

Development and internal validation of a modified Caprini score for postoperative venous thromboembolism in gastrointestinal adenocarcinoma: a retrospective cohort study

Zheyang Mi

Huzhou Central Hospital, Fifth School of Clinical Medicine of Zhejiang Chinese Medical University

Huaping Shen

shenhuaping3508@163.com

Huzhou Central Hospital, Fifth School of Clinical Medicine of Zhejiang Chinese Medical University

Jiajie Zhong

Huzhou Central Hospital, Fifth School of Clinical Medicine of Zhejiang Chinese Medical University

Xuedong Chen

Huzhou Normal University

Shiyu Zhou

Huzhou Central Hospital, Fifth School of Clinical Medicine of Zhejiang Chinese Medical University

Research Article

Keywords: Gastrointestinal adenocarcinoma, Venous thromboembolism, Caprini risk assessment model, Risk assessment, Prediction model

Posted Date: October 19th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10869564/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

The conventional Caprini score may have limited discriminatory ability in patients undergoing gastrointestinal cancer surgery because many are classified as high risk. This study examined factors associated with postoperative venous thromboembolism (VTE) and developed and internally validated a modified Caprini score.

Methods

This retrospective cohort study included 220 patients with gastrointestinal adenocarcinoma who underwent surgery between June 2023 and December 2024. To reduce double counting of risk information already captured by the conventional Caprini score, its logistic regression coefficient was fixed at 1, and incremental coefficients were estimated for tumor-node-metastasis stage III/IV, operative time ≥ 240 min, perioperative blood transfusion, and postoperative day 1 (POD1) D-dimer > 5.0 mg/L. Three missing or non-POD1 D-dimer values were median-imputed, and a complete-case sensitivity analysis was performed. Model performance was assessed using receiver operating characteristic analysis, the DeLong test, calibration intercept and slope, the Brier score, the index of prediction accuracy (IPA), and 1,000 bootstrap resamples.

Results

Postoperative VTE occurred in 49 patients (22.3%). After accounting for the conventional Caprini score, stage III/IV disease [odds ratio (OR), 3.587; $P = 0.001$], perioperative blood transfusion (OR, 2.358; $P = 0.024$), and POD1 D-dimer > 5.0 mg/L (OR, 2.937; $P = 0.005$) provided significant incremental information. Operative time ≥ 240 min had a positive but non-significant association (OR, 2.060; $P = 0.076$) and was retained in the score. The apparent area under the curve (AUC) was 0.726 for the modified score and 0.571 for the conventional score (DeLong $Z = 3.983$; $P < 0.001$). After bootstrap correction, the AUC was 0.711, calibration intercept was -0.004 , calibration slope was 0.942, Brier score was 0.150, and IPA was 13.7%. The grouped Hosmer-Lemeshow test indicated local miscalibration ($\chi^2=10.025$; $df = 4$; $P = 0.040$). At a cutoff of ≥ 7 points, sensitivity was 59.2% and specificity was 82.5%.

Conclusions

The modified Caprini score showed better discrimination than the conventional score in this cohort. However, the modest incremental predictive accuracy, grouped calibration deviation, instability of integer weights, and uncertain timing of POD1 D-dimer sampling relative to VTE diagnosis warrant cautious interpretation. External validation and prospective evaluation are required before clinical implementation.

Background

Venous thromboembolism (VTE) is a frequent and potentially fatal complication in patients with cancer [1]. Patients undergoing major surgery for gastrointestinal cancer are especially vulnerable because malignancy-related hypercoagulability is compounded by operative tissue injury and reduced mobility after surgery. The Caprini risk assessment model (RAM) is widely used in surgical practice and has been validated in several surgical populations [2–4]. Its ability to separate patients by risk may nevertheless be reduced in gastrointestinal oncology because both malignancy and major surgery contribute points to the score. Many patients are therefore placed in the same high-risk category despite potentially meaningful differences in postoperative risk. We examined factors associated with VTE after surgery for gastrointestinal adenocarcinoma and developed a modified score that incorporates information not already represented by the conventional Caprini RAM.

Methods

Study design and participants

The Medical Ethics Committee of Huzhou Central Hospital approved this single-center retrospective cohort study (approval No. 202308010-01) and waived the requirement for informed consent because of its retrospective design. Clinical trial number: not applicable.

We retrospectively reviewed the clinical and follow-up records of 220 patients who underwent surgery for a gastrointestinal malignancy at Huzhou Central Hospital between June 2023 and December 2024. Descriptive comparisons were based on all available observations. D-dimer measurements were missing or were not obtained on postoperative day 1 (POD1) for three patients (1.4%). For the primary model, these values were replaced with the overall observed median of 3.79 mg/L so that all 220 patients could be retained. A complete-case analysis was also performed as a sensitivity analysis.

Patients were eligible if they had pathologically confirmed gastrointestinal adenocarcinoma, underwent radical surgery or palliative resection, and had sufficient clinical and follow-up data for analysis. Exclusion criteria were VTE diagnosed before surgery, a recent history of venous thrombosis, long-term anticoagulant therapy before surgery, or severe concomitant systemic disease that rendered the clinical data unsuitable for analysis.

Patients were grouped according to whether postoperative VTE occurred. VTE included deep vein thrombosis (DVT) and pulmonary embolism (PE). DVT was diagnosed by duplex ultrasonography of the lower-extremity veins, whereas PE was diagnosed by computed tomography pulmonary angiography. The VTE group comprised 49 patients and the non-VTE group 171 patients. The database did not contain timestamps detailed enough to determine whether VTE developed before POD1 blood collection. POD1 D-dimer was therefore treated as an early postoperative marker rather than a strictly prospective predictor.

Data collection

The collected variables covered baseline characteristics (sex, age, body mass index, and comorbidities, including hypertension, diabetes mellitus, and chronic obstructive pulmonary disease); operative characteristics (surgical approach, operative time, intraoperative blood loss, postoperative length of stay, and perioperative blood transfusion); pathological findings (tumor size, TNM stage, and microvascular invasion); and laboratory measurements (preoperative and postoperative albumin, hemoglobin, platelet count, D-dimer, and coagulation indices).

Statistical analysis

Data were cleaned and analyzed using R version 4.3.0 and Python. Continuous variables with approximately symmetric distributions were reported as the mean $\pm$ standard deviation and compared with independent-samples t tests. Discrete or skewed continuous variables were reported as the median and interquartile range and compared with the Mann–Whitney U test. Categorical variables were reported as frequencies and percentages and compared with the chi-square test or Fisher's exact test, as appropriate.

Variables associated with VTE at $P < 0.20$ in univariable analyses were considered for multivariable modeling so that potentially relevant predictors were not excluded prematurely. Given the 49 VTE events, we limited the candidate set to reduce overfitting and unstable coefficient estimates. Four factors were retained after considering their univariable associations, clinical relevance, interpretability, and alignment with the original framework: TNM stage, operative time, perioperative blood transfusion, and POD1 D-dimer.

Multicollinearity among the four added factors was assessed using variance inflation factors (VIFs), with values < 5 considered acceptable. Possible nonlinear relationships were explored in sensitivity analyses by replacing the dichotomized operative-time or POD1 D-dimer variable with standardized linear and quadratic terms. Binary thresholds were retained to keep the score clinically usable. Any evidence of nonlinearity was treated as a limitation of dichotomization, rather than as evidence supporting the selected cutoff.

To avoid counting risk information already represented in the Caprini score twice, we fixed the coefficient of the conventional Caprini score at 1 in the primary logistic model: $\text{logit}(p) = \alpha + 1 \times \text{Caprini} + \beta'_1 \times \text{TNM stage III/IV} + \beta'_2 \times \text{operative time} \geq 240 \text{ min} + \beta'_3 \times \text{perioperative transfusion} + \beta'_4 \times \text{POD1 D-dimer} > 5.0 \text{ mg/L}$. Under this specification, each β' represents the additional contribution to the log odds of VTE beyond the information already contained in the conventional Caprini score.

Each incremental coefficient (β') was rounded to the nearest integer on the same log-odds scale as the fixed Caprini coefficient to obtain the additional points. Discrimination was assessed using receiver operating characteristic curves and the area under the curve (AUC). AUCs for the conventional and modified scores were compared with the paired DeLong test, and the cutoff that maximized the Youden

index was identified. Calibration was examined using the calibration intercept and slope, grouped calibration estimates, the Hosmer–Lemeshow statistic, the Brier score, and the index of prediction accuracy (IPA; $1 - \text{Brier score}/\text{null-model Brier score}$).

Internal validation used 1,000 bootstrap resamples. Coefficient estimation, integer point assignment, and score recalibration were repeated in each resample, and optimism-corrected AUC, calibration intercept and slope, Brier score, and IPA were reported. Grouped goodness-of-fit tests can be unreliable when predictions are tied and group sizes are small; the Hosmer–Lemeshow result was therefore considered together with the calibration curve and the other calibration measures. All tests were two-sided, and $P < 0.05$ was considered statistically significant.

Use of generative artificial intelligence

During manuscript preparation, ChatGPT (OpenAI; accessed August 2026) was used solely to improve English expression, clarity, and conformity with journal formatting. It was not used to generate, modify, or analyze study data or to draw scientific conclusions. The authors reviewed and revised all AI-assisted text and assume full responsibility for the final manuscript.

Results

Baseline and clinical characteristics

The analysis included 220 patients who underwent surgery for a gastrointestinal malignancy. Postoperative VTE was identified in 49 patients (22.3%), while the other 171 patients formed the non-VTE group. Patients in the VTE group were older than those in the non-VTE group (71.33 ± 8.55 vs. 67.60 ± 10.46 years; $P = 0.023$). Sex and body mass index were similar between the groups.

The median conventional Caprini score was 5.00 (interquartile range [IQR], 4.00–5.00) in the VTE group and 4.00 (IQR, 4.00–5.00) in the non-VTE group ($P = 0.105$). Median operative time was longer among patients with VTE (235 min; IQR, 209–275) than among those without VTE (185 min; IQR, 150–244; $P < 0.001$). Operative time ≥ 240 min was also more common in the VTE group (42.9% vs. 26.3%; $P = 0.026$).

Stage III/IV disease was present in 49.0% of the VTE group and 25.7% of the non-VTE group ($P = 0.002$). Perioperative blood transfusion was likewise more frequent among patients with VTE (57.1% vs. 26.9%; $P < 0.001$). The median POD1 D-dimer concentration was 6.29 mg/L (IQR, 3.67–11.16) in the VTE group and 2.83 mg/L (IQR, 1.53–5.76) in the non-VTE group ($P < 0.001$).

Preoperative D-dimer was higher and fibrinogen was lower in the VTE group (both $P < 0.05$), while preoperative albumin and C-reactive protein were comparable between groups. Age, preoperative D-dimer, and fibrinogen were not retained after the predictor set was restricted according to the

prespecified framework, parsimony, interpretability, and model stability. Table 1 provides the full univariable comparisons.

Table 1
Clinical characteristics and univariable comparisons between patients with and without VTE

Variable	VTE group (n = 49)	Non-VTE group (n = 171)	Statistic	P value
Sex, male/female, n	29/20	117/54	1.456	0.228
Age, years	71.33 ± 8.55	67.60 ± 10.46	2.286	0.023
BMI, kg/m ²	22.45 ± 3.60	22.56 ± 3.14	-0.223	0.824
Conventional Caprini score	5.00 (4.00–5.00)	4.00 (4.00–5.00)	4782.000	0.105
Operative time, min	235.00 (209.00–275.00)	185.00 (150.00–244.00)	6017.000	< 0.001
Operative time ≥ 240 min, n (%)	21 (42.9)	45 (26.3)	4.962	0.026
Perioperative blood transfusion, n (%)	28 (57.1)	46 (26.9)	15.605	< 0.001
TNM stage III/IV, n (%)	24 (49.0)	44 (25.7)	9.640	0.002
Preoperative albumin, g/L	36.78 ± 4.07	37.77 ± 4.15	-1.476	0.141
Preoperative D-dimer, mg/L	0.81 (0.54–1.72)	0.44 (0.25–0.71)	5894.500	< 0.001
Postoperative day 1 D-dimer, mg/L	6.29 (3.67–11.16)	2.83 (1.53–5.76)	6191.000	< 0.001
Fibrinogen, g/L	3.19 ± 0.63	3.44 ± 0.64	-2.364	0.019
C-reactive protein, mg/L	0.50 (0.50–3.00)	0.65 (0.50–2.92)	4087.500	0.834
Notes: Values are presented as the mean ± standard deviation, median (interquartile range), or n (%), as appropriate. Test statistics are from Student's t test, the Mann–Whitney U test, or the Pearson chi-square test. Available-case denominators were used; POD1 D-dimer was unavailable for three patients in the univariable comparison. BMI, body mass index; TNM, tumor–node–metastasis; VTE, venous thromboembolism.				

Risk factors associated with postoperative VTE

Because the cohort contained 49 VTE events, the multivariable analysis was kept parsimonious. The coefficient for the conventional Caprini score was fixed at 1, and four clinically relevant factors from the original framework were entered as incremental terms: operative time ≥ 240 min, perioperative blood transfusion, TNM stage III/IV, and POD1 D-dimer > 5.0 mg/L.

After accounting for the conventional Caprini score, TNM stage III/IV, perioperative blood transfusion, and POD1 D-dimer > 5.0 mg/L each contributed significant incremental information. The coefficient for operative time $\geq$ 240 min was positive but did not reach the prespecified significance level (β' = 0.723; OR, 2.060; 95% CI, 0.927–4.579; P = 0.076). VIFs were 1.107 for operative time, 1.043 for TNM stage, 1.065 for transfusion, and 1.066 for POD1 D-dimer, with no evidence of substantial multicollinearity.

Age, preoperative D-dimer, and fibrinogen were associated with VTE in the univariable analyses but were not included in the primary score. This decision reflected the aim of revising the original four-factor framework while limiting overfitting and maintaining clinical usability. Their exclusion should not be interpreted as evidence that they lack prognostic value. Their incremental contribution and possible site-specific effects require assessment in larger cohorts. The complete primary model is shown in Table 2.

Table 2
Multivariable logistic regression of factors associated with postoperative VTE

Predictor	β'	SE	Wald χ^2	P value	OR (95% CI)	Points
Operative time $\geq$ 240 min	0.723	0.407	3.147	0.076	2.060 (0.927–4.579)	1
TNM stage III/IV	1.277	0.394	10.526	0.001	3.587 (1.658–7.759)	1
POD1 D-dimer > 5.0 mg/L	1.077	0.380	8.019	0.005	2.937 (1.393–6.191)	1
Perioperative blood transfusion	0.858	0.380	5.094	0.024	2.358 (1.119–4.965)	1
Note: The coefficient for the conventional Caprini score was fixed at 1; each β' therefore represents information incremental to the conventional score. Three D-dimer values that were missing or not measured on POD1 were median-imputed in the primary analysis (n = 220). The complete-case analysis (n = 217) assigned the same 1 point to each of the four added factors.						

Development of the modified model and refinement of risk stratification

The modified score was constructed by adding the incremental terms estimated in the fixed-Caprini-coefficient model to the conventional score. Fixing the Caprini coefficient at 1 kept the incremental coefficients on the same log-odds scale, allowing them to be converted directly into additional integer points.

Additional points = Round(β')

The incremental coefficients were 0.723 for operative time $\geq$ 240 min, 1.277 for TNM stage III/IV, 0.858 for perioperative transfusion, and 1.077 for POD1 D-dimer > 5.0 mg/L. Rounding to the nearest integer assigned 1 additional point to each factor. This method estimates risk information beyond the

conventional Caprini score without rescaling the contribution of factors already represented in that score.

Modified Caprini score = conventional Caprini score + 1 × operative time ≥ 240 min + 1 × TNM stage III/IV + 1 × perioperative blood transfusion + 1 × POD1 D-dimer > 5.0 mg/L.

The conventional categories were retained, and the upper category was subdivided to preserve the original clinical framework: low risk (0–2 points), moderate risk (3–4 points), high risk (5–8 points), and very high risk (≥ 9 points). Only four patients fell into the very-high-risk category; this subdivision should therefore be regarded as exploratory.

Receiver operating characteristic curve analysis

The conventional Caprini score had an AUC of 0.571 (95% CI, 0.484–0.658), reflecting limited discrimination in this cohort.

The apparent AUC of the modified score was 0.726 (95% CI, 0.638–0.815). In the paired DeLong test, the AUC difference was 0.156 in favor of the modified score ($Z = 3.983$; $P < 0.001$).

After 1,000 bootstrap resamples, the optimism-corrected AUC was 0.711. Discrimination therefore remained moderate after accounting for model-development optimism, although this internal validation does not demonstrate transportability to other gastrointestinal cancer populations (Fig. 1).

Figure 1. Receiver operating characteristic curves for the conventional and modified Caprini models

Receiver operating characteristic curves comparing the conventional and modified Caprini scores for postoperative VTE after gastrointestinal cancer surgery. The AUC was 0.571 (95% CI, 0.484–0.658) for the conventional score and 0.726 (95% CI, 0.638–0.815) for the modified score. The paired difference was statistically significant (DeLong $Z = 3.983$; $P < 0.001$).

Clinical predictive utility and risk stratification

For the modified score, the maximum Youden index was 0.416 at a cutoff of ≥ 7 points, corresponding to a sensitivity of 59.2% and a specificity of 82.5%. The conventional score had a maximum Youden index of 0.124 at a cutoff of ≥ 5 points, with a sensitivity of 51.0% and a specificity of 61.4%.

At its data-derived optimal cutoff, the modified score had higher sensitivity and specificity than the conventional score. These estimates came from the development cohort and may be optimistic. The threshold should be specified in advance and reassessed in an external validation cohort.

Using the proposed categories, the modified score classified 1 patient as low risk (0 VTE events; 0%), 45 as moderate risk (5 events; 11.1%), 170 as high risk (41 events; 24.1%), and 4 as very high risk (3 events; 75.0%). VTE incidence increased across the categories, but estimates for the low- and very-high-risk

groups were based on very few patients and are imprecise. Figure 1 and Table 3 summarize the performance measures.

Table 3
Predictive performance of the conventional and modified Caprini scores

Model	AUC	95% CI	Youden index	Sensitivity	Specificity
Conventional Caprini score	0.571	0.484–0.658	0.124	0.510	0.614
Modified Caprini score	0.726	0.638–0.815	0.416	0.592	0.825

Note: Optimal cutoffs were identified by maximizing the Youden index. AUCs were compared with the paired DeLong test ($Z = 3.983$; $P < 0.001$). AUC, area under the curve; CI, confidence interval.

Internal validation and calibration

For the modified score, the apparent Brier score was 0.144 and the null-model Brier score was 0.173, giving an apparent IPA of 17.1%. After 1,000 bootstrap resamples, the optimism-corrected AUC was 0.711, the calibration intercept was -0.004 , the calibration slope was 0.942, the Brier score was 0.150, and the IPA was 13.7%. These results indicate limited optimism and a calibration intercept close to zero, but only a modest improvement in overall prediction error. The grouped Hosmer–Lemeshow statistic was $\chi^2 = 10.025$ with 4 degrees of freedom ($P = 0.040$), suggesting local departures from calibration. Because tied integer scores produced only six prediction groups, the test was interpreted cautiously and considered alongