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Predicting Risk Of Venous Thromboembolism In Hospitalized Cancer Patients: Utility of A Risk Assessment Tool

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Abstract

Inpatient venous thromboembolism (VTE) is a priority preventable illness; risk in cancer varies and prophylaxis is inconsistently used. A previously validated tool [Khorana Score, KS] identifies VTE risk in cancer outpatients with 5 easily available variables but has not been studied in the inpatient setting. We evaluated the validity of KS in predicting VTE risk in hospitalized cancer patients. We conducted a retrospective cohort study of consecutive oncology inpatients at the Cleveland Clinic from 11/2012–12/2014 (n= 3531). Patients were excluded for VTE on admission (n=304), incomplete KS data (n=439) or other reasons (n=8). Data collected included demographics, cancer type, length of stay (LOS), anticoagulant use and laboratory values. Multivariate risk factors were identified with stepwise logistic regression, confirmed with bootstrap analysis. Of 2,780 patients included, 106 (3.8%) developed VTE during hospitalization. Median age was 62 (range, 19–98) years and 56% were male. Median LOS was 5 (range, 0–152) days. High risk KS (≥ 3) was significantly associated with VTE in uni- and multivariate analyses (adjusted OR 2.5, 95% CI 1.3–4.9). Other significant variables included male gender (OR 1.67, 1.1–2.53), older age (OR 0.86, 0.75–0.99) and use of anticoagulants (OR 0.57, 0.39–0.85). Recursive partitioning analysis suggested optimal cut point for KS is 2 (OR 1.82, 1.23–2.69). This is the first report validating KS as a risk tool to predict VTE in hospitalized cancer patients. Using this tool could lead to more consistent and successful application of inpatient thromboprophylaxis.

Keywords

Cancer; Venous Thromboembolism; Risk Assessment Tool; Khorana Score

Introduction

The incidence of VTE in hospitalized cancer patients has been shown to be considerably higher than the incidence (<1%) reported in acutely ill medical patients without cancer. (1–

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3) The occurrence of VTE in cancer patients has several adverse consequences including increased risk of inpatient mortality, VTE recurrence, requirement for long-term therapeutic anticoagulation with a high risk of major bleeding, negative impact on quality of life and increased consumption of health care resources. (4–8) Thromboprophylaxis in hospitalized cancer patients is almost universally recommended, (3,9) and quality panels and regulators have focused on inpatient VTE as a priority preventable illness; VTE prophylaxis has even been introduced as an important pay-for-performance measure. (10,11) However, despite the known increased risk; prophylaxis rates amongst hospitalized cancer patients are inconsistent and not risk-adjusted. (12–14) A risk assessment tool could optimize benefit to patients and provide clinicians with a formalized method to determine need for prophylaxis and has been strongly advocated for by the American Society Of Clinical Oncology (ASCO) and the American Society of Chest Physicians. (15,16) Indeed a recent commentary cited the current lack of evidence to guide best practice for prophylaxis of inpatient VTE in malignancy “unacceptable”. (17) Multiple scoring systems to predict inpatient VTE currently exist; two in particular are widely cited - the Padua Prediction Score (18) and IMPROVE VTE risk assessment tool; (19,20). Unfortunately, both have been derived from populations of medically ill hospitalized patients and neither have been validated specifically for hospitalized cancer patients. (9)

A risk assessment model generally known as the Khorana Score (KS) to predict VTE in ambulatory cancer patients has been developed (21) and subsequently externally validated in multiple cohort studies (22–24). It was developed from a prospective registry, using a cohort of 2701 patients and validated in an independent cohort of 1365 patients from the same registry. Further this RAM was externally validated both prospectively by the Vienna CATS consortium in 819 patients and in numerous retrospective studies. (23,31) It utilizes five clinical variables (cancer site, hemoglobin, platelet and leukocyte counts and body mass index [BMI]) that are commonly available at the time of hospital admission and therefore could potentially also be utilized in the inpatient setting to predict VTE risk. However, this score has never been evaluated in cancer inpatients. We therefore chose to evaluate this risk assessment tool at the time of admission in predicting risk of VTE during hospitalization in a cohort of hospitalized cancer patients.

