Caprini VTE computerized risk assessment improves the use of thromboprophylaxis in hospitalized patients with pulmonary disorders

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Abstract

Background. Adequate thromboprophylaxis reduces the risk of venous thromboembolism (VTE) by half in hospitalized patients. A single scoring system is recommended to improve thromboprophylaxis.

Objectives. We investigated the impact of implementing a computerized system to prevent VTE in inpatients with pulmonary diseases and identified predictors of the overuse and underuse of pharmacological thromboprophylaxis.

Materials and methods. We compared the use of thromboprophylaxis with enoxaparin in all patients hospitalized for pulmonary disorders in a tertiary hospital in Kraków, Poland, in 2014 and 2017, before and after introducing a computerized thromboprophylaxis system. Using the Caprini risk assessment, the overuse and underuse of thromboprophylaxis were defined as the use in patients with <5 points and ≥ 5 points, respectively.

Results. Both cohorts ($n = 2007$ in 2014 and $n = 1570$ in 2017) were similar with regard to age and sex. The most frequent causes of hospitalization were intestinal lung disease (39.0%) and lung cancer (20.4%) in 2017, and pneumonia (38.8%) and lung cancer (27.5%) in 2014. Although the use of thromboprophylaxis was comparable in both cohorts, it was used more frequently in high VTE risk patients in 2017 compared with 2014 (96.98% compared to 29.17%, respectively, $p < 0.001$), with a concomitant reduction in its overuse (2.26% compared to 6.26%, respectively, $p < 0.001$). In 2017, no predictors of thromboprophylaxis underuse were identified. The overuse was mainly predicted by the diagnosis of airway diseases (odds ratio (OR) = 0.16, 95% confidence interval (95% CI) = 0.02–1.17, $p = 0.015$).

Conclusions. Our findings indicate the benefits of using a computerized system to manage pharmacological thromboprophylaxis in pulmonary inpatients.

Key words: pulmonary diseases, thromboprophylaxis, Caprini VTE risk assessment

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Background

The risk of developing venous thromboembolism (VTE) is associated with a number of clinical situations, including hospitalization that is responsible for 10–20% of the VTE episodes.[1] It has been shown that 42% of hospitalized patients are at intermediate or high risk for VTE[2,3] and 10% of in-hospital deaths are related to VTE.[4–6] Adequate thromboprophylaxis reduces the risk of VTE by half,[7,8] which enhances inpatients' safety, reduces the prevalence of VTE, and decreases the costs of treatment. The American College of Chest Physicians (ACCP) guidelines strongly recommend pharmacological thromboprophylaxis in all patients with high risk for VTE (Grade 1B).[8,9] Various validated scoring systems are used to identify patients at high risk for developing VTE. It is important to use one of them consistently.[10] Implementation of a computerized model to prevent VTE increases the guideline-appropriate VTE prophylaxis (by 80%) and improves VTE outcomes in inpatients.[11–13]

The risk of VTE among patients with specific internal diseases is heterogeneous. For example, the reported frequency of VTE among patients with chronic obstructive pulmonary disease (COPD) exacerbation ranges from 5% to 29%,[14,15] with an up to twenty-fold increase reported among lung cancer patients.[16] A frequent overuse and underuse of thromboprophylaxis was observed in our previous study when the decision to administer prophylaxis was at the discretion of the treating physician.[17] To improve thromboprophylaxis, a computerized system based on the Caprini risk assessment was implemented.

Objectives

We sought to compare the risk of overuse and underuse of pharmacological thromboprophylaxis before and after introducing routine use of a computerized system in a specific group of patients with pulmonary disorders.

Materials and methods

We collected data from the medical records of all patients aged >18 years admitted to the Department of Lung Diseases of the John Paul II Hospital in Kraków, Poland, within 2 time intervals.

The 2017 cohort represents patients hospitalized from April 1, 2017, to December 31, 2017, following the implementation of the use of the Caprini VTE computerized risk assessment tool. After 2014, it became standard practice to routinely use a recommended VTE risk assessment tool for the patients hospitalized in the department.

