



Venous Thromboembolism in a Single Korean Trauma Center: Incidence, Risk Factors, and Assessing the Validity of VTE Diagnostic Tools

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Purpose: Trauma increases the risk of venous thromboembolism (VTE) in hospitalized patients. However, the risk and incidence of VTE in Korean trauma patients are limited. Therefore, we aimed to evaluate the incidence and identify potential predictors of VTE occurrence in Korean trauma patients. Moreover, we assessed the validity of the Greenfield risk assessment profile (RAP) and the trauma embolic scoring system (TESS) in these patients.

Materials and Methods: This retrospective cohort study used the data of trauma patients who were admitted to a regional trauma center between 2010 and 2016 and were eligible for entry into the Korea Trauma Data Bank. Clinical data were collected from hospital medical records. The patient's baseline characteristics and clinical data were compared between VTE and non-VTE groups.

Results: We included 9472 patients. The overall VTE rate was 0.87% (n=82), with 56 (0.59%) events of deep vein thrombosis and 39 (0.41%) of pulmonary embolism. Multiple regression analysis revealed that variables, including VTE history, pelvic-bone fracture, ventilator use, and hospitalization period, were significant, potential predictors of VTE occurrence. This study showed that increased RAP and TESS scores were correlated with increased VTE rate, with rates of 1% and 1.5% for the RAP and TESS scores of 6, respectively. The optimal cut-off value for RAP and TESS scores was 6.

Conclusion: RAP and TESS, which are well-known diagnostic tools, demonstrated potentials in predicting the VTE occurrence in Korean trauma patients. Additionally, patients with pelvic-bone fractures and long-term ventilator treatment should be carefully examined for possible VTE.

Key Words: Venous thromboembolism, multiple trauma, incidence, pulmonary embolism, prevention

INTRODUCTION

Venous thromboembolism (VTE) encompasses deep vein thrombosis (DVT) of the leg or pelvis and pulmonary embolism

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(PE).¹ Although the incidence of VTE is relatively low in Asian populations,²⁻⁶ recent literature suggests that it has been consistently and rapidly increasing in Korea.⁷

Trauma is one of the highest risk factors of VTE in hospitalized patients,^{1,8} and evidence from Western countries suggests that patients with trauma carry a 13-times higher risk of developing VTE, as compared to non-trauma patients.¹ Particularly, several trauma-related risk factors, such as an injury severity score (ISS) of >8 (ISS>8), hip fractures, and isolated pelvic or acetabular fractures that require surgery, have been described.⁹ Accurate risk assessment as well as early and timely prophylaxis are essential to effectively prevent VTE in trauma patients.¹⁰ However, as trauma patients experience complex medical and surgical conditions, with possible risks of hemorrhage, it is not easy to apply VTE prophylaxis in a clinical setting.¹¹

To aid health care providers in predicting patient needs and making appropriate decisions regarding VTE prophylaxis, a stratification scoring method with a predictive tool for the quantification of VTE risks is required. Currently, the Greenfield risk assessment profile (RAP) and trauma embolic scoring system (TESS) are available for VTE risk assessment in patients with trauma.¹²⁻¹⁴ The RAP, developed in 1997, estimates VTE risk using factors such as underlying conditions, iatrogenic factors, injury-related factors, and age.¹⁴ It assigns points for each factor, and the higher the score, the higher the risk of VTE. The TESS is a more recent and simpler tool for estimating VTE risk, especially in trauma patients. It was derived from a large cohort with a diverse trauma history and validated with data from the National Trauma Data Bank (NTDB).¹³ The TESS includes factors, such as age, ISS, preexisting obesity, ventilator use, and lower-extremity fractures, as predictors of VTE. Both methods have been validated for use in the prediction and prophylaxis of VTE among trauma patients in Western clinical settings.^{12,13,15,16} However, limited information exists on the application of these methods in Korean trauma patients. Currently, there is no standard risk factor assessment or prophylaxis protocol accepted for use in trauma patients in Korea. As the incidence of VTE and the involved risk factors may be different based on the ethnicity of patients, the validation of RAP and TESS in the Korean population is necessary before clinical application. Accordingly, the purposes of this study were as follows: 1) to evaluate the incidence of VTE in patients with trauma in Korea, 2) to assess the validity of RAP and TESS and compare the area under the receiver operating characteristic (ROC) curve (AUC), 3) to suggest a cut-off value for risk management in this population, and 4) to identify potential predictors of the development of VTE in Korean trauma patients.

