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Evaluation of D-dimer and coagulation parameters in predicting venous thromboembolism risk among hospitalized patients

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Abstract

Background: Venous thromboembolism (VTE) remains an important preventable complication among hospitalized patients, highlighting the need for effective risk assessment. This study evaluated D-dimer and routine coagulation parameters for predicting VTE and compared their performance with the Padua Prediction Score. **Methods:** In this prospective observational cohort study, 300 hospitalized adults at risk of VTE underwent admission assessment of D-dimer, coagulation parameters, and Padua score. Patients were followed for objectively confirmed VTE during hospitalization. Predictive performance was evaluated using receiver operating characteristic analysis and multivariable logistic regression. **Results:** VTE occurred in 44 patients (14.7%). Median D-dimer was higher in patients who developed VTE than in those who did not (1.76 versus 0.58 µg/mL; p<0.001). D-dimer showed the highest discrimination (AUC = 0.751), compared with the Padua score (AUC = 0.687) and conventional coagulation parameters. At 0.5 µg/mL, D-dimer demonstrated 86% sensitivity and 94% negative predictive value. D-dimer remained independently associated with VTE in multivariable analysis (OR = 2.29 per standard-deviation increase; 95% CI: 1.40-3.75; p<0.001). **Conclusion:** Admission D-dimer showed greater predictive performance than conventional coagulation parameters and the Padua score and may complement clinical VTE risk assessment in hospitalized patients.

Keywords: *Venous thromboembolism, D-dimer, Coagulation, Padua prediction score, Risk assessment, Negative predictive value, Hospitalized patients*

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1. Introduction

Venous thromboembolism (VTE), comprising deep vein thrombosis and pulmonary embolism, is an important and potentially preventable cause of morbidity and mortality among hospitalized patients. Hospitalization-related factors such as immobility, acute medical illness, and invasive interventions may interact with patient-specific risk factors to increase thrombotic risk. Appropriate thromboprophylaxis can reduce hospital-associated VTE; however, its benefits must be balanced against the risk of bleeding, emphasizing the need for accurate identification of patients at increased thromboembolic risk (Raskob *et al.*, 2014; Heit, 2015; Khan *et al.*, 2021).

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Clinical risk-assessment models are widely used to guide VTE risk stratification. The Padua Prediction Score incorporates established clinical risk factors and is commonly used to identify hospitalized medical patients at increased risk of VTE (Barbar *et al.*, 2010; Schunemann *et al.*, 2018; Gibson *et al.*, 2017). Nevertheless, its predictive performance varies across patient populations and depends on accurate identification and documentation of individual risk factors (Nendaz *et al.*, 2014; Darzi *et al.*, 2020; Zhou *et al.*, 2018). Laboratory biomarkers reflecting activation of coagulation may therefore provide complementary information for VTE risk assessment.

Routine coagulation parameters, including Prothrombin Time (PT), activated Partial Thromboplastin Time (aPTT), and the International Normalized Ratio (INR), primarily assess abnormalities in coagulation pathways and are conventionally used to evaluate haemostatic function and bleeding tendency. Their role in predicting thrombotic events is comparatively limited (Johnson *et al.*, 2019). D-dimer, in contrast, is a degradation product of cross-linked fibrin and reflects ongoing fibrin formation and breakdown, providing a biological marker of coagulation and fibrinolytic activity (Weitz *et al.*, 2017).

D-dimer is well established in diagnostic algorithms for suspected VTE because of its high sensitivity and negative predictive value, particularly when interpreted alongside clinical probability (Wells *et al.*, 2003; Righini *et al.*, 2014; Tritschler *et al.*, 2018; Konstantinides *et al.*, 2020). However, elevated D-dimer concentrations are non-specific and may also occur with infection, inflammation, malignancy, increasing age, and other acute conditions. Although previous studies have investigated D-dimer in thromboembolic risk assessment, its value as an admission predictor of subsequent VTE among hospitalized medical patients, particularly in comparison with routine coagulation parameters and an established clinical risk score, remains an area requiring further evaluation (Fang *et al.*, 2022; Snir *et al.*, 2021; Pulivarthi and Gurram, 2014).