The 2014 cohort comprises all adult patients hospitalized from April 1, 2014, to December 31, 2014, who were admitted prior to the implementation of the use of the Caprini tool.[17] All archived records of patients were analyzed and scored using the Caprini VTE risk assessment tool, and the final score was compared with archived records of admitted patients who received thromboprophylaxis.

The computerized Caprini risk assessment model was implemented upon admission to the pulmonary department.[18] Individuals who scored 5 or more points were identified as high-risk for VTE and in need of thromboprophylaxis. Subjects who scored fewer than 5 points (≤4 points) were identified as low-risk. Administration of enoxaparin (40 mg once daily, subcutaneuos (SQ) injection) on each day of hospitalization was used as thromboprophylaxis for all high-risk patients. Mechanical thromboprophylaxis was not used. Patients who stayed in the hospital for more than 24 h were eligible for inclusion in the study. No additional criteria for including patients in the study were used. The study was carried out in accordance with the local legal and ethical regulations. All patients were classified into one of the 6 groups based on the main cause of hospitalization identified at admission to the hospital and confirmed during discharge (Table 1).

The underuse of thromboprophylaxis was defined as denying thromboprophylaxis in subjects who scored 5 or more points according to the Caprini risk assessment. The overuse of thromboprophylaxis was defined as thromboprophylaxis administration for patients with 4 or fewer points accordingly.

Statistical analysis

Variables were presented as numbers and percentages or median and interquartile ranges (IQRs) as appropriate. Nominal variables in the subgroups were compared with the Pearson's χ^2 test or the Fisher's exact test. Continuous variables were compared using the Mann–Whitney U test. To identify independent predictors of thromboprophylaxis overuse or underuse, a univariate logistic regression analysis was performed. Associations between 2 variables were expressed as odds ratios (OR) along with 95% confidence intervals (95% CI) and analyzed for variables represented in at least 5% of study cohorts. Two-sided p-values below 0.05 were considered statistically significant. All calculations were done with JMP® v. 13.1.0 (SAS Institute Inc., Cary, USA).

Results

The characteristics of the 2 cohorts comprising 2007 individuals in the year 2014 and 1570 in 2017 are presented in Table 1. Both cohorts were similar with regard to age and gender (Table 1). There was no difference in the prevalence of comorbidities between both groups. The median Caprini risk score was 4 in the 2014 cohort and 3 in the 2017

Table 1. Characteristics of the study cohorts in 2014 and 2017 year. Data are shown as the number (percentage)