MATERIALS AND METHODS

Study design and sample

This retrospective cohort study used the data of trauma patients who were admitted to a regional trauma center between 2010 and 2016. The trauma center is an academic medical center, with approximately 2000 to 3000 trauma patients receiving in-patient trauma care per year. Permission to perform this retrospective study was obtained from the Institutional Review Board (IRB # MED-MDB-18-066).

Trauma patients who were eligible for entry into the Korea Trauma Data Bank (KTDB) based on the International Classification of Diseases, 10th revision (ICD-10) codes for trauma, starting with S or T, with the exclusion of those with superficial injuries (ICD codes of S00.-S90.XX, T00.X), foreign body entering through a natural orifice (T15.X-T19.X), or poisoning (T36.X-T65.X) were included in the analysis of this study. Eligibility was assessed using the ICD trauma codes at the time of discharge. The study sample included those aged ≥ 18 years

who had been hospitalized for at least 24 h in the center. Of the 14339 trauma patients registered with the KTDB during the study period, 2387 were <18 years old, and 1033 were hospitalized for <24 h in the center; therefore, the aforementioned were excluded from the study. Moreover, we similarly excluded those with missing data on the ISS ($n=823$) and body mass index ($n=624$), both of which are necessary to calculate RAP or TESS. As a result, a final sample of 9472 trauma patients were analyzed in this study (Fig. 1).

Measurements

Potential predictors of VTE were selected based on the results of previous studies.^{8-11,13} The medical records of the participants were used to acquire the required data, which included gender, age, initial systolic blood pressure (SBP), initial heart rate, initial base deficit, initial hemoglobin level, initial Glasgow coma scale (GCS), hospitalization period, status of intensive care unit (ICU) admission, status of VTE during hospital stay, and other variables that were included either in RAP or TESS. The first values of parameters, such as GCS, SBP, heart rate, base deficit, and hemoglobin level, which were measured immediately after arrival at the hospital, were used. VTE was confirmed with CT angiography or compression ultrasound, and ISS was coded by certified trauma coordinators.

RAP and TESS, as risk stratification scoring systems, were used to estimate the risk of VTE in trauma patients. RAP assigns points for factors such as underlying conditions, iatrogenic factors, injury-related factors, and age. Adding the points for these factors produces a possible maximum score of 47. In this study, information regarding femoral central venous catheterization >24 h was not available, and excluding this factor resulted in a maximum possible RAP score of 45. TESS includes age, ISS, preexisting obesity, number of days on ventilation, and lower-extremity fractures as predictors of VTE; and the maximum possible TESS score is 14.

Statistical analysis

The data were analyzed with SPSS 22 (SPSS Statistics, IBM Corp., Armonk, NY, USA) and MedCalc 17.7 (MedCalc, Inc.,

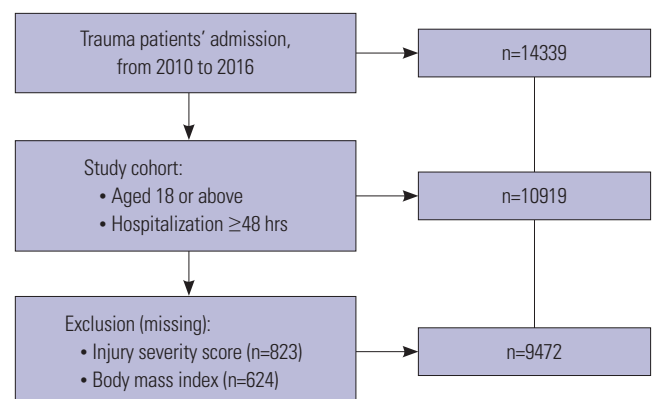


Fig. 1. Flow charts.

Mariakerke, Belgium). Data are presented as frequencies and percentages for categorical variables and means (\pm standard deviations) for continuous variables. Furthermore, a bivariate analysis was performed using chi-squared tests for categorical variables and t-tests for continuous variables. Rates of VTE by RAP and TESS scores are shown graphically. The predictive accuracies of RAP and TESS for VTE events were evaluated with ROC curve analysis using MedCalc. ROC gives a graphical display by plotting sensitivity vs. 1-specificity for each point on the curve. The area under the AUC represents how well a test discriminates between those with VTE and those without VTE. AUC values less than 0.7, between 0.7 and 0.9, or higher than 0.9 were considered to indicate low, moderate, and high predictive accuracies, respectively.¹⁷ The differences in AUCs between RAP and TESS were compared by a z test, and the best cut-offs of ROC were identified by a maximal Youden's index

(sensitivity+ specificity-1).