Therefore, the present study evaluated admission D-dimer and routine coagulation parameters for the prediction of subsequent VTE in hospitalized medical patients. Their discriminative performance was compared with the Padua Prediction Score, the predictive characteristics of D-dimer across different cut-off values were examined, and independent associations with VTE were assessed using multivariable analysis.

2. Materials and methods

2.1. Study design and setting

This was a prospective observational cohort study conducted in the medical wards of a tertiary care teaching hospital over a defined enrolment period. The study was designed to evaluate, in patients at risk of venous thromboembolism, the value of admission D-dimer and the routine coagulation parameters for the prediction of a subsequent thromboembolic event, and to compare their performance with that of an established clinical risk-assessment model. The design and conduct of the study, and the reporting of this article, follow the Strengthening the Reporting of Observational Studies in Epidemiology recommendations for cohort studies (Vandenbroucke *et al.*, 2007).

2.2. Eligibility criteria

Adults of eighteen years or older admitted to the medical wards and considered to be at risk of venous thromboembolism, by virtue of an anticipated stay of three days or more together with one or more recognised risk factors, were eligible for inclusion. Patients were excluded if they were already receiving therapeutic anticoagulation at admission, since this would both alter the coagulation parameters and modify the risk of the event; if they were admitted with an established diagnosis of venous thromboembolism, since the markers were to be assessed as predictors of a subsequent rather than a prevalent event; if they had a known inherited or acquired coagulopathy, active major bleeding, or advanced liver disease that would independently disturb the coagulation parameters; or if an adequate admission blood sample could not be obtained. These criteria ensured that the coagulation parameters were measured in the untreated state and were assessed before, and as predictors of, any thromboembolic event.

2.3. Clinical assessment and risk stratification

At enrolment, the demographic details, admitting diagnosis, comorbidities and thromboembolic risk factors of each patient were recorded on a structured proforma by a trained investigator. The Padua Prediction Score, the

validated risk-assessment model for medical inpatients, was computed for every patient from eleven weighted clinical items, namely active cancer, previous venous thromboembolism, reduced mobility and a known thrombophilic condition, each contributing three points; recent trauma or surgery, contributing two points; and age of seventy years or more, heart or respiratory failure, acute myocardial infarction or ischaemic stroke, acute infection or rheumatological disorder, obesity and ongoing hormonal treatment, each contributing one point. In accordance with the original derivation, a total score of four or more was taken to denote high thromboembolic risk. The score was calculated by an investigator who was unaware of the coagulation results, so that the clinical risk assessment and the laboratory assessment were made independently.

2.4. Blood sampling and coagulation assays

A venous blood sample was drawn from each patient at admission, before the administration of any anticoagulant or thromboprophylaxis, by clean venepuncture with minimal stasis. Samples for coagulation testing were collected into tubes containing 3.2% buffered sodium citrate in the standard nine-to-one ratio of blood to anticoagulant, and were processed without delay. The citrated samples were centrifuged to yield platelet-poor plasma, and testing was completed within the interval recommended for the stability of the analytes.

D-dimer was measured in the plasma by a quantitative immunoturbidimetric assay on an automated coagulation analyser, and the result was expressed in micrograms per millilitre of fibrinogen-equivalent units, the assay being calibrated and its performance verified against the manufacturer’s standards. The prothrombin time and the activated partial thromboplastin time were measured by standard clot-based methods on the same analyser, the prothrombin time being converted to the international normalised ratio using the international sensitivity index of the thromboplastin reagent, and fibrinogen was measured by the Clauss clotting method (Besser and MacDonald, 2016). The platelet count was obtained from the complete blood count performed on an automated haematology analyser. Internal quality-control material at two concentrations was analysed with each batch, and all assays were required to fall within the laboratory’s defined control limits before results were released.

