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ORIGINAL ARTICLE

Adequacy of venous thromboprophylaxis in acutely ill medical patients (IMPART): multisite comparison of different clinical decision support systems

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Summary. *Background*: The adequacy of thromboprophylaxis prescriptions in acutely ill hospitalized medical patients needs improvement. *Objective*: To prospectively assess the efficacy of thromboprophylaxis adequacy of various clinical decision support systems (CDSS) with the aim of increasing the use of explicit criteria for thromboprophylaxis prescription in nine Swiss medical services. *Methods*: We randomly assigned medical services to a pocket digital assistant program (PDA), pocket cards (PC) and no CDSS (controls). In centers using an electronic chart, an e-alert system (eAlerts) was developed. After 4 months, we compared post-CDSS with baseline thromboprophylaxis adequacy for the various CDSS and control groups. *Results*: Overall, 1085 patients were included (395 controls, 196 PC, 168 PDA, 326 eAlerts), 651 pre- and 434 post-CDSS implementation: 472 (43.5%) presented a risk of VTE justifying thromboprophylaxis (31.8% pre, 61.1% post) and 556 (51.2%) received thromboprophylaxis (54.2% pre, 46.8% post). The overall adequacy (% patients with adequate prescription) of pre- and post-CDSS implementation was 56.2 and 50.7 for controls ($P = 0.29$), 67.3 and 45.3 for PC ($P = 0.002$), 66.0 and 64.9 for PDA ($P = 0.99$), 50.5 and 56.2 for eAlerts ($P = 0.37$), respectively, eAlerts limited overprescription (56% pre, 31% post, $P = 0.01$). *Conclusion*: While pocket cards and handhelds did not improve thromboprophylaxis adequacy, eAlerts had a modest effect, particularly on the reduction of overprescription. This effect only partially contributes to the improvement of patient safety and more work is needed towards institution-tailored tools.

Keywords: clinical decision support systems, internal medicine, medical education, thromboembolism, thromboprophylaxis.

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Introduction

Venous thromboembolism (VTE) is frequent in hospitalized patients in internal medicine, as 50%–75% of VTEs occur in medical wards [1]. Among patients not receiving thromboprophylaxis, deep vein thrombosis (DVT) can be found in 5%–15%, proximal DVT in 2%–5% and pulmonary embolism (PE) in 0.3%–1.5% [1]. PE may be responsible for up to 10% of hospital deaths, a figure that may be underestimated as the diagnosis is not often suspected clinically [1]. Moreover, DVT may be asymptomatic in up to 70% of the cases. Most of these serious events can be prevented by anticoagulant prophylaxis, as shown in a recent meta-analysis [2]. The relative risk of symptomatic VTE in patients with thromboprophylaxis was 0.43 (95% CI 0.26–0.71), representing an absolute risk reduction of 0.29%.

Several risk factors for VTE in internal medicine have been recognized and explicit criteria have been developed to support physicians' decision about thromboprophylaxis prescription. These criteria have been inferred from randomized, controlled trials [3,4] and summarized in recommendations [5] but have not been prospectively validated. Chopard *et al*. [6] have summarized these criteria in a score (Fig. 1) which correlated well (kappa 0.88) with the use of explicit criteria. Despite the recognition of thromboprophylaxis efficacy and the publication of criteria to better define the medical patients at risk of VTE, the adequacy and homogeneity of thromboprophylaxis prescription are weak [7]. For example, the rate of prophylaxis may vary from 30% to 89% in different medical services of large hospitals in the same country, with major underuse (45%)

Cardiac failure	2
Respiratory failure	2
Recent stroke	2
Recent myocardial infarction	2
Acute infectious disease (including sepsis)	2
Acute rheumatic disease	2
Malignancy	2
Myeloproliferative syndrome	2
Nephrotic syndrome	2
History of venous thromboembolism	2

Known hypercoagulable state	2
Immobilization (<30 min walk per day)	1
Recent travel >6 h	1
Age >60	1
Obesity (BMI >30)	1
Chronic venous insufficiency	1
Pregnancy	1
Hormonal therapy (substitutive or contraceptive)	1
Dehydration	1