Methods

The study comprised a cohort of 3,531 consecutive adults with a diagnosis of malignancy and care provided by a hematologist/oncologist admitted to the Cleveland Clinic from November 2012– December 2014. Prior approval from the institutional review board was obtained. Patients over the age of 18 with an active diagnosis of malignancy at the time of admission were included. Patients were excluded for VTE on admission (n=304), incomplete KS data (n=439) or other reasons (n=8). For patients with multiple admissions who did not develop VTE during any admission, only the first admission was included in the analysis.

Data were primarily collected using an electronic query system of the electronic health records (EHR). We identified VTE events using ICD-9 codes (415.11, 415.13, 415.19, 451.11, 451.19, 451.81, 453.4, 453.40, 453.41, 453.87, 453.9). VTE events were those

coded as not present on index admission. For patients with multiple hospitalizations who did not develop VTE, only the first hospitalization was used, and the rest excluded. This was verified by manual review by one investigator (RP). In addition, reason for admission, care in an intensive care unit and surgery during index admission were also manually recorded for the study population.

Baseline data collected included patient demographics, BMI, cancer type, use of anticoagulants and antiplatelet agents on admission, laboratory values (up to 48 hours from admission), and primary indication for admission. However data on dosage of anticoagulation (i.e. therapeutic or prophylactic) was not available.

Admission indications were grouped into 9 categories. Data were also collected on length of stay (LOS) and transfer to ICU or surgery during hospitalization.

Standard descriptive statistics were used to describe characteristics of study patients. For each characteristic, the number and percentage of patients with VTE was described. Recursive partitioning analysis (RPA) was used to identify a cut point in KS that best predicted VTE risk. Three variations of KS were used in the analysis: the published and validated risk score (0 low, 1–2 intermediate, ≥3 high), the actual score (range 0–5 in this study), and the RPA risk cut point (0–1 low, ≥2 high). Logistic regression analysis was used to identify risk factors for VTE, with results summarized as odds ratio (OR) and 95% confidence interval (CI). A stepwise selection procedure with a variable entry criterion of $P \leq 0.10$ and a variable retention criterion of $P \leq 0.05$ was used to identify a multivariable model; this model was confirmed with bootstrap analysis. In brief, 1000 samples of size 2,780 were randomly selected with replacement from the study data and stepwise logistic regression analysis was performed on these samples. Variables that occurred in >50% of these models were considered to be significant. Model-based probabilities of VTE were calculated for combinations of significant multivariable risk factors. All statistical tests were two-sided; $P \leq 0.05$ indicated statistical significance. Data were analyzed using SAS software, Version 9.4 (SAS Institute, Cary, NC).

Results

Study Population

The study population comprised 2,780 patients (Table 1). Of these, 1545 (56%) were male, and median age was 62 (range, 19–98) years. A total of 1,728 (62%)had solid tumors and 1,052 (38%) patients had a hematologic malignancy. The most common primary sites for solid tumors included gastrointestinal tract (n=556; 20%, including 6% colorectal cancer), lung (n=361; 13%), breast (n=167; 6%) and head and neck (n=139; 5%). The most common sites for hematologic malignancies included leukemia and lymphoma (14% each) and myeloma (8%). Reasons for admission were grouped into nine categories of which elective chemotherapy (571;21%), infection (552;20%) and gastrointestinal symptoms (386;14%) were the most frequent. Median length of stay (LOS) was five days with a range of 0–152 days (Patients in observation for less than two nights, would be classified as 0 admission days). Use of anticoagulation and antiplatelet medications occurred on day of admission in 65% (n=1800) and 14% (n=379) of patients respectively and increased to 77% (n=2140) and

18% (n=500) when including use anytime during admission. During hospitalization, 9% (n=264) of patients were transferred to the intensive care unit and 3% (n=89) had surgery. In-hospital mortality was 5% (n=138).

VTE Events

VTE occurred in 106 patients (3.8%). Median time to first VTE was 10 days (range 1–137). All VTE events were vetted by manual screening of records. Patients that had VTE events soon after admission (e.g. 1–2 days), had either recent negative studies prior to admission and had no clinical features to suggest that VTE existed on admission. Deep vein thrombosis occurred in 86 patients (81%), whereas 20 (19%) developed pulmonary embolism, including 13 that also had evidence of deep vein thrombosis.