Logistic regression analyses were used to identify the predictors associated with the development of VTE in the participants. First, univariate logistic regressions were performed using all variables included in Table 1. Independent variables found to be significantly associated with the development of VTE in the univariate regression analysis ($p < 0.01$) are presented in Table 2, and were considered candidates for inclusion in the following enter method of multiple logistic regression model. Before performing the multiple regression analysis, multicollinearity was examined using correlation coefficients (< 0.8) and was determined not to be an issue of concern. All analyses were two-tailed, and p -values < 0.05 were considered statistically significant.

Table 1. Characteristics of Participants (n=9472)

| Variables | Overall (n=9472) | Non-VTE (n=9390) | VTE (n=82) | t or χ^2 | p value |
|--|--------------------|--------------------|--------------------|---------------|---------------------|
| VTE (yes) | 82 (0.9) | | | | |
| PE (yes) | 39 (0.4) | | | | |
| DVT (yes) | 56 (0.6) | | | | |
| Gender (men) | 6266 (66.2) | 6211 (66.1) | 55 (67.1) | 0.031 | 0.860 |
| Age (yr) [‡] | 51.03 \pm 18.50 | 51.01 \pm 18.49 | 53.84 \pm 18.62 | -1.381 | 0.167 |
| BMI ≥ 30 kg/m ² [‡] | 385 (4.1) | 380 (4.0) | 5 (6.1) | | 0.388 [†] |
| Malignancy (yes) [‡] | 217 (2.3) | 214 (2.3) | 3 (3.7) | | 0.438 [†] |
| Coagulation abnormality [‡] | 1742 (18.4) | 1719 (18.3) | 23 (28.0) | 5.140 | 0.023 |
| History of VTE (yes) [‡] | 15 (0.2) | 13 (0.1) | 2 (2.4) | 27.211 | <0.001 |
| Transfusion in 24 h ≥ 4 [‡] | 1267 (13.4) | 1235 (13.2) | 32 (39.0) | 46.960 | <0.001 |
| Surgical procedure > 2 h [‡] | 2831 (29.9) | 2807 (29.9) | 24 (29.3) | 0.015 | 0.902 |
| Vascular repair [‡] | 20 (0.2) | 20 (0.2) | | | |
| AIS chest > 2 [‡] | 1649 (17.4) | 1626 (17.3) | 23 (28.0) | 6.512 | 0.011 |
| AIS head > 2 [‡] | 1888 (19.9) | 1873 (19.9) | 15 (18.3) | 0.139 | 0.709 |
| AIS abdomen > 2 [‡] | 852 (9.0) | 835 (8.9) | 17 (20.7) | 13.920 | <0.001 |
| ISS [‡] | 10.70 \pm 9.50 | 10.65 \pm 9.46 | 16.78 \pm 11.91 | -4.651 | <0.001 |
| GCS < 8 [‡] | 313 (3.3) | 309 (98.7) | 4 (1.3) | 0.641 | 0.349 |
| Lower extremity fracture [‡] | 3295 (34.8) | 3249 (34.6) | 46 (56.1) | 16.559 | <0.001 |
| Pelvic bone fracture [‡] | 570 (6.0) | 552 (5.9) | 18 (22.0) | | <0.001 [†] |
| Quadriplegia or paraplegia [‡] | 72 (0.8) | 71 (0.8) | 1 (1.2) | | 0.467 [†] |
| Ventilator use (yes) [‡] | 1761 (18.6) | 1716 (18.3) | 45 (54.9) | 71.960 | <0.001 |
| SBP (mm Hg) | 130.63 \pm 23.67 | 130.72 \pm 23.65 | 120.37 \pm 24.01 | 3.949 | <0.001 |
| Heart rate (bpm) | 86.45 \pm 15.41 | 86.40 \pm 15.36 | 92.21 \pm 19.49 | -2.690 | 0.009 |
| Hemoglobin [*] | 13.04 \pm 2.12 | 13.04 \pm 2.12 | 12.54 \pm 2.39 | 2.154 | 0.031 |
| Base excess [*] | -2.10 \pm 4.23 | -2.08 \pm 4.23 | -3.79 \pm 4.23 | 3.498 | <0.001 |
| Days of hospitalization | 21.96 \pm 26.07 | 21.71 \pm 25.83 | 50.10 \pm 36.48 | -7.030 | <0.001 |
| ICU admission (yes) | 2633 (27.8) | 2590 (27.6) | 43 (52.4) | 25.024 | <0.001 |
| RAP | 5.58 \pm 3.77 | 5.55 \pm 3.75 | 8.34 \pm 4.49 | -5.610 | <0.001 |
| TESS | 3.79 \pm 3.12 | 3.76 \pm 3.10 | 6.77 \pm 3.57 | -8.720 | <0.001 |

VTE, venous thromboembolism; PE, pulmonary embolism; DVT, deep vein thrombosis; BMI, body mass index; AIS, abbreviated injury scale; ISS, injury severity score; GCS, Glasgow coma scale; SBP, systolic blood pressure; ICU, intensive care unit; RAP, Greenfield risk assessment profile; TESS, trauma embolic scoring system.