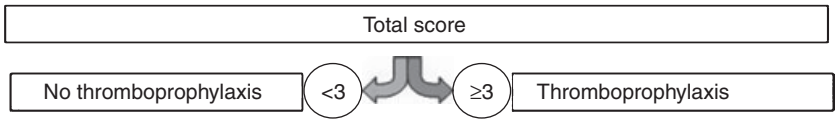

Fig. 1. Criteria used to assess the indication to thromboprophylaxis. BMI, body mass index.

or overuse (31%) [8]. Other studies also raised the need to improve the appropriateness of thromboprophylaxis [9,10].

Research in medical education has shown that different tools may help physicians change their practice, among which electronic reminders at the time of the prescription are the most efficient, compared with simple guidelines [7,11]. The use of electronic alerts linked to an electronic patient chart significantly improved the compliance of physicians with local thromboprophylaxis guidelines in one orthopedic surgery ward [12] from 83% to 95%. In another institution, the implementation of electronic alerts increased the use of mechanical or pharmacologic prophylaxis and reduced VTE rate in a population of mixed, medical and surgical high-risk patients [13]. Recently, Kucher [14] showed that the rate of appropriate prophylaxis increased from 44% to 76% in a medical ward using electronic alerts. However, comparison among different clinical decision support systems (CDSS) to improve thromboprophylaxis prescription in medical patients has not been explored yet. Our study aims to assess the efficacy of different CDSS to improve the adequacy of thromboprophylaxis prescription in acutely ill hospitalized medical patients.

Methods

Setting and intervention

In October 2006, all eligible patients from 10 randomly selected Swiss hospitals were enrolled in the multinational, observational, cross-sectional Epidemiologic International Day for the Evaluation of Patients at Risk for Venous Thromboembolism in the Acute Hospital Care Setting (ENDORSE) study, coordinated by the Center for Outcomes Research (University of Massachusetts Medical School, Worcester, MA, USA) [15]. Among the 10 Swiss centers participating in the ENDORSE survey, eight accepted to participate in the present study, representing nine medical services (two were distinct medical sections in one large institution). The Swiss medical patients data were extracted from the ENDORSE database to assess a baseline thromboprophylaxis adequacy, according to the set of criteria summarized in the score by Chopard *et al.* [6] (Fig. 1). In centers already using an electronic chart an e-alert system (eAlerts) was developed, computing the thromboembolic risk score and providing to the clinician the indication for thromboprophylaxis. In one center, an alert kept flashing on the nurses' and physicians' computer screens until the score was used. In another center, a window inviting the physician to utilize the score kept occupying a portion of the physicians' computer screens until it was used. The centers without electronic charts were randomly assigned to pocket cards (PC) or pocket digital assistants (PDA) providing the thromboembolic risk score, or received no CDSS (controls, C). Four months after the implementation of the CDSSs in each center, we conducted a 1-day survey to collect the same kind of information as collected for the ENDORSE study and we again assessed the adequacy of thromboprophylaxis. The study was approved by the ethical committees of each institution, according to national and local regulations.

Outcomes and statistical analyses

The main outcome was the difference in the adequacy of thromboprophylaxis prescription between the baseline survey and the post-CDSS implementation assessment. Low-molecular-weight heparins, low-dose unfractionated heparin, vitamin K antagonists, fondaparinux, other anticoagulants and aspirin given for protection against venous thromboembolism were considered adequate, as well as mechanical prevention (intermittent pneumatic compression or graduated compression stockings). Overall adequacy was defined as the percentage of patients for whom the decision to prescribe thromboprophy-