2.5. Outcome ascertainment

The outcome was objectively confirmed venous thromboembolism developing after enrolment and during the hospital admission. Deep vein thrombosis was diagnosed by compression ultrasonography of the affected limb, and pulmonary embolism by computed tomographic pulmonary angiography, imaging being performed when thromboembolism was clinically suspected in accordance with prevailing diagnostic pathways. The diagnosis was confirmed by the reporting radiologist and reviewed by an investigator who was unaware of the admission coagulation results, so that the ascertainment of the outcome was blinded to the predictors under study. Patients were followed from enrolment until discharge or the occurrence of the event, whichever came first.

2.6. Statistical analysis

Continuous variables were summarized as mean ± SD or median (IQR), as appropriate, and categorical variables as frequencies and percentages. Groups with and without VTE were compared using the independent-samples t-test, Mann–Whitney U-test, chi-square test, or Fisher’s exact test, as appropriate. Predictive discrimination was evaluated using ROC curves and AUCs with 95% CIs, with AUCs compared using DeLong’s method (Hanley and McNeil, 1982; DeLong *et al.*, 1988). D-dimer sensitivity, specificity, positive predictive value, and negative predictive value were assessed across predefined cut-offs. Multivariable logistic regression identified independent predictors of VTE, with results reported as adjusted ORs and 95% CIs. A two-sided $p<0.05$ was considered statistically significant.

2.7. Ethical considerations

The study was approved by the Institutional Ethics Committee before commencement and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from every participant, participation was voluntary, and all records were anonymised and identified only by a study code.

3. Results

3.1. Cohort and thromboembolic events

The study included 300 patients with a mean age of 60.1 years and an approximately equal sex distribution. Overall, 150 patients (50.0%) were classified as high risk according to the Padua score. During hospitalization, objectively confirmed VTE occurred in 44 patients, corresponding to an incidence of 14.7%. Immobilization (37.3%) and acute infection (34.3%) were among the most frequent VTE risk factors, followed by heart or respiratory failure (25.7%), age ≤70 years (23.0%), obesity (21.0%), and active cancer (20.3%) (Table 1).

Table 1: Characteristics of the 300 hospitalised patients and the frequency of risk factors

Characteristic	n (%)
Demographic characteristic	
Age ≥70 years	69 (23.0)
VTE risk factors	
Active cancer	61 (20.3)
Previous VTE	27 (9.0)
Immobilization	112 (37.3)
Recent trauma/surgery	52 (17.3)
Heart/respiratory failure	77 (25.7)
Acute infection	103 (34.3)
Obesity	63 (21.0)
Risk classification	
Padua score ≥4 (high risk)	150 (50.0)
Study outcome	
Confirmed VTE	44 (14.7)

3.2. Coagulation parameters according to VTE status

Median D-dimer concentration was significantly higher in patients who developed VTE than in those who did not (p<0.001). Fibrinogen was also higher in the VTE group (p = 0.010), while platelet count was lower (p

Table 2: Coagulation parameters and Padua score in patients with and without venous thromboembolism

Parameter	VTE	No VTE	p
D-dimer (ug/mL)	1.76 [0.72-2.26]	0.58 [0.36-1.02]	<0.001
Fibrinogen (mg/dL)	395 ± 113	346 ± 98	0.010
Prothrombin time (s)	13.6 ± 1.2	13.2 ± 1.4	0.112
aPTT (s)	32.7 ± 4.2	31.5 ± 4.0	0.071
INR	1.02 ± 0.11	1.00 ± 0.11	0.240
Platelet count (x10^9/L)	238 ± 77	264 ± 76	0.049
Padua score	5 [3-7]	3 [1-5]	<0.001

= 0.049). PT, aPTT, and INR did not differ significantly between groups. The median Padua score was significantly higher among patients who developed VTE (p<0.001) (Table 2 and Figure 1).