Data are presented as mean \pm standard deviation or n (%).

*n may vary, [†]Fisher's exact test, [‡]Variables included in either RAP or TESS.

Table 2. Results of Logistic Regression Analyses for Predicting VTE Events

| Variables | Univariate Analysis | | | Multivariate Analysis | | |
|-------------------------------|---------------------|--------------|---------|-----------------------|---------------|---------|
| | OR | 95% CI | p value | OR | 95% CI | p value |
| Coagulation abnormality | 1.740 | 1.071–2.824 | 0.025 | 0.840 | 0.466–1.513 | 0.561 |
| History of VTE (yes) | 18.033 | 4.004–81.212 | <0.001 | 17.000 | 1.995–144.872 | 0.010 |
| Transfusion in 24 h \geq 4 | 4.226 | 2.701–6.613 | <0.001 | 1.264 | 0.657–2.433 | 0.482 |
| AIS chest >2 | 1.364 | 1.071–1.739 | 0.012 | 0.859 | 0.633–1.167 | 0.332 |
| AIS abdomen >2 | 1.637 | 1.250–2.143 | <0.001 | 0.985 | 0.721–1.347 | 0.925 |
| ISS | 1.046 | 1.030–1.062 | <0.001 | 0.988 | 0.959–1.017 | 0.413 |
| Lower extremity fracture | 2.415 | 1.558–3.743 | <0.001 | 1.385 | 0.804–2.387 | 0.241 |
| Pelvic bone fracture | 4.503 | 2.651–7.650 | <0.001 | 2.059 | 1.050–4.038 | 0.036 |
| Ventilator use (yes) | 5.439 | 3.510–8.429 | <0.001 | 2.621 | 1.375–4.996 | 0.003 |
| SBP (mm Hg) | 0.982 | 0.973–0.991 | <0.001 | 0.994 | 0.985–1.004 | 0.239 |
| Heart rate (bpm) | 1.021 | 1.009–1.033 | 0.001 | 1.005 | 0.992–1.017 | 0.468 |
| Hemoglobin | 0.901 | 0.819–0.991 | 0.031 | 1.093 | 0.977–1.222 | 0.121 |
| Base excess | 0.927 | 0.888–0.967 | <0.001 | 0.985 | 0.928–1.046 | 0.616 |
| ICU admission (yes) | 2.895 | 1.872–4.476 | <0.001 | 1.047 | 0.621–1.764 | 0.863 |
| Hospitalization period (days) | 1.023 | 1.014–1.032 | <0.001 | 1.009 | 1.004–1.014 | <0.001 |

VTE, venous thromboembolism; AIS, abbreviated injury scale; ISS, injury severity score; SBP, systolic blood pressure; ICU, intensive care unit; OR, odds ratio; CI, confidence interval.

RESULTS

Table 1 shows the demographic and clinical characteristics of the sample and differences in the characteristics owing to the development of VTE events. Of 9472 trauma patients, 66.2% were men, with a mean age of 51 years. The average ISS was 10.70, and approximately 35% of the patients had fractures in their lower extremities.

The overall VTE rate was 0.87% (n=82), with 56 (0.59%) events of DVT and 39 (0.41%) events of PE. More patients with VTE than those without VTE had past histories of VTE (2.4% vs. 0.1%; $p<0.001$), abnormal coagulation results (28.0% vs. 18.3%; $p=0.023$), four or more transfusion within 24 h of arrival (39.0% vs. 13.2%; $p<0.001$), abbreviated injury scale (AIS) chest >2 (28.0% vs. 17.3%; $p=0.011$), AIS abdomen >2 (20.7% vs. 8.9%; $p<0.001$), lower extremity fracture (56.1% vs. 34.6%; $p<0.001$), fracture of the pelvic bone (22.0% vs. 5.9%; $p<0.001$), and admission to the ICU (52.4% vs. 27.6%; $p<0.001$). The average ISS and hospitalization period were significantly higher in those with VTE than in those without VTE. Overall, the average scores for RAP and TESS were 5.58 and 3.79, respectively, and the scores were higher in those with VTE. The average RAP scores for the non-VTE and VTE groups were 5.55 and 8.34, respectively, and the average TESS scores for the non-VTE and VTE groups were 3.76 and 6.77, respectively.