laxis or not was correct, according to the risk score. Overuse was defined as the percentage of patients to whom thromboprophylaxis was prescribed although not indicated by the score. Underuse was defined as the percentage of patients to whom thromboprophylaxis was not prescribed although indicated by the score. We compared for each CDSS the changes from the baseline adequacy using chi-squared tests and constructed binary logistic regression models including the phase of the study (baseline or after the implementation of CDSS), the CDSS used and the interaction between these two terms to predict adequacy. To take into account a cluster effect at the hospital level, we used a Generalized Estimating Equations (GEE) model with an exchangeable working correlation matrix to assess global adequacy of thromboprophylaxis prescription. To have a sense of the actual use of the tools, we performed sub-analyses of the computer logs of the electronic patient chart accesses in one eAlerts institution. SPSS version 15.0 (SPSS Inc, Chicago, IL, USA) and SAS version 9.1 (SAS Institute Inc., Cary, NC, USA) were used to conduct the statistical analyses.

The study needed 388 patients in each arm to possess an 80% power to detect a 10% difference in overall thromboprophylaxis adequacy, given a *P*-value set at 0.05. In each CDSS group, 173 patients were required to significantly detect a 15% difference in adequacy.

Results

The study included 1085 patients (395 C, 196 PC, 168 PDA, 326 eAlerts), with 651 at baseline and 434 post-CDSS implementation (Table 1). Patient characteristics and risk factors for thromboembolism are shown in Table 2 for both study groups. They were generally similar in both groups except the fact that more patients in the post-CDSS group had malignancy or acute infection.

The changes in overall adequacy (% patients with adequate decisions) for each CDSS and each center are detailed in Table 3, whereas Tables 4 and 5 show thromboprophylaxis underuse or overuse (% patients with underuse or overuse). Adequacy decreased with time, essentially because of an increase in underprescription. No CDSS implementation significantly changed this decline. A binary logistic regression model including the phase of study (baseline vs. post-CDSS implementation), the type of CDSS and the interaction between these two terms showed that, compared with no intervention, the odds ratios (OR) for overall adequacy were 0.5 for PC (95% CI 0.24–1.03, $P = 0.06$), 1.19 for PDA (95% CI 0.56–2.54, $P = 0.65$) and 1.56 for eAlerts (95% CI 0.85–2.87, $P = 0.14$), respectively. The GEE models taking into account the center clustering provided the same results: OR values were 0.54 for PC (95% CI 0.27–1.10, $P = 0.09$), 1.27 for PDA (95% CI 0.60–2.70, $P = 0.52$) and 1.68 for eAlerts (95% CI 0.93–3.07, $P = 0.09$), respectively. Adjustment for the increased number of patients with the infection criterion in the post-CDSS phase did not affect the results of the interventions.

As presented in Tables 4 and 5, eAlerts significantly limited the overprescription of thromboprophylaxis. However, no CDSS could significantly correct the baseline increase in its underprescription.

Table 1 Distribution of the patients among the diverse study groups, at baseline and 4 months after the decision support system supply

	Baseline ($n = 651$)	Post-CDSS* ($n = 434$)	Total ($n = 1085$)
No CDSS	251	144	395
Pocket cards	110	86	196
Pocket digital assistant	94	74	168
eAlerts	196	130	326

*CDSS, Clinical Decision Support System.

Table 2 Patient characteristics and risk factors for thromboembolism at baseline and 4 months after the decision support system supply

	Baseline ($n = 651$)	Post-CDSS* ($n = 434$)	*P*
Age (mean years)	68.2	69.7	0.07
Weight (mean kg)	72.8	72.6	0.88
Height (mean cm)	168.4	168.3	0.87
BMI (mean)	26.1	25.5	0.32
Acute infection (% of patients)	10.9	33.9	< 0.001
Immobilization (% of patients)	3.7	4.1	0.41
Acute heart failure (% of patients)	20.4	18.0	0.18
Acute non-infectious respiratory failure (% of patients)	7.1	9.4	0.10
Recent stroke (% of patients)	7.5	8.5	0.31
Active malignancy (% of patients)	10.0	21.4	< 0.001
Chronic venous insufficiency (% of patients)	4.6	8.1	0.03
Previous thromboembolism (% of patients)	5.5	7.4	0.25
Thromboprophylaxis indicated (% of patients)	31.8	61.1	< 0.001
Thromboprophylaxis prescribed (% of patients)	54.2	46.8	0.01

*CDSS, Clinical Decision Support System.

