerts are tools that help but do not transform the decision-making process, which is the responsibility of the physicians' team.

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