The rates of development of VTE by RAP and TESS are shown graphically in Figs. 2 and 3, respectively. Generally, the rate of VTE increased with an increase in RAP or TESS scores. For those with a RAP score of 6, the rate of VTE was 1%, and the rate increased up to 4% for those with a RAP score of 13 (Fig. 2). In contrast, the rate of VTE was >1% for a TESS score of \geq 6 (Fig. 3).

Fig. 4 presents the predictive accuracy of RAP and TESS based on AUCs. The AUC for RAP was 0.68 [95% confidence interval (CI)=0.67–0.69], which depicts low discrimination, while the AUC for TESS was 0.74 (95% CI=0.73–0.75), which depicts moderate discrimination. The difference in the predictive accuracy of the occurrence of VTE between RAP and TESS was statistically significant ($Z=2.202$, $p=0.028$). In this sample, the optimal cut-offs that produced the maximum discrimination for both scores were 6. Sensitivity and specificity at the cut-off of 6 for RAP were 68.3% and 54.9%, respectively. In contrast, the cut-off TESS scores of 6 yielded a sensitivity and specificity of 64.6% and 77.0%, respectively (Table 3).

Logistic regression analyses were performed to identify potential predictors of VTE (Table 2). Significant predictor variables in the univariate regression analyses ($p<0.01$) were included in the multiple regression analysis. Four variables were found to be statistically significant potential predictors of VTE occurrence, controlling for other factors in the model (χ^2 of Hosmer-Lemeshow goodness of fit test=14.088, $p=0.079$). These variables included a history of VTE, pelvic bone fracture, ventilator use, and the number of days of hospitalization. Trauma patients with a past history of VTE and pelvic bone fracture had respectively, a 17-fold [odds ratio (OR)=17.000; 95% CI=1.995–144.872] and 2-fold (OR=2.059; 95% CI=1.050–4.038) increased risk of developing VTE compared to their counterparts. Ventilator care and a 1-day increase in hospitalization increased the risk of VTE by about 2.6 times (OR=2.621; 95% CI=1.375–4.996) and 1.1 times (OR=1.009; 95% CI=1.004–1.014), respectively, after adjusting for confounding factors in the model.

DISCUSSION

As a national trauma system establishment project launched in 2012 in South Korea, 15 regional trauma centers have been established to provide appropriate trauma management. Our

center is a regional trauma center that was built in 2013 through government funding, similar to a level I trauma center in the United States (US), capable of treating 2000 to 3000 trauma patients every year. We created a VTE prevention protocol in 2015. Based on our VTE protocol, intermittent pneumatic com-