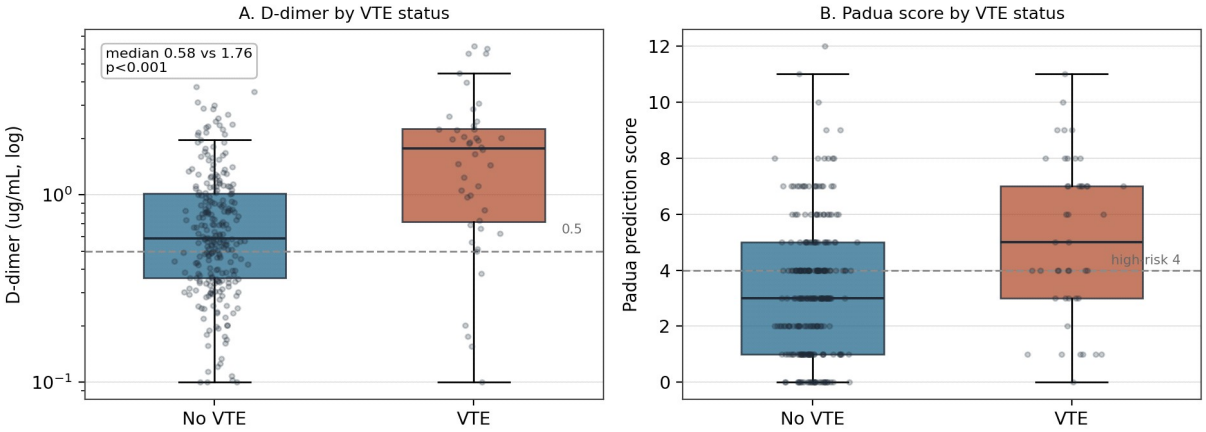


Figure 1: D-dimer (A) and Padua score (B) in patients with and without venous thromboembolism

3.3. Discrimination of thromboembolism

Ranked by their discrimination of thromboembolism, D-dimer was the best, with an area under the curve of

Table 3: Discrimination of venous thromboembolism by each parameter (area under the ROC curve)

Parameter	AUC	95% CI
D-dimer	0.751	0.664-0.838
Padua score	0.687	0.595-0.779
Fibrinogen	0.616	0.522-0.711
Prothrombin time	0.565	0.471-0.660
aPTT	0.586	0.491-0.680
Platelet count	0.589	0.494-0.683

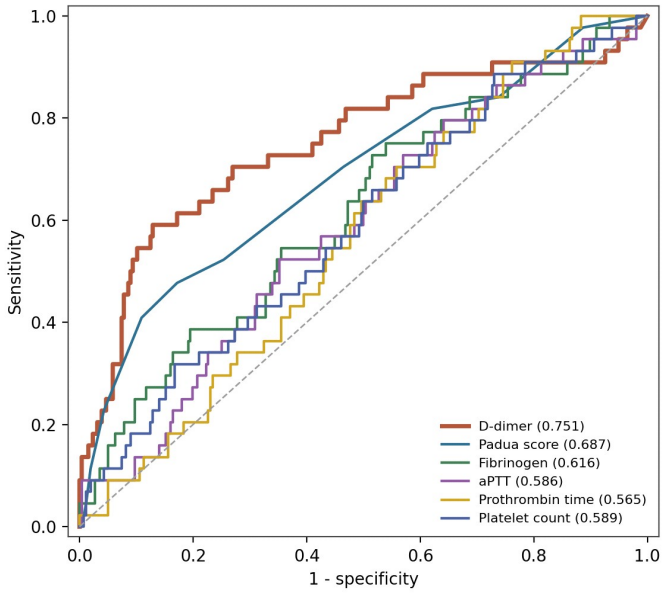


Figure 2: Receiver operating characteristic curves for the prediction of venous thromboembolism

0.751, exceeding the Padua score at 0.687 and far exceeding the conventional coagulation parameters, of which fibrinogen reached only 0.62 and the prothrombin time, the activated partial thromboplastin time and the platelet count barely rose above chance. That the clotting times discriminated so poorly is the expected corollary of their physiology (Table 3 and Figure 2).