Variable	All patients			Patients with thromboprophylaxis			Patients without thromboprophylaxis		
	2014 (n = 2007)	2017 (n = 1570)	p-value	2014 (n = 368) (18.4%)	2017 (n = 349) (22.2%)	p-value	2014 (n = 1636) (81.6%)	2017 (n = 1221) (77.8%)	p-value
Demographics									
Age 41–60 years	543 (24.7)	345 (21.9)	0.05	60 (14.4)	42 (12.0)	0.35	483 (27.2)	303 (24.8)	0.15
Age 61–74 years	936 (42.6)	750 (47.7)	0.002	193 (46.4)	171 (49.0)	0.50	741 (41.7)	579 (47.3)	0.002
Age >75 years	444 (20.2)	263 (16.7)	0.007	141 (33.9)	140 (40.1)	0.07	302 (17.0)	123 (10.1)	<0.0001
Men	1253 (57.0)	922 (58.6)	0.33	242 (58.2)	187 (53.6)	0.22	1010 (56.8)	735 (60.1)	0.07
BMI > 25 kg/m^2	1180 (53.7)	1018 (64.7)	<0.0001	268 (64.4)	251 (71.9)	0.03	910 (51.2)	767 (62.7)	<0.0001
Cause of the hospitalization									
Airway diseases*	330 (16.4)	293 (18.7)	0.08	65 (17.7)	32 (9.2)	0.0005	263 (16.1)	261 (21.4)	0.0004
Interstitial lung disease	268 (13.4)	613 (39.0)	<0.0001	11 (3.0)	123 (35.2)	<0.0001	257 (15.7)	490 (40.1)	<0.0001
Lung cancer	551 (27.5)	320 (20.4)	<0.0001	160 (43.5)	97 (27.8)	<0.0001	390 (23.8)	223 (18.3)	0.0003
Pneumonia	778 (38.8)	179 (11.4)	<0.0001	77 (20.9)	37 (10.6)	0.0002	701 (42.9)	142 (11.6)	<0.0001
Respiratory failure	28 (1.4)	148 (9.4)	<0.0001	9 (2.5)	52 (14.9)	<0.0001	19 (1.2)	96 (7.9)	<0.0001
Other	52 (2.6)	17 (1.1)	0.0011	46 (12.5)	8 (2.3)	<0.0001	6 (0.4)	9 (0.7)	0.17
Comorbidities									
Cardiovascular disease	733 (71.9)	773 (49.1)	<0.0001	142 (55.5)	213 (61.0)	0.0001	589 (77.5)	560 (45.8)	<0.0001
Diabetes	81 (8.0)	16 (1.0)	0.003	17 (6.6)	1 (0.3)	0.008	63 (8.3)	15 (1.2)	0.05
Renal disease	2	14 (0.9)	<0.0001	1$^{\#}$	8 (2.3)$^{\#}$	0.01$^{\#}$	1$^{\#}$	6 (0.5)$^{\#}$	0.005$^{\#}$
Heart failure	14 (0.6)	27 (1.7)	0.002	10 (2.4)	16 (4.6)	0.09	4 (0.2)	11 (0.9)	0.01
Thyroid disorders	33 (3.2)	0.0	<0.0001	3 (1.2)$^{\#}$	1 (0.01)	0.26$^{\#}$	30 (4.0)	1 (0.1)	<0.0001
Previous venous thromboembolism	11 (0.5)	33 (3.2)	0.002	8 (1.9)	3 (1.2)	0.46	3 (0.2)	30 (4.0)	1.00
Varicose veins	185 (8.4)	23 (1.5)	<0.0001	78 (18.8)	21 (6.0)	<0.0001	105 (5.9)	2 (0.2)	0.005
Malignancies	545 (24.8)	226 (14.4)	<0.0001	194 (46.6)	120 (34.4)	<0.0001	350 (19.7)	106 (8.7)	<0.0001
Other diseases	44 (4.3)	119 (7.6)	<0.0001	20 (7.8)	94 (26.9)	<0.0001	24 (3.2)	25 (2.0)	0.002
Caprini VTE risk assessment score									
Low risk (1–2 points)	361 (16.4)	476 (30.3)	<0.0001	8 (1.9)$^{\#}$	3 (0.9)$^{\#}$	0.36$^{\#}$	353 (19.9)	473 (38.6)	<0.0001
Medium risk (3–4 points)	858 (39.1)	766 (48.7)	<0.0001	62 (14.9)	25 (7.2)	0.001	796 (44.8)	741 (60.5)	<0.0001
High risk (≥5 points)	978 (44.5)	331 (21.0)	<0.0001	346 (83.2)	321 (92.0)	0.0003	629 (35.4)	10 (0.8)	<0.0001

BMI – body mass index; * – asthma, chronic obstructive pulmonary disease and bronchiectasis; VTE – venous thromboembolism. For comparisons marked with $^{\#}$, the Fisher's exact test was used; in all other Pearson's χ^2 test was used.

cohort ($p < 0.001$, Mann–Whitney U test). Eighty-seven (4.3%) individuals in 2014 and 19 (1.2%) in 2017 were receiving chronic oral anticoagulation treatment. The most common causes of hospitalization in 2014 and 2017 are presented in Table 1. The duration of hospitalization was similar (both groups had a median of 5 days). The proportions of individuals who received thromboprophylaxis with low molecular weight heparin (LMWH) were comparable in both cohorts (Table 1). However, in the 2017 cohort, pharmacological thromboprophylaxis was administered in a markedly larger patient group with high VTE risk compared with the 2014 cohort (n = 321, 96.98% compared to n = 259, 29.17%, respectively, $p < 0.001$, Pearson's χ^2 test). The number of inpatients identified as low-risk for VTE was comparable in both cohorts but in the 2017 cohort, the overuse of thromboprophylaxis was significantly lower (Table 2,3).