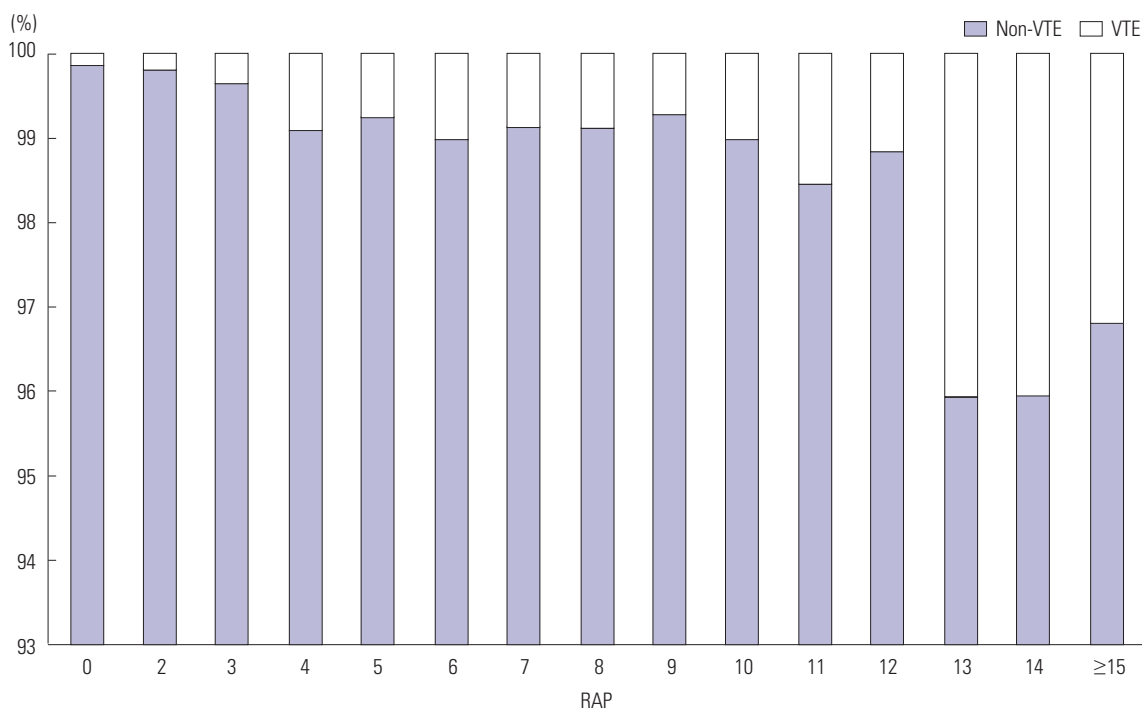


Fig. 2. The relationship between Greenfield risk assessment profile (RAP) scores and the development of VTE in trauma patients. VTE, venous thromboembolism.

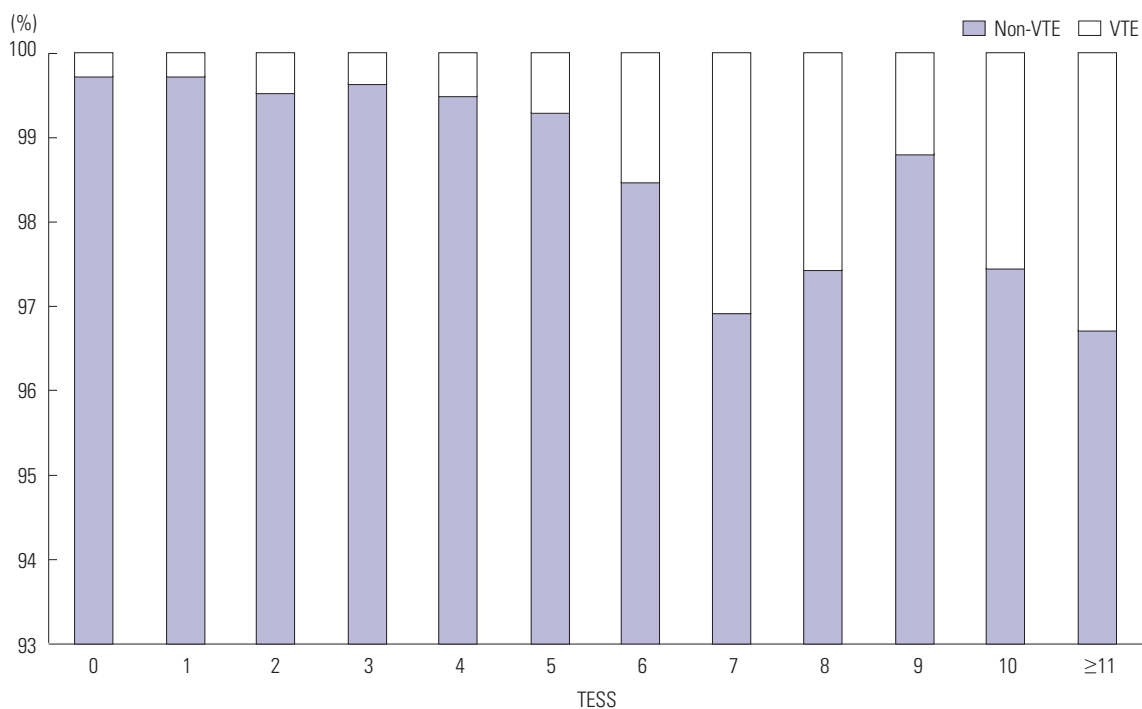


Fig. 3. The relationship between trauma embolic scoring system (TESS) and the development of VTE in trauma patients. VTE, venous thromboembolism.

pression (IPC) is to be applied to high-risk patients for VTE with no contraindication to IPC, and low-molecular-weight heparin (LMWH) is administered when the risk of bleeding is reduced. Prior to 2015, the VTE prevention protocol did not exist, but it was randomly implemented through IPC, compression stockings, LMWH, and heparin. Likewise, our center is lacking in multiple aspects compared to the renowned trauma centers in the US and Europe. Despite these limitations, our study successfully assessed the prevalence and risk factors of VTE in approximately 9500 Korean patients with multiple traumatic events, using data accumulated over 7 years.