Table 3 Percent (95% CI) of patients with adequate prescription decision, at baseline and 4 months after the decision support system supply

	Center number	Baseline ($n = 651$)	Post-CDSS* ($n = 434$)	*P*
No CDSS	1	52.6	49.4	0.66
($n = 395$)	2	58.3	52.4	0.42
	All	56.2 (50.0–62.2)	50.7 (42.6–58.7)	0.29
Pocket	3	69.0	38.6	< 0.001
cards	4	60.9	58.6	0.87
($n = 196$)	All	67.3 (58.1–75.3)	45.3 (35.3–55.8)	0.002
Pocket digital	5	74.3	57.9	0.14
assistant	6	56.3	72.7	0.29
($n = 168$)	7	62.8	71.4	0.55
	All	66.0 (55.9–74.7)	64.9 (53.5–74.8)	0.99
eAlerts	8	52.1	56.9	0.42
($n = 326$)	9	41.9	50.0	0.61
	All	50.5 (43.0–57.4)	56.2 (47.6–64.4)	0.37

*CDSS, Clinical Decision Support System.

Table 4 Percent (95% CI) of patients with underprescription, at baseline and 4 months after the decision support system supply

	Baseline (n = 288)	Post-CDSS* (n = 290)	P
No CDSS	31.0 (23.2–40.0)	48.5 (38.8–58.3)	0.01
Pocket cards	56.8 (42.2–70.3)	71.9 (59.2–81.9)	0.14
Pocket digital assistant	25.9 (16.1–38.9)	24.4 (14.2–38.7)	0.99
eAlerts	40.3 (30.0–51.4)	49.5 (39.4–59.5)	0.28

*CDSS, Clinical Decision Support System.

Table 5 Percent (95% CI) of patients with overprescription, at baseline and 4 months after the decision support system supply

	Baseline (N = 363)	Post-CDSS* (n = 144)	P
No CDSS	54.3 (46.0–62.4)	51.1 (37.2–64.7)	0.73
Pocket cards	16.7 (09.6–27.4)	20.7 (09.8–38.4)	0.67
Pocket digital assistant	45.0 (30.7–60.2)	51.7 (34.4–68.6)	0.63
eAlerts	55.5 (46.5–64.1)	30.8 (18.6–46.4)	0.01

*CDSS, Clinical Decision Support System.

We also conducted the analyses of adequacy by applying the ACCP criteria for thromboprophylaxis [5]. Although there were some variations in the adequacy compared with the present results, none of the CDSS significantly improved or worsened the adherence to the ACCP guidelines in comparison to baseline (data not shown).

A subgroup analysis of 167 patients in one institution with eAlerts showed that the physicians actually used the electronic window proposing to compute the score automatically for only 51 patients (31%). Among these 51 occurrences of e-score use, 35% were applied to low-risk patients without an indication to thromboprophylaxis, and 65% to patients with an indication to thromboprophylaxis (P = 0.86). Those using the e-score had an overall adequation of 64%, compared with 53% when the e-score was not used (P = 0.24). Among the 29 patients for whom the e-score recommended thromboprophylaxis, 22 (76%) had thromboprophylaxis prescribed.

Discussion

In the present study including several institutions, no CDSS could significantly change the low baseline rate of adequate prescription of thromboprophylaxis, although there was an improvement in the rate of overprescription with eAlerts. The proportion of patients at risk of thromboembolism in the post-CDSS phase of this study (61.1%) was similar to reported rates in Switzerland [6,8] and other countries [9]. However, our baseline prevalence of at-risk patients, determined by Chopard's risk score on the ENDORSE data, was lower (31.8%), as was the prevalence determined by the ACCP criteria (21%) [15,16]. The baseline thromboprophylaxis prescription rate in the present study (54.2%) was similar to previous studies, in which the adequacy to prescribe thromboprophylaxis to at-risk patients was relatively high (up to 60%). According to our study and previous ones, there is room for improvement in overprescription, more than in underprescription. This may partially explain the difficulty in demonstrating an improvement in underprescription while there was a significant decrease in overprescription with electronic alerts in this study. Only preventing overprescription is, however, of lesser interest for patient safety, because the risk of complication of an unnecessary thromboprophylaxis is probably less important than the risk of a thromboembolic event that could be prevented. Additionally, as thromboprophylaxis tends to be underprescribed in patients with cancer [7,17], our results may partly be explained by the higher proportion of patients with malignancy in the post-CDSS phase of the study.