48 of 106 VTE patients had an admission prior to the study admission. In these 48, LOS of the prior admission was a median of 5 days (range 1–44). The prior admission began at a median of 74 days, (range 8–1042), before the study admission.

Univariate Analysis

Variables significantly associated with inpatient VTE on univariate analysis (table 2) included KS, age at admission, gender and use of anticoagulants on admission. KS was shown to have a significant association with VTE for the published high-risk score (OR 2.23, 95% CI 1.16–4.28, P=0.016) as well as for every one point increase in score (OR 1.30 95% CI 1.09–1.54, P=0.003) and the RPA cut point of ≤2 versus 0–1(OR 1.70 95% CI 1.16–2.51, P=0.007). Of note, the rate of anticoagulant use on admission varied by risk category, with 74% of high-risk KS patients receiving anticoagulants at admission, compared to 61% of intermediate-risk and 67% of low-risk patients (P<0.001).

Multivariable Analysis

KS, age, gender, and use of anticoagulants on admission remained prognostic for VTE in multivariable analysis (Table 3). Specifically, when adjusting for age, gender, and baseline anticoagulant use, high-risk KS remained associated with greater VTE risk (OR 2.51, 95% CI 1.31–4.86, P=0.006; Model #1). When the RPA KS cut point was substituted for the published KS in this model, it was also significant (OR 1.82, 95% CI 1.23–2.69, P=0.003; Model #2).

Model-based Probability

Model-based probability of VTE was calculated for combinations of variables from the multivariable model (Table 4). Age is a continuous variable so for the purpose of this analysis, age cut-points of 25, 50, and 75 were selected to represent a reasonable age spectrum within the range of the data. The probability of VTE ranged from 1.2% in patients with lowest risk profile (low-risk KS, female, older and received anticoagulation) to 15.6% in those with the highest risk profile (high-risk KS, male, younger and not receiving anticoagulation).

Discussion

We conducted a validation study of a risk assessment model previously utilized for ambulatory cancer outpatients in a cohort of hospitalized cancer patients. We found that this risk tool is significantly associated with the risk of inpatient VTE. This represents the first validation of a risk assessment tool specifically for hospitalized cancer patients.

The 3.8% rate of inpatient VTE reported by us is consistent with the rate of 4.1% a large study of 1,824,316 hospitalizations at 133 U.S medical centers that utilized the University Health System Consortium. (8) It also falls within the range described in prior data of 0.6–8%. (2,8,25–27) This range is at least in part attributable to heterogeneity of study populations across studies, with a variable distribution of the several risk factors that have been associated with cancer-related thrombosis. (28,29) We note here that a significant proportion (65%) of patients received anticoagulants on admission, which have been clearly shown to reduce the risk of hospital-acquired VTE and rates would likely have been higher without use of prophylaxis. (30)

In our study, a higher KS was significantly associated with the risk for VTE despite increased use of anticoagulants in this population. The incidence of VTE in the high-risk group (KS≤3) was associated with a VTE incidence of 7% over a median of 6 months in the original study (21) and 17% in the external validating Vienna cohort (23), which utilized a significantly longer follow-up. In our study with a median LOS of 5 days, the incidence of inpatient VTE in patients with high-risk KS was 5.5% whereas patients with low-risk KS had incidence of 2.5%; the inherent differences in the acuity of patients hospitalized as compared to their counterparts in the clinic makes direct comparisons challenging. In addition, a high proportion of patients received thromboprophylaxis in this study (as recommended by most guidelines) whereas outpatient thromboprophylaxis is not routinely employed. Importantly, in multivariable analysis, our data suggests that high-risk KS was associated with a 2.5 fold increase in the risk of developing VTE when compared to patients with low-risk KS.

Via RPA, the optimal cut off for KS was ≤2, which remained significant in multivariable analysis. Other studies have also suggested that this cut-off of risk score is optimal to differentiate risk. Ay et al, (23) utilizing a prospective cohort of cancer patients with newly diagnosed cancer or progression of disease after complete or partial remission, showed that a KS of 2 was associated with a HR of 5.5 (95% CI 2.4–12.6). In a recent prospective study, rate of VTE was 11 % in patients with KS>2 further supporting a lower cut-off. (22) In our study the incidence of VTE for patients with KS ≤ 2 was 5.1%, compared to 3.0% for patients with KS 0–1.