The main predictors of the underuse of thromboprophylaxis in the 2014 cohort included age (41–60 years) and the presence of interstitial lung disease, pneumonia, and swollen legs (Table 3). Predictors of underuse were not identified in the 2017 cohort. Age (41–60 years) and airway diseases were identified as overuse predictors in the 2017 cohort (Table 2).

Of the total recorded deaths during patients' hospital stays, 7 in 2014 and 3 in 2017, all of them resulted from end-stage pulmonary diseases. No autopsy was performed. No significant adverse events such as allergic reactions or heparin-induced thrombocytopenia were observed. No major bleeding or symptomatic VTE was recorded. The number of blood recipients who received packed blood cells was similar in both cohorts. Chronic anemia due to lung cancer was the major cause of blood transfusion in 2014 and 2017.

Table 2. Use of thromboprophylaxis according to Caprini VTE risk assessment. Data were shown as the number (percentage)

Variable	Patients with indications for thromboprophylaxis			Patients who did not receive thromboprophylaxis despite indication			Patients without indications for thromboprophylaxis			Patients who received thromboprophylaxis without indication		
	2014	2017	p-value	2014	2017	p-value	2014	2017	p-value	2014	2017	p-value
Number of subjects	888 (100.00)	331 (100.00)	<0.0001	629 (70.83)#	10 (3.02)#	<0.0001#	1119 (100.00)	1239 (100.00)	<0.0001	70 (6.26)	28 (2.26)	<0.0001
Airway diseases*	138 (15.54)	31 (9.37)	0.0055	88 (9.91)#	0 (0.00)#	0.37#	192 (17.16)	262 (21.15)	0.0142	17 (1.52)	1 (0.08)	0.0066
Lung cancer	449 (50.56)	98 (29.61)	<0.0001	292 (32.88)#	4 (1.21)#	0.54#	102 (9.12)	222 (17.92)	<0.0001	4 (0.36)#	3 (0.24)#	0.68#
Interstitial lung disease	47 (5.29)	109 (32.93)	<0.0001	38 (4.28)#	4 (1.21)#	0.0035#	221 (19.75)	504 (40.68)	<0.0001	2 (0.18)	18 (1.45)	<0.0001
Respiratory failure	16 (1.80)	50 (15.11)	<0.0001	10 (1.13)#	1 (0.30)#	0.17#	12 (1.07)	98 (7.91)	<0.0001	3 (0.27)#	3 (0.24)#	0.38#
Pneumonia	203 (22.86)	38 (11.48)	<0.0001	144 (16.22)#	1 (0.30)#	0.46#	575 (51.39)	141 (11.38)	<0.0001	18 (1.61)	0 (0.00)	0.001
Other	35 (3.94)	5 (1.51)	0.0341	4 (0.45)#	0 (0.00)#	1.00#	17 (1.52)	12 (0.97)	0.23	15 (1.34)	3 (0.24)	0.11
Age 41–60 years	105 (11.82)	33 (9.97)	0.69	69 (7.77)#	2 (0.60)#	0.31#	438 (39.14)	312 (25.18)	<0.0001	24 (2.14)	11 (0.89)	0.64
Age 61–74 years	476 (53.60)	167 (50.45)	0.58	309 (34.80)#	5 (1.51)#	1.00#	460 (41.11)	583 (47.05)	<0.0001	28 (2.50)	9 (0.73)	0.47
Age >75 years	390 (43.92)	137 (41.39)	0.63	252 (28.38)#	3 (0.91)#	0.75#	54 (4.83)	126 (10.17)	<0.0001	4 (0.36)#	6 (0.48)#	0.03#
History of VTE	10 (1.13)	21 (6.34)	<0.0001	2 (0.23)	0 (0.00)	–	1 (0.09)#	2 (0.16)#	1.00#	0 (0.00)	0 (0.00)	–
Varicose veins	147 (16.55)	120 (36.25)	<0.0001	75 (8.45)#	5 (1.51)#	0.0041#	38 (3.40)	106 (8.56)	<0.0001	8 (0.71)#	5 (0.40)#	0.51#
Congestive heart failure	12 (1.35)	17 (5.14)	<0.0001	2 (0.23)#	1 (0.30)#	0.0463#	2 (0.18)	10 (0.81)	0.0224	0 (0.00)	0 (0.00)	–
Swollen legs	87 (9.80)	86 (25.98)	<0.0001	20 (2.25)#	7 (2.11)#	<0.0001#	22 (1.97)	26 (2.10)	0.60	9 (0.80)#	0 (0.00)#	0.06#
Serious lung diseases	716 (80.63)	184 (55.59)	<0.0001	429 (48.31)	5 (1.51)	–	316 (28.24)	216 (17.43)	<0.0001	36 (3.22)	11 (0.89)	0.28
Abnormal pulmonary function	884 (99.55)	191 (57.70)	<0.0001	626 (70.50)#	6 (1.81)#	0.3041#	1040 (92.94)	239 (19.29)	<0.0001	69 (6.17)	9 (0.73)	<0.0001
Cancer	526 (59.23)	92 (27.79)	<0.0001	333 (37.50)#	1 (0.30)#	0.0084#	19 (1.70)	27 (2.18)	0.26	2 (0.18)#	3 (0.24)#	0.14#
Thrombophilia	2 (0.23)#	1 (0.30)#	1.00#	2 (0.23)	0 (0.00)	–	0 (0.00)	0 (0.00)	–	0 (0.00)	0 (0.00)	–
BMI > 25 kg/m^2	656 (73.87)	243 (73.41)	0.0316	410 (46.17)#	9 (2.72)#	0.18#	524 (46.83)	775 (62.55)	<0.0001	24 (2.14)	17 (1.37)	0.0166