This study confirms difficulties related to the implementation of CDSS in a medical service. First, although the different CDSSs were implemented in each institution with explanations and theoretical support by the local director of the service, followed by reminders during the intervention period, the compliance with the use of the different CDSSs may have remained weak. This possibility is suggested in our study by a subgroup analysis of patients in one institution using eAlerts, showing an actual use of around 30%. Although a measure of compliance with the other tools used in this study was not possible, it is likely that pocket card- or PDA-scores were also underutilized. The hypothesis that physicians used the tool only for low-risk patients to obtain reassurance about their decision of not prescribing thromboprophylaxis was not confirmed by the analysis of this subgroup.

Second, even when a CDSS is used, it is not certain that the proposal made by the tool is followed by the physician. Still in our analysis of an e-alert subgroup, three-quarters of physicians actually followed the recommendation made by the tool. Although a CDSS is intended to support – and not replace – the physician's reasoning and decisions, this illustrates the difficulty for a clinician to comply with a recommendation based on an external tool in case of disagreement with his or her own opinion. An additional difficulty is represented by the fact that hospital services are subject to several shifts of residents among their diverse rotations, making a close follow-up of any CDSS use difficult. This requires continuous information and intensive coaching to make the staff use any CDSS and follow an internal policy.

Third, despite the supply of a tool to an institution, local policies about thromboprophylaxis or other contextual influences may counteract the effect of any intervention. This might have happened in hospital number 3, to which PCs were assigned. It is unlikely that the observed significant and important decrease in adequacy in this institution was due to this tool itself, but rather to an unknown underlying factor belonging to this particular site. Finally, the data collected for the ENDORSE study were suitable to assess the thromboembolic risk using the ACCP criteria, but lacked some information (e.g. nephrotic syndrome or malignant haemopathies) to fully apply the scored criteria used in this study. Given the lower prevalence of these diseases in internal

medicine patients, this problem probably played a minor role in the results.

Although this study was multicentric, it was conducted in a single country, which may reduce the generalizability of our results. This also limited the number of eligible centers, thus potentially influencing power. In each CDSS group of this study, the number of patients included provided a power of 80% to detect a 15%–20% difference in thromboprophylaxis accuracy. A lack of power might thus explain why smaller differences could not reach statistical significance (e.g. 5% difference for eAlerts). Nevertheless, the magnitude of the absolute changes remains small, which represents a limited 'clinical' relevance that does not fundamentally change the conclusions drawn from our data.

The eAlert systems used in this study informed the physicians that the thromboprophylaxis score had not been used. Although these types of warnings might be disturbing because they keep flashing and occupying a portion of the computer screen, they were apparently not disturbing enough because a portion of the physicians had the ability to ignore them and prescribe thromboprophylaxis as they intended. Additional features are now under development to force the physicians to open the risk score, for example by making them unable to use the patient chart until the thromboprophylaxis score has been used, or a justification provided for not using it. These changes need future evaluation.

In conclusion, interventions providing pocket card- or PDA-scores could not improve the adequacy of thromboprophylaxis in this study, while eAlerts had a potential effect, particularly on overprescription. However, overprescription prevention may only partially contribute to the improvement of patient safety. The observed poor compliance of any CDSS use is a limiting factor of efficacy, reinforcing the need for an individualized and continuous incentive to use the tools developed to help physicians make better decisions.

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Disclosure of Conflict of Interests

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