Determining venous thromboembolic risk assessment for patients with trauma: The Trauma Embolic Scoring System

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BACKGROUND: This study aimed to determine the relative "weight" of risk factors known to be associated with venous thromboembolism (VTE) for patients with trauma based on injuries and comorbidities.

METHODS: A retrospective review of 16,608 consecutive admissions to a trauma center was performed. Patients were separated into those who developed VTE (n = 141) versus those who did not (16,467). Univariate analysis was performed for each risk factor reported in the trauma literature. Risk factors that were shown to be significant ($p < 0.05$) by univariate analysis underwent multivariate analysis to develop odds ratios for VTE. The Trauma Embolic Scoring System (TESS) was derived from the multivariate coefficients. The resulting TESS was compared with a data set from the National Trauma Data Bank (2002–2006) to determine its ability to predict VTE.

RESULTS: The multivariate analysis demonstrated that age, Injury Severity Score, obesity, ventilator use for more than 3 days, and lower-extremity trauma were significant predictors of VTE in our patient population. The TESS was from 0 to 14, with the best prediction for those patients with a score of more than 6 (sensitivity, 81.6%; specificity, 84%). Overall, the model had excellent discrimination in predicting VTE with a receiver operating characteristic curve of 0.89. The VTE rates for TESS in the National Trauma Data Bank data set were similar for all integers except for 3 and 4, in which the VTE rates were significantly higher (3, 0.2% vs. 0.6%; 4, 0.4% vs. 1.0%).

CONCLUSION: The TESS provides an objective measure of classifying VTE risk for patients with trauma. The TESS could allow informed decision making regarding prophylaxis strategies in patients with trauma. (*J Trauma Acute Care Surg*. 2012;73: 511–515. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Prognostic study, level II.

KEY WORDS: Determining VTE risk assessment; Trauma Embolic Scoring System; VTE risk assessment.

Venous thromboembolism (VTE), the third leading cause of death in hospitalized patients with trauma, remains a vexing and capricious complication for trauma centers.[1] Numerous studies have identified specific injury patterns and comorbidities associated with venous thromboembolic risk in patients with trauma.[2–5] However, no study has created a clinically practical predictive model for VTE risk. A predictive tool with objective quantification of VTE risk in an individual patient with trauma would allow the clinician to make an informed decision on the appropriate VTE prophylaxis. We sought to develop such a tool by reviewing our experience with VTE and the risk factors in our population associated with it. The resulting risk scoring system (the Trauma Embolic Scoring System [TESS]) was then validated using the National Trauma Data Bank (NTDB).

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PATIENTS AND METHODS

A detailed literature review was performed to identify common risk factors associated with VTE. Each of these factors was assessed for its association with VTE using univariate analysis for 16,608 consecutive trauma admissions in our trauma center (Lancaster General Hospital [LGH], a Pennsylvania State Trauma Foundation Level II trauma center) between 2000 and 2009, using χ^2 tests (and Fisher's exact test where appropriate) as well as calculated (unadjusted) odds ratios (ORs) with 95% confidence intervals (CIs). Those variables that proved to be significant or marginally significant ($p < 0.3$; purposeful selection) in the univariate analysis were compiled in a multivariate binary logistic regression model from which a score was developed to assess risk of VTE. Owing to missing values, 225 subjects (1.4%) were excluded from the logistic regression model for a total of 16,383 included in the analysis. For ease-of-model application in a clinical setting and to address the lack of linearity in the logit, we categorized three important continuous variables as follows: age, Injury Severity Score (ISS), and ventilation days. These were categorized based upon clinically meaningful categories and similar cutoffs found in the literature. TESS was derived using a method in the Framingham Study, which determines a base coefficient from one of the predictors and then divides all of the other coefficients by the base to determine the appropriate points for each patient characteristic.[6] The TESS was used to identify low, moderate, high, and very high-risk

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patients for VTE complications using the modified Delphi technique. Individually standardized VTE prophylactic strategies for each of these four categories were created to address the particular risk for patients in the different groupings.

To validate the model developed at LGH, we applied it to the NTDB for the interval 2007 (n = 507,262). We excluded 273,230 patients with missing data necessary to calculate TESS score, leaving 234,032 patients for which a score could be calculated and used for a validation data set. We compared the VTE rate at our facility to that of NTDB for each integer of the TESS, using the Cochran-Mantel-Haenszel (CMH) test and logistic regression to calculate individual ORs for each stratum. We also did sensitivity and specificity analysis as well as area under the receiver operating characteristic (ROC) curve for our data and for the NTDB data to predict VTE. Statistical significance was attributed to a $p < 0.05$. For the purposes of this study, VTE included both deep vein thrombosis (DVT) and pulmonary embolism (PE) and were defined using the 2011 NTDB data set dictionary definitions.[7] These standard definitions were used in both the development (LGH) and validation (NTDB) data sets.