Trauma patients have a high risk of developing VTE. The incidence of VTEs after trauma varies widely, ranging from <1% to 65%, depending on the demographics of the study population, the nature of injuries, and various other factors.^{11,18,19} Haut, et al.²⁰, using NTDB data, reported that although the overall DVT rate was reported to be 0.76%, there was a difference in DVT rates between trauma centers that performed screening (1.18%) and centers that did not perform screening (0.35%). Similarly, Knudson, et al.¹¹ used NTDB data and showed that the overall incidence of VTE was 0.36%. The incidence of PE has been reported to be 0.13–20% by several studies.^{11,21}

The rate of VTE incidence is known to vary among different

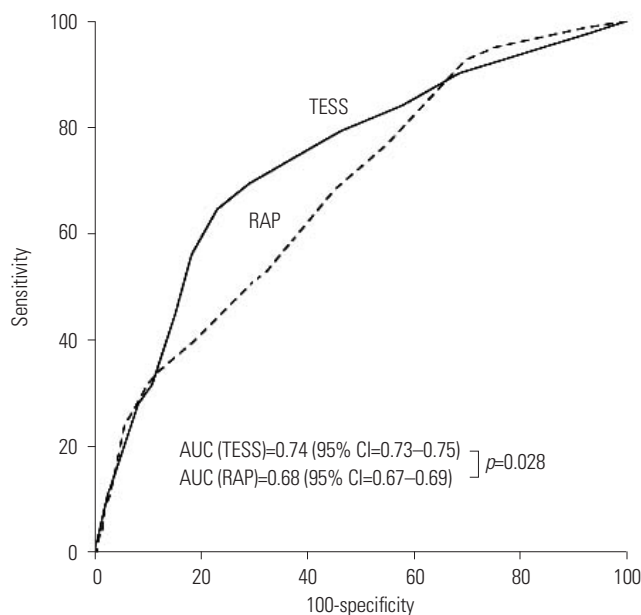


Fig. 4. Comparison of the area under the ROC curve (AUCs) of ROC curves. ROC, receiver operating characteristic; RAP, risk assessment profile; TESS, trauma embolic scoring system; CI, confidence interval.

Table 3. Comparison of AUCs between RAP and TESS Scores

| | AUC | 95% CI | p value | Cut-off | Sensitivity (95% CI) | Specificity (95% CI) | Comparison |
|------|------|-----------|---------|---------|----------------------|----------------------|------------|
| RAP | 0.68 | 0.67–0.69 | <0.001 | 6 | 68.3 (57.1–78.1) | 54.9 (53.9–55.9) | p=0.027 |
| TESS | 0.74 | 0.73–0.75 | <0.001 | 6 | 64.6 (53.3–74.9) | 77.0 (76.1–77.9) | |

RAP, Greenfield risk assessment profile; TESS, trauma embolic scoring system; AUC, area under the receiver operating characteristic curve; CI, confidence interval.

racess and ethnicities. Specifically, the incidence rate in Asians is reported to be approximately 70% of the rate in other races. Moreover, several studies have shown that the incidence rate of VTE in Asians is 3–5-fold lower than that in Caucasians.²² Although there are multiple, clinically helpful published guidelines for VTE, these guidelines are based on datasets that rarely include Asian populations; therefore, there are several limitations to applying these guidelines in Asian countries. Specifically, in South Korea, very few studies have been conducted on VTE in trauma patients. Of these few studies, Jang, et al.⁷ reported that the incidence rate of VTE in the Korean population is merely 10–20% of that in the Caucasian population. In addition, there are very few studies assessing the VTE of trauma patients in Asia, and the overall incidence rate of VTE in Korean trauma patients has never been reported.

Interestingly, the incidence rate of DVT in the trauma patients included in our study was similar to the prevalence of DVT (0.24–0.76%) reported in US-based studies using NTDB,^{11,20} unlike previous studies which showed the prevalence of DVT in an Asian population to be lower than that in a Caucasian population.^{7,22} Specifically, a VTE screening tool was not used during the data collection period of this study. Considering the outcome of NTDB analysis, which stated that the incidence rate of VTE in trauma centers without screening protocol was approximately 3-fold lower than that of those performing screenings,²⁰ active diagnoses of VTE using a screening tool will probably result in an increased incidence rate of VTE in Korean trauma patients, compared to the outcome of this study.