3.4. Diagnostic performance and cut-off value of D-dimer

At a D-dimer cut-off of 0.5 µg/mL, sensitivity for subsequent VTE was 86%, specificity was 39%, positive predictive value was 20%, and negative predictive value was 94%. Increasing the threshold resulted in progressively greater specificity at the expense of sensitivity. At 2.0 µg/mL, specificity increased to 93% and positive predictive value to 47%, whereas sensitivity declined to 39%. These findings demonstrate that lower D-dimer concentrations were associated with a relatively low probability of subsequent VTE, whereas elevated values had limited positive predictive value because of low specificity (Figure 3).

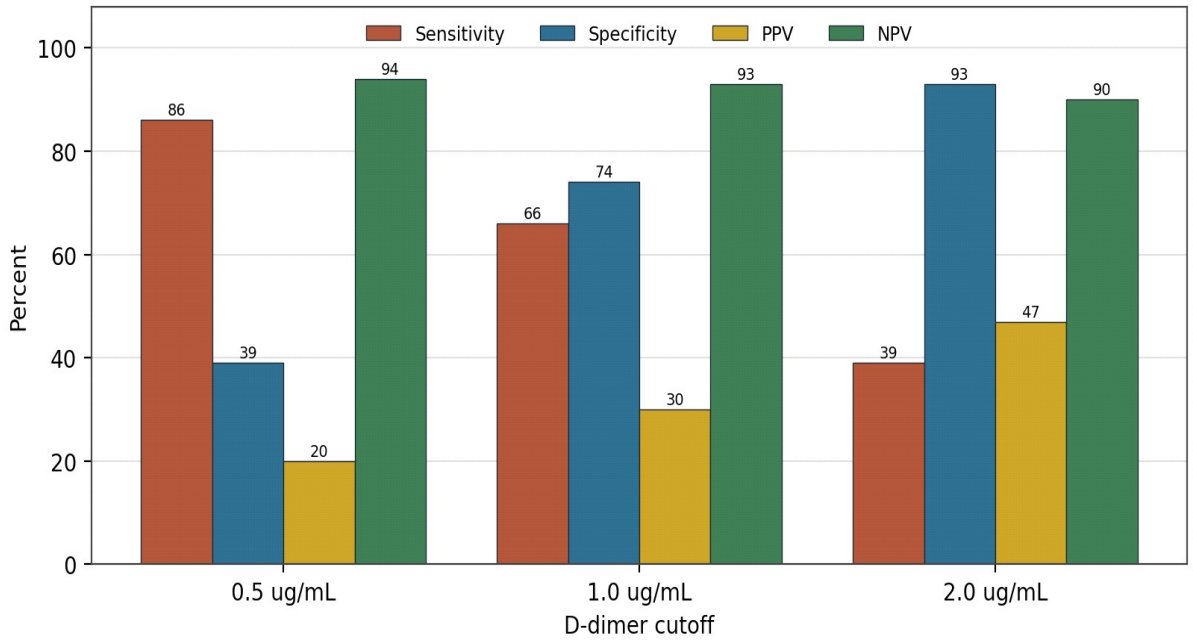


Figure 3: Sensitivity, specificity and predictive values of D-dimer across cut-off concentrations

3.5. Comparison with the Padua score and independent prediction

D-dimer demonstrated a higher AUC than the Padua score alone (0.751 versus 0.687), while combining D-dimer with the Padua score produced an AUC of 0.759, representing only a small numerical increase over D-dimer alone. In multivariable logistic regression, log-transformed D-dimer remained independently associated with VTE (OR = 2.29 per SD increase, 95% CI 1.40–3.75; p<0.001). In contrast, the Padua score (OR = 1.11; p = 0.186), fibrinogen (OR = 1.02; p = 0.923), platelet count (OR = 0.80; p = 0.217), and age (OR = 0.87; p = 0.435) were not independently associated with VTE in the adjusted model (Table 4 and Figure 4).

Table 4: Multiple logistic regression for venous thromboembolism

Predictor	Odds ratio	95% CI	p
D-dimer (per SD, log)	2.29	1.40 to 3.75	<0.001
Padua score (per point)	1.11	0.95 to 1.30	0.186
Fibrinogen (per SD)	1.02	0.68 to 1.52	0.923
Platelet (per SD)	0.80	0.56 to 1.14	0.217
Age (per SD)	0.87	0.62 to 1.23	0.435

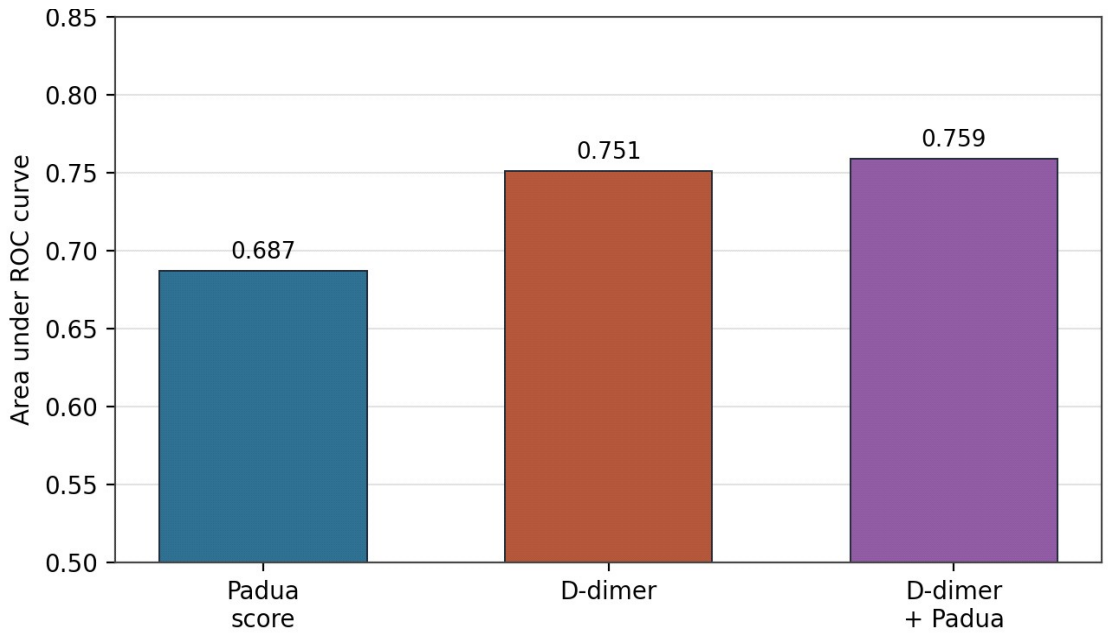


Figure 4: Discrimination of D-dimer, the Padua score and their combination

4. Discussion

This prospective cohort study evaluated admission D-dimer and routine coagulation parameters for the prediction of VTE among hospitalized medical patients. D-dimer showed the strongest discriminative performance among the evaluated laboratory parameters and a numerically higher AUC than the Padua Prediction Score. At the 0.5 µg/mL threshold, D-dimer demonstrated high sensitivity and negative predictive value but low specificity and positive predictive value. In multivariable analysis, D-dimer remained independently associated with subsequent VTE, whereas the Padua score and conventional coagulation parameters did not. Combining D-dimer with the Padua score produced only a small numerical increase in discrimination compared with D-dimer alone. These findings suggest that admission D-dimer may provide complementary information for VTE risk assessment in hospitalized medical patients.

The poor performance of the prothrombin and activated partial thromboplastin times is not a disappointment but a confirmation of their physiology, and it is worth stating plainly because these tests are so often ordered as a general screen of coagulation. They measure the time to form a clot when the procoagulant factors are the limiting reagent, and are prolonged by the deficiency or inhibition of those factors, a state that predisposes to bleeding; they say nothing about the propensity of the blood to form a thrombus in vivo, and their inability to predict thromboembolism follows directly. That fibrinogen, an acute-phase reactant that rises with inflammation and contributes to clot formation, discriminated a little better, and the platelet count a little, is consistent with their partial involvement in the thrombotic process, but neither approached D-dimer.

D-dimer's superiority reflects its position as a direct marker of the process in question. Because it is produced by the formation and lysis of fibrin, its elevation signals that coagulation has been activated and that thrombus is being turned over, which is precisely the state that precedes and accompanies thromboembolism. This is why it discriminated the patients who developed thromboembolism from those who did not better than a clinical score assembled from indirect risk factors, a superiority that has been reported in other inpatient populations and that our findings reproduce.

The high negative predictive value observed at the lower D-dimer threshold suggests potential utility for identifying patients with a lower probability of subsequent VTE. However, D-dimer should not be considered a standalone basis for withholding thromboprophylaxis or diagnostic evaluation. Decisions regarding prophylaxis should continue to incorporate validated clinical risk assessment, bleeding risk, and established guideline recommendations. The present findings instead support further investigation of D-dimer as an adjunct to clinical risk stratification.

The addition of the Padua score to D-dimer increased the AUC only modestly from 0.751 to 0.759. This suggests substantial overlap in the predictive information captured by the two measures, although the present analysis does not establish that clinical risk assessment can be replaced by D-dimer. The Padua score incorporates clinically relevant factors such as previous VTE, thrombophilia, malignancy, and immobility that remain important for patient-level risk assessment. D-dimer may therefore be more appropriately considered a complementary biomarker rather than an alternative to established clinical risk models.

5. Strengths and limitations

This study has several strengths, including its prospective cohort design, consecutive enrolment, measurement of coagulation parameters before the study outcome, and objective confirmation of clinically suspected VTE. Several limitations should nevertheless be considered. First, this was a single-centre study with a moderate sample size and relatively few VTE events, which may limit precision and generalizability. Second, imaging for VTE was performed when clinically indicated rather than through systematic screening of all participants; therefore, asymptomatic thromboembolic events may have been missed. Third, D-dimer was measured only at admission, and temporal changes during hospitalization were not evaluated. Fourth, D-dimer concentrations are influenced by age, infection, inflammation, malignancy, and other acute clinical conditions, which may affect predictive performance across different patient populations. Fifth, age-adjusted D-dimer thresholds were not evaluated. Finally, although D-dimer was independently associated with VTE, the study was observational and does not establish that D-dimer-guided modification of thromboprophylaxis improves clinical outcomes. Larger multicentre prospective studies are needed to externally validate these findings.

6. Conclusion

Admission D-dimer was more strongly associated with subsequent venous thromboembolism than the conventional coagulation parameters evaluated in this cohort and demonstrated the highest discriminative performance. At a threshold of 0.5 µg/mL, D-dimer showed high sensitivity and negative predictive value but limited specificity and positive predictive value, indicating greater potential for identifying patients at lower VTE probability than for confirming high risk. D-dimer remained independently associated with VTE in multivariable analysis, while the Padua score, fibrinogen, platelet count, and age were not independently associated after adjustment. Combining D-dimer with the Padua score produced only a small numerical increase in discrimination. These findings support further evaluation of admission D-dimer as an adjunct to established clinical risk assessment rather than as a replacement for clinical risk models. External validation and prospective studies are required before D-dimer-based strategies can be used to guide thromboprophylaxis decisions.

Ethical approval

The study was approved by the Institutional Ethics Committee and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from every participant.

Conflict of interest

The authors declare that no conflict of interest exists in relation to this work.

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Data availability

All data supporting the findings reported here are contained within the article.

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