BMI – body mass index; * – asthma, chronic obstructive pulmonary disease and bronchiectasis; VTE – venous thromboembolism. For comparisons marked with #, the Fisher's exact test was used; in all other, Pearson's χ^2 test was used.

Discussion

The major findings of the current study were:

1. For pulmonary disease inpatients, using the Caprini risk assessment in a computerized system supports the appropriate recommendations of pharmacological thromboprophylaxis, increasing its use in high-risk VTE inpatients while reducing its use in patients with low VTE risk.

2. We have demonstrated that specific pulmonary diseases, like asthma and COPD, have a major impact on the prediction of appropriate thromboprophylaxis among inpatients. Thus, a better implementation of prophylaxis among inpatients requires evaluation of specific patient groups to identify those at elevated risk of under- or overuse. The current study highlights benefits from a computerized system to support the use of thromboprophylaxis in hospitals and the constant need for optimizing it in specific clinical settings, such as internal medicine wards.

Within 1 year of implementing the Caprini risk assessment in a computerized system to guide thromboprophylaxis among patients admitted to the pulmonary

Table 3. The risk factors of venous thromboembolism (VTE) prophylaxis overuse and underuse

Variable	Overuse in the 2014 cohort		Overuse in the 2017 cohort		Underuse in the 2014 cohort		Underuse in the 2017 cohort	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
BMI > 25 kg/m^2	0.44 (0.27; 0.72)	0.001	–	NS	1.94 (1.60; 2.35)	<0.001	–	NS
Swollen legs	2.99 (1.44; 6.19)	0.009	–	NS	0.55 (0.33; 0.89)	0.01	32.40 (8.26; 127.11)	<0.001
Varicose veins	–	NS	–	NS	1.83 (1.34; 2.49)	<0.001	6.07 (1.74; 21.15)	0.01
Malignancy	0.09 (0.02; 0.35)	<0.001	–	NS	7.22 (5.83; 8.94)	<0.001	–	NS
Age 41–60 years	–	NS	2.35 (1.09; 5.06)	0.037	0.28 (0.22; 0.37)	<0.001	–	NS
Age 61–74 years	–	NS	–	NS	1.45 (1.21; 1.75)	<0.001	–	NS
Age >75 years	0.23 (0.08; 0.64)	0.001	–	NS	4.81 (3.86; 5.99)	<0.001	–	NS
Abnormal pulmonary function	–	NS	–	NS	7.31 (2.28; 23.49)	<0.001	4.03 (1.13; 14.35)	0.03
Cardiovascular disease	–	NS	–	NS	1.53 (1.27; 1.85)	<0.001	4.17 (0.88; 19.71)	0.04
Diabetes	–	NS	–	NS	1.82 (1.26; 2.62)	0.002	–	NS
Airway diseases	2.11 (1.19; 3.76)	0.016	0.16 (0.02; 1.17)	0.015	–	NS	–	NS
Interstitial lung disease	0.22 (0.05; 0.91)	0.008	2.87 (1.31; 6.25)	0.007	0.37 (0.26; 0.53)	<0.001	–	NS
Lung cancer	0.19 (0.07; 0.52)	<0.001	–	NS	4.66 (3.77; 5.76)	<0.001	–	NS
Pneumonia	–	NS	–	NS	0.42 (0.34; 0.52)	<0.001	–	NS