The symptoms of VTE are non-specific and unclear; therefore, it is difficult to predict the disease and perform examinations solely based on the symptoms. Nonetheless, VTE can induce multiple health risks in the patient and PE, in particular, is a dangerous condition that can be fatal. Therefore, it is crucial to predict the possible onset of VTE and prevent the condition by monitoring the risk factors of VTE. Multiple studies have previously introduced tools to predict potential VTE development. The Wells score and Caprine score are widely used tools to predict VTE. Although not as many studies have been performed, there are scoring systems that can predict VTE in trauma patients. The TESS, published by Rogers, et al.,¹³ recommends wearing venous compression boots for low risk patients (TESS score of 3–6) and mechanical & chemical prophylaxis for higher risk patients (predictive incidence rate of VTE 5–20%; TESS score of ≥ 7). Greenfield, et al.¹⁴ compiled the RAP for thromboembolism. Using the modified Delphi technique, the authors classified known risk factors into four categories: underlying conditions, iatrogenic factors,

injury-related factors, and age. They defined high risk as a RAP score of >5, and in those patients, the incidence of VTE was 2–3 times that reported in the literature.

In this study, we assessed the validity of RAP and TESS, which have validated applicability in Caucasian trauma patients, as predictive tools of VTE risk in Korean trauma patients to demonstrate their clinical utility. In our study, the optimal cut-off for RAP and TESS scores was 6. The outcomes of this study have shown that increased RAP and TESS scores were correlated with increased VTE rate, with VTE rates of 1% and 1.5% for RAP and TESS scores of 6, respectively. In addition, TESS scores were more useful than RAP scores. Based on these results, we believe that RAP and TESS scores can be equally applied to Korean trauma patients.

The risk factors of VTE in trauma patients are well known, and the risk factors in our study are similar to the known risk factors. The risk factors identified in the Asian population were similar to these factors, including increased ISS, head injury, pelvic injury, and spinal cord injury.^{8–11,23} Based on the multivariate analysis of this study, VTE history, pelvic bone fracture, number of days on ventilator, and hospitalization period were the only significant risk factors. These results indicate that the prevention and diagnosis of VTE are crucial in patients with a pelvic bone fracture who are under long-term ventilator care. However, other risk factors from multiple previous studies were not significant in this study, probably due to the retrospective nature of this study. In the future, a prospective, multi-centered study should be performed to confirm our findings. In addition, our research had several limitations. First, in this study, the VTE diagnostic protocol was not routinely performed during data collection. Since VTE was diagnosed based on symptoms or medical examinations for other purposes, not all VTE cases were screened. Second, since the medical records of patients over a 7-year period were used, missing data were inevitable. Third, due to the limitations of retrospective review, we cannot completely exclude the issue of causal inference between the time of data collection and VTE occurrence. Despite these limitations, our study newly identified that the incidence rate of VTE in Korean trauma patients is, in fact, similar to that in US-based trauma centers. In addition, we demonstrated that a higher risk of VTE was observed in Korean trauma patients requiring long-term ventilator treatment and hospitalization due to pelvic bone fracture. Finally, we confirmed that RAP and TESS—which are renowned diagnostic tools for trauma patients—can be useful as predictive tools for VTE occurrence in Korean trauma patients.

In conclusion, the incidence rate of DVT and PE in Korean trauma patients, assessed by our center, was 0.59% and 0.41%, respectively. These rates were extremely similar to the incidence rates of DVT in US-based trauma centers. Moreover, RAP and TESS, which are renowned predictive tools, demonstrated their potential as clinical tools to predict VTE occurrence in Korean trauma patients. Moreover, patients with pelvic bone fracture

undergoing long-term ventilator treatment should be more carefully examined for possible VTE occurrence. However, since information regarding VTE in Korean trauma patients is limited, additional analyses, using a more accurate and larger dataset, should be performed for appropriate prevention and diagnosis of VTE in Korean trauma patients. Specifically, a well-planned, prospective study with appropriate protocol and screening tools should be conducted in the near future.

AUTHOR CONTRIBUTIONS

Conceptualization: Jonghwan Moon. **Data curation:** all authors. **Formal analysis:** all authors. **Investigation:** all authors. **Methodology:** Sunjoo Boo, Hyunjin Oh, Kyungjin Hwang, and Jonghwan Moon. **Project administration:** all authors. **Resources:** all authors. **Software:** all authors. **Supervision:** all authors. **Validation:** all authors. **Visualization:** all authors. **Writing—original draft:** Sunjoo Boo, Hyunjin Oh, and Jonghwan Moon. **Writing—review & editing:** Sunjoo Boo, Hyunjin Oh, and Jonghwan Moon. **Approval of final manuscript:** all authors.

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