RESULTS

The literature review identified 19 variables associated with VTE for patients with trauma (Table 1). Of these, 13 variables were found to be significant predictors of VTE by univariate analysis (Table 2).

These variables were integrated into a multivariate logistic model, and five risk factors proved significant for the development of VTE (Table 3). The model showed excellent discrimination and goodness-of-fit, with an area under the ROC curve of 0.89 (95% CI, 0.87–0.92) and Hosmer-Lemeshow p = 0.101, respectively.

Based on the coefficients from the logistic model, scores were assigned for each risk factor. These score ranges have been compiled to create the TESS, which can range from 0 to 14 (Table 2). To assess performance of the TESS, we calculated the TESS score for each subject (median, 2; Q1, 1; Q3, 5; range, 0–14). The resulting sensitivity (81.6%) and specificity (84.0%) were optimized at a cutoff TESS score of 6. The TESS-predicted prevalence closely approximates that observed in the LGH trauma sample (Fig. 1).

TESS was applied to 507,262 patients in the NTDB 2007 data set. We excluded 273,230 patients with missing data necessary to calculate TESS score, leaving 234,032 patients for analysis. Using the CMH test to assess each TESS integer strata, we found the combined CMH OR to be 1.23 (1.04–1.47; p = 0.017) suggesting that the combined NTDB VTE rates across the strata were higher, although the test for homogeneity (p = 0.028) suggests that there is a lack of homogeneity across the stratum. To further assess differences within the strata, we calculated individual ORs for each stratum using logistic regression. The VTE rates for both the NTDB and LGH models were similar for each TESS integer, except for a TESS scores of 3 (LGH, 0.2% vs. NTDB, 0.6%; OR, 2.80; 95% CI, 1.04–7.56; p = 0.042) and 4 (LGH, 0.4% vs. NTDB, 1.0%; OR, 2.47; 95% CI, 1.16–5.23; p = 0.019) where the VTE rate was significantly higher in the NTDB (Fig. 2). To assess discrimination, we calculated an area under the ROC curve of 0.89 (95% CI, 0.87–0.92) for the LGH cohort and a 0.84 (95% CI, 0.83–0.84) for the NTDB sample. We calculated sensitivity and specificity values for each data set and found that in both the LGH and NTDB databases, the optimal score which maximized sensitivity and specificity was an integer value of 5 or higher (Table 4).

The assessment of "appropriate" prophylaxis was completed using the modified Delphi technique for low (0–3), moderate (>3–6), high (>6–10) and very high (>10) TESS scores and is being used in an ongoing prospective study of this new scoring system. Patients' individual total TESS score determines the aggressiveness of VTE prophylaxis. The TESS score for each patient is computed daily, owing to the possibility

TABLE 1. Comparison of Subject Demographics Between Developing and Validating Dataset

	Developing (LGH), n (%) or Median (IQR)	Validating (NTDB), n (%) or Median (IQR)
Age, y		
<30	6,376 (38.4)	202,169 (40.9)
30–64	6,286 (37.9)	206,157 (41.7)
≥65	3,942 (23.7)	85,844 (17.4)
Missing	4	13,092
Median (IQR)	40 (21–63)	37 (21–56)
Sex		
Female	6,273 (37.8)	168,047 (33.1)
Male	10,333 (62.2)	323,446 (63.8)
Missing	2	15,769
ISS		
Low (1–9)	10,548 (64.3)	312,746 (64.3)
Moderate (10–16)	2,881 (17.6)	79,112 (16.3)
Severe (17–25)	1,769 (10.8)	58,869 (12.1)
Very severe (>25)	1,198 (7.3)	35,866 (7.4)
Missing	212	20,669
Median (IQR)	9 (4–13)	9 (4–14)
Injury type		
Blunt	15,585 (93.9)	417,487 (86.9)
Burn	161 (1.0)	11,902 (2.5)
Penetrating	855 (5.2)	50,945 (10.6)
Missing	7	26,928
Discharge status		
Alive	16,052 (96.7)	437,778 (95.5)
Dead	555 (3.3)	20,556 (4.5)
Missing	1	48,928
VTE status		
None	16,464 (99.1)	353,281 (98.6)
VTE	144 (0.9)	4,881 (1.4)
Missing	0	149,100
Ventilation days		
None	15,156 (91.3)	251,346 (85.3)
≥1 d	1,441 (8.7)	43,499 (14.8)
Missing	11	212,417
Length of stay, d		
Median (IQR)	2 (1–5)	3 (1–6)
Missing	0	1,259
n	16,608	507,262

IQR, interquartile range.