BMI – body mass index; OR – odds ratio; 95% CI – 95% confidence interval; NS – not significant.

department, there was a significant improvement in the adequate use of prophylaxis, from 38.96% to 96.98%. Furthermore, we detected a rapid decrease of underuse of thromboprophylaxis – from 64.51% to 3.02% – among high-risk patients.

The implementation of health recommendations is an international challenge, illustrated by a 34% median of recommendation adherence, suggesting that patients do not always benefit from medical guidelines.[19] Most data show that the proportion of inpatients at high risk of VTE receiving thromboprophylaxis is between 50% and 68.95%.[13,19] Bhalla et al.[11] showed that the implementation of an obligatory computerized scoring model enforced proper medical practices, which confirms the present study. When the simple computerized system reminder was used, the percentage of inpatients at high risk of VTE receiving thromboprophylaxis increased from 42.8% to 60.0% ($p < 0.001$).[10]

The impact of specific diagnoses, such as lung disease, on the use of thromboprophylaxis appears to be underestimated. Our study showed that underuse among pulmonary inpatients is greatest in lung cancer patients, despite evidence showing a high risk of VTE in patients with this type of malignancy.[16] This study highlights the need for education on VTE in cancer patients, who are often perceived as unsuitable candidates for thromboprophylaxis due to a higher bleeding risk.

Respiratory failure and interstitial lung disease comprised larger patient subgroups in 2017 compared with 2014. This is likely a consequence of patients' aging and wider availability of improved diagnostic tools.[20–23] Age (younger adults) and airway diseases were predictors for the overuse of thromboprophylaxis. It might be speculated that the first predictor, age, was a consequence of a growing number of relatively young patients with interstitial lung diseases. This growth is the result of the development of tools for detecting connective tissue disease-associated interstitial lung diseases (CTD-ILD).[24] The airway diseases predictor was probably connected with physicians awareness that any associated dyspnea could reduce patients' daily activity after admission.[2,3,12] The main predictors of the underuse of thromboprophylaxis in the 2014 cohort, including age (41–60 years), interstitial lung disease and pneumonia, were absent in the analysis of patients from the 2017 cohort. Current predictors were different from those reported by Spirk et al.,[25] indicating that a range of specific diseases diagnosed in patients undergoing prophylaxis can markedly affect predictors of its under- and overuse, and the results of a whole patient population cannot be extrapolated to subgroups.

Limitations

This study has several limitations. The study is retrospective, which causes some problems with data acquisition and their precision (i.e., in some patients, the diagnosis could have been unestablished because some patients suffered simultaneously from different pulmonary diseases). Evaluation of asymptomatic VTE during hospital stay and post-discharge follow-up was beyond the scope of the current study. Cost-effectiveness of thromboprophylaxis and costs of its overuse were not evaluated, although this problem is important in clinical practice.[26]

Conclusions

We conclude that the use of computerized Caprini VTE risk assessment in all hospitalized patients increases the proportion of patients with pulmonary diseases who can benefit from thromboprophylaxis, and reduces its overuse among patients with low risk of VTE. To optimize thromboprophylaxis, its use should be assessed in departments dealing with patients with specific diseases.

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