Other RAMs used to stratify patients admitted with acute medical illnesses include IMPROVE and the Padua Prediction Score (18,19,32,33). Although both these scores include an active diagnosis of cancer as an important contributing factor they have not been validated specifically to stratify risk in cancer inpatients.

Risk factors previously shown to be associated with higher VTE risk in cancer inpatients include African American ethnicity, older age, female gender, cancer site (including GI

cancer, kidney, brain, ovary, and lung) the use of red cell or platelet transfusions and certain comorbidities. (34) Our analysis differs from these prior studies as both older age and female gender were shown to be associated with lower VTE risk. These differences may be related to the greater proportion of genitourinary cancers and hematologic malignancies in our study population as compared to prior studies.

Our study has certain limitations. Although a large number of patients were included in the final analysis, a significant number (n=439; 12%) had to be excluded as one or more data components to calculate the KS were missing. Moreover, due to the retrospective nature of the study, diagnostic studies were only performed when clinically indicated; prospective design with scheduled screening might lead to a more accurate estimation of VTE rate. Asymptomatic VTE on admission could not be excluded and as this was a retrospective study patient were not be objectively screened for VTE. Events such as ICU admission or surgery during the admission and total LOS almost certainly influence risk of VTE, but because they were not known on the day of admission, we chose not to include them in this analysis. Similarly we did not have any data on post discharge VTE events; rates could be potentially higher if this could be accounted for. Indeed in a large, multicenter prospective study of over 15,000 patients aiming to validate IMPROVE score, 45% of all VTE events occurred post discharge. (20) It would have been useful to attempt to validate the IMPROVE and Padua prediction models and compare them with the KS in this study population. However variables such as prior history of VTE and inherited or acquired thrombophilia are important components of these scoring systems and were not available for us to calculate retrospectively. Thromboprophylaxis and anticoagulation would influence VTE rates during hospitalization, to account for this we used any administration of an anticoagulation medication within 24 hours of admission; however we could not differentiate between therapeutic or prophylactic anticoagulation nor could we account for the possibility of changes in anticoagulant dosing during hospitalization. Of the patients that did not receive anticoagulation on admission, it was not possible to determine what was the reason for the same. We speculate this could be based on the guidelines recommending VTE prophylaxis with LMWH for those hospitalized for 3 or more days (LOS range in our study was 0–152 days); also patients could well have had contraindications (for example bleeding or significant thrombocytopenia on admission). It has been suggested that expanding the Khorana scoring system by using certain biomarkers (eg sP-Selectin and D dimer) further improves stratification of the KS (23). However, these biomarkers are not routinely collected at time of admission and levels were unavailable to us. Utility of improving the KS with addition of biomarkers is an important research question that can be addressed in future prospective cohort studies.

In summary, this cohort study is the first to demonstrate that the KS can be used to predict inpatient VTE risk in hospitalized cancer patients. Stratifying patients based on risk can assist clinicians in practice to individualize management, shield patients from both under- and over-utilization of thromboprophylaxis and guide further researchers to focus on interventions based on delineated groups. Further studies to corroborate our findings, compare the performance of KS with other risk assessment tools in cancer patients and to incorporate biomarker data to improve risk assessment are warranted.

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Table 1

Characteristics of the study population and associated rates of venous thromboembolism.

	Study Population (n=2780)		VTE (n=106)	
		%		%
Age at admission, years				
<40	192	7	11	10
40–59	990	35	40	38
60–79	1376	49	49	46
≥80	222	8	6	6
Gender				
Male	1545	55	71	67
Female	1220	45	35	33
Reason for admission				
Elective Chemotherapy	571	20	21	20
Infection	552	20	17	16
Gastrointestinal Symptoms (excluding bleeding)	386	14	11	10
Pain Management	219	8	12	11
Neurologic symptoms	199	7	9	8
Cardio-respiratory symptoms	179	6	9	8
Bleeding/Anemia	156	6	7	7
Other	391	14	17	19
Antiplatelet medications on admission				
Yes	379	14	96	91
No	2401	86	10	9
Anticoagulant medications on admission				
Yes	1800	65	51	48
No	980	35	55	52
Admission to ICU During Hospitalization				
Yes	264	9	41	16
No	2516	91	65	3
Surgery During Hospitalization				
Yes	89	3	15	17
No	2691	97	91	3
Length of Stay				
0–8	1821	66	14	0
9–17	508	18	14	6
18–29	292	10	29	10
≥30	159	25	30	19
Khorana Score				
Low Risk (0)	707	25	18	3

	Study Population (n=2780)		VTE (n=106)	
		%		%
Intermediate Risk (1–2)	1710	62	68	4
High Risk (≥3)	363	13	20	6
0	707	25	18	3
1	1031	37	35	3
2	679	24	33	5
3	278	10	14	5
4	77	3	5	7
5	8	<1	1	13
0–1	1738	63	53	3
2–5	1042	37	53	5
Model score for platelet count				
0	2456	88	90	4
1	326	12	18	6
Model score for hemoglobin				
0	1727	62	57	3
1	1055	38	51	5
Model score for white blood cell count				
0	2072	75	66	3
1	710	25	42	6
Model score for BMI				
0	2427	87	87	4
1	355	13	21	6
Discharge Status				
Alive	2642	95	88	3
Dead	138	5	18	13

Table 2

Univariable Logistic Regression analysis

Variable	OR	95% CI	P
Age at admission, years Per 10 year increase	0.87	0.76–0.99	0.04
Gender Male/Female	1.63	1.08–2.46	0.02
Reason for Admission			
Gastrointestinal/Renal	1.21	0.33–4.42	0.77
Infection/Renal	1.31	0.38–4.55	0.67
Chemotherapy/Renal	1.58	0.46–5.37	0.47
Bleeding/Renal	1.94	0.49–7.67	0.34
Neurologic/Renal	1.96	0.52–7.37	0.32
Cardio-respiratory/Renal	2.19	0.52–7.37	0.25
Pain management/Renal	2.4	0.66–8.66	0.18
Khorana Score			
Intermediate/low-risk	1.58	0.94–2.68	0.09
High/low-risk	2.2	1.16–4.28	0.016
Per 1 point increase	1.3	1.09–1.54	0.003
>2/0–1	1.7	1.16–2.51	0.007
Antiplatelet agents on day of admission	0.65	0.34–1.26	0.2
Anticoagulant agents on day of admission	0.57	0.39–0.85	0.005
Length of stay, days Per 1 level increase	1.4	1.32–1.48	<0.001

Table 3

Multivariable logistic regression analysis

	Model # 1			Model #2		
Variable	**OR**	**95% CI**	**P**	**OR**	**95% CI**	**P**
Khorana Score						
Intermediate/low risk	1.58	0.93–2.68	0.09			
High/low risk	2.52	1.31–4.86	0.006			
≥2/0–1				1.82	1.23–2.69	0.003
Age at admission, years						
Per 10 year increase	0.86	0.75–0.99	0.034	0.86	0.75–0.98	0.028
Gender Male/Female	1.67	1.1–2.53	0.015	1.65	1.09–2.49	0.018
Anticoagulants on day of admission Yes/No	0.57	0.39–0.85	0.005	0.58	0.39–0.85	0.006

Table 4

Model Based Probability of VTE

		Anticoagulation/Prophylaxis			No Anticoagulation/Prophylaxis		
Gender	**Age**						
Female							
	75 yrs	1.2 %	1.8%	2.9%	2.0%	3.2%	5.0%
	50 yrs	1.7%	2.7%	4.2%	2.9%	4.6%	7.1%
	25 yrs	2.4%	3.8%	6.0%	4.2%	6.5%	10.0%
Male							
	75 yrs	2.0%	3.1%	4.8%	3.4%	5.2%	8.1%
	50 yrs	2.8%	4.4%	6.8%	4.8%	7.4%	11.3%
	25 yrs	4.0%	6.2%	9.6%	6.8%	10.4%	15.6%