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TABLE 2. Univariate Associations with DVT/PE in LGH Patients With Trauma

Variable	DVT/PE, n (%)	*p*	Unadjusted OR	95% CI
Age, y				
<30	30 (0.5)	<0.001	Reference	
30–64	60 (1.0)		2.04	1.31–3.16
≥65	54 (1.4)		2.94	1.88–4.60
ISS				
Low (1–9)	20 (0.2)	<0.001	Reference	
Moderate (10–16)	29 (1.0)		5.35	3.02–9.48
Severe (17–25)	31 (1.8)		9.39	5.34–16.51
Very severe (>25)	64 (5.3)		29.71	17.91–49.27
Preexisting conditions				
Preexisting conditions	99 (1.1)	0.001	1.75	1.23–2.50
No preexisting conditions	45 (0.6)		Reference	
Hematologic preexisting condition				
Yes	10 (0.9)	0.794	1.09	0.57–2.08
No	134 (0.9)		Reference	
Malignancy preexisting condition				
Yes	1 (1.1)	0.544*	1.29	0.18–9.30
No	143 (0.9)		Reference	
Neurologic preexisting condition				
Yes	13 (1.0)	0.564	1.18	0.67–2.10
No	131 (0.9)		Reference	
Obesity preexisting condition				
Yes	18 (2.2)	<0.001	2.76	1.68–4.55
No	126 (0.8)		Reference	
Pregnancy preexisting condition				
Yes	0 (0.0)	0.647*	—	—
No	144 (0.9)		Reference	
Ventilation days				
Yes	87 (6.0)	<0.001	17.62	12.13–23.88
No	57 (0.4)		Reference	
Prolonged extrication				
Yes	36 (3.0)	<0.001	4.41	3.01–6.47
No	105 (0.7)		Reference	
Central line				
Yes	7 (1.7)	0.099*	1.97	0.92–4.24
No	137 (0.9)		Reference	
Repair of venous injury				
Yes	5 (6.2)	<0.001*	7.76	3.09–19.47
No	139 (0.8)		Reference	
Transfusion				
Yes	15 (5.7)	<0.001*	7.63	4.41–13.22
No	129 (0.8)		Reference	
Spinous fracture				
Yes	29 (2.5)	<0.001	3.36	2.23–5.07
No	115 (0.8)		Reference	
Lower-extremity fracture				
Yes	42 (1.8)	<0.001	2.52	1.75–3.62
No	102 (0.7)		Reference	
Pelvic fracture				
Yes	10 (3.9)	<0.001	4.86	2.53–9.35
No	134 (0.8)		Reference	
Spinal cord				
Yes	2 (9.1)	0.015*	11.58	2.68–50.01
No	142 (0.9)		Reference	

*p value was calculated with the Fisher's exact test owing to low expected cell counts. p values calculated with χ^2 test.

of the patient's score changing over time. For instance, once the patient is on the ventilator for more than 3 days, his or her TESS score would increase by four points, possibly indicating the need for more aggressive VTE prophylaxis.

DISCUSSION

It is widely recognized that patients with trauma are at high risk for VTE.[8] The literature enumerates a number of "significant" risk factors for VTE, but there is no evaluation of their cumulative or individual effect in producing either DVT or PE. Shackford et al.[2] examined various risk factors for VTE in a population of 719 patients with trauma and found age more than 45 years to be the only factor predictive of VTE by logistic regression analysis. Knudson et al.,[3] using the 450,375 patients from the NTDB, found six factors to be significant by logistic regression for VTE: age more than 40 years (OR, 2.01; 95% CI, 1.74–2.32), lower-extremity fracture with Abbreviated Injury Scale score of 3 or higher (OR, 1.92; 95% CI, 1.64–2.26), head injury with Abbreviated Injury Scale score of 3 or higher (OR, 1.24; 95% CI, 1.05–1.46), ventilator use for more than 3 days (OR, 8.08; 95% CI, 6.86–9.52), venous injury (OR, 3.56; 95% CI, 2.22–5.72), and a major operative procedure (OR, 1.53; 95% CI, 1.30–1.80). In a cohort of 716 patients with trauma, Geerts et al.[4] identified older age (not defined; OR, 1.05; 95% CI, 1.03–1.06), blood transfusion (OR, 1.74; 95% CI, 1.03–2.93), surgery (OR, 2.30; 95% CI, 1.08–4.89), femur or tibia fracture (OR, 4.82; 95% CI, 2.79–8.33), and spinal cord injury (OR, 8.59; 95% CI, 2.92–25.28) as predictors of VTE.

Several authors have attempted to address this deficiency in the literature by devising scoring systems to risk stratify patients with trauma for VTE. Greenfield et al.[9] compiled the Risk Assessment Profile for Thromboembolism (RAPT). Using the modified Delphi technique, the authors divided known risk factors into four categories: underlying conditions, iatrogenic factors, injury-related factors, and age. They defined high risk as a RAPT score of greater than 5, and in those patients, the incidence of VTE was two to three times that reported in the literature. Subsequently, Gearhart et al.[10] validated the use of the RAPT score in a cohort of 160 high-risk (n = 102; RAPT score > 1) and low-risk (n = 58; RAPT score ≤ 5) patients with trauma. In the high-risk group, there were 10.8% DVT, whereas in the low-risk group, there were 0% DVT. Schuerer et al.[5] developed a similar risk assessment profile assigning numerical scores to various injuries, underlying conditions, and so on also using the modified Delphi

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TABLE 3. Significant Prediction Factors for VTE in Multivariate Model (n = 16,383)

Predictor	Coefficient	OR	*p*	95% CI	TESS Score
Age, y					
18–29	Referent	1.00			0
30–64	0.480556	1.62	0.039	1.03–2.55	1
≥65	0.827127	2.29	0.001	1.44–3.64	2
ISS					
1–9	Referent	1.00			0
10–16	1.42017	4.14	<0.001	2.32–7.38	3
17–25	1.62973	5.10	<0.001	2.79–9.33	3
>25	2.18105	8.86	<0.001	4.91–15.97	5
Preexisting obesity					
No preexisting obesity	Referent	1.00			0
Preexisting obesity	0.557299	1.75	0.041	1.02–2.98	1
Ventilation days					
No ventilation days	Referent	1.00			0
Ventilation days	1.88068	6.56	<0.001	4.33–9.94	4
Lower-extremity fracture					
No lower-extremity fracture	Referent	1.00			0
Lower-extremity fracture	0.925682	2.52	<0.001	1.72–3.70	2
Constant	−7.06655				

Hosmer-Lemeshow $p = 0.101$.
Area under the ROC curve, 0.89.

technique. When they implemented this scoring system into a practice guideline, they found a decrease in VTE rates (1.9% vs. 1.0%; $p = 0.059$).

Our study is unique in that it takes the significant risk factors in our sizeable trauma population (more than 16,000 patients) and develops a numerical scoring system, TESS. TESS accurately quantifies the relative risk of VTE, which can assist the clinician in determining the appropriate prophylaxis regimen for his or her individual patient. At our hospital, we are now using TESS to score our patients' VTE risk prospectively and assign prophylactic modalities. A score of 0 to 2 indicates

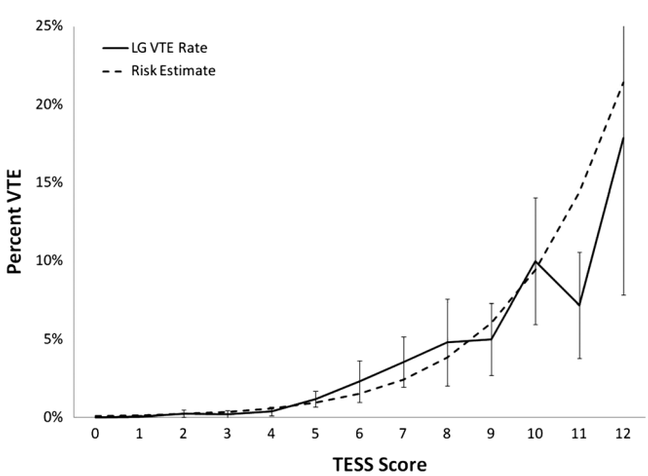

Figure 1. TESS score total and observed percent VTE with 95% CI.

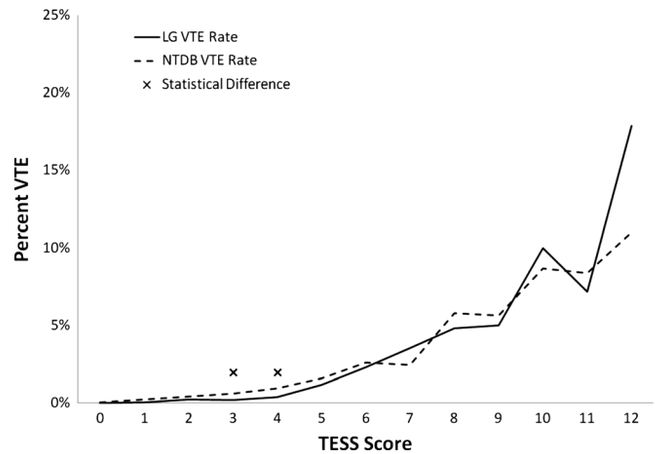

Figure 2. VTE rates versus TESS for LGH versus NTDB data set.

no risk, and in these patients, no prophylaxis was required. A TESS score of 3 to 6 is considered low risk, and these patients received venous compression boots. Patients with a TESS score greater than 7 are considered to be at moderate to high risk for VTE (with a predicted VTE rate of 5 to >20%; Fig. 1), and as such, both venous compression devices and prophylactic anticoagulation with low–molecular weight heparin is recommended. In those patients who could not be prophylactically anticoagulated for more than 48 hours due to their injuries, the insertion of a temporary vena cava filter is considered for VTE prophylaxis.

The TESS developed in our observational cohort has applicability to a larger trauma population. To that end, we examined more than 200,000 patients with trauma in the NTDB to determine how well the TESS predicts VTE. Generally, a model and scoring system would be created from the NTDB, but this study started as a local effort to better manage risk and prevent VTE. After the model was developed, we wanted to access the NTDB data to assess generalizability based upon our local model. In all integers of TESS except for 3 and 4, there was no significant difference in the TESS to predict VTE in the NTDB sample and LGH cohort. At a TESS scores of 3 and 4, the NTDB had a significantly higher rate of VTE (TESS score, 3: VTE, 0.2% LGH vs. 0.4% NTDB; TESS score, 4: VTE, 0.4% LGH vs. 1.0% NTDB). How clinically significant these differences are in these databases with large numbers of sample size is subject to interpretation, but the comparative discrimination was similar based on their area under the ROC curve of 0.89 and 0.84 (LGH vs. NTDB, respectively). Sensitivity, specificity, positive predictive values, and negative predictive values were similar

TABLE 4. Sensitivity and Specificity for Application of TESS to LGH and NTDB with Optimal TESS Score Value of 5 or Higher

	LGH	NTDB
Sensitivity, %	87.5	77.4
Specificity, %	77.5	75.6
Positive predictive value, %	3.3	4.1
Negative predictive value, %	99.9	99.6

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between the LGH and NTDB. At the optimal TESS point where sensitivity and specificity are maximized, the TESS score when negative (<5) is much better at identifying those who will not have a VTE. In assessing the missing data from the LGH cohort, none of the 225 subjects with missing data had a VTE outcome. Based on the overall VTE rate, we would have expected two subjects in this cohort to experience a VTE if they were similar to the cohort with complete data (0.9%, n = 16,383), although the difference was not significant (p = 0.148). In the NTDB cohort, the VTE rate in the cohort with missing data was 1.4% (n = 152,122) and the VTE rate in the cohort without missing data was 1.3% (n = 206,040) (p = 0.191). We assessed the missing values for the LGH cohort and found no evidence of biases in the results. When assessing missing values for the NTDB cohort, we did find that those who were missing VTE status had slightly lower ISS scores than those with complete data. Those missing an age value had a slightly lower VTE rate (0.9%) than the overall VTE rate (1.4%). The use of ventilation days may introduce some survivorship bias, although we minimized the impact by using a ventilator variable based on the use (yes or no) so that the time element is not biased by mortalities. Data on exact ventilator initiation/discontinuation time frames were not available in the retrospective registry, which did not allow us to calculate ventilation-free days. We did assess in the LGH cohort the VTE rate for those who used/did not use the ventilation stratified by mortality and found that for those who were discharged alive, the VTE rate for those using the ventilation and not using the ventilation were 7.1% and 0.4%, respectively (p < 0.001) and, for those that died, the VTE rate for those using the ventilation and not using the ventilation were 1.4% and 1.4%, respectively (p = 0.996). Based upon these additional analyses, the limitations of missing data or survivorship biases have been minimized in the models.

CONCLUSION

The TESS accurately predicts VTE rate. The TESS allows the trauma surgeon to objectively quantify the risk of VTE in an individual patient with trauma. This will enable a rational decision with regard to VTE prophylaxis.

AUTHORSHIP

F.B.R., S.R.S., M.A.H., and E.B. designed this study. J.A.M. acquired the data. M.A.H. performed the statistical analyses. F.B.R., A.R., and M.K. prepared the article, whereas S.R.S., D.W., and A.R. provided editorial oversight.

DISCLOSURE

The authors declare no conflicts of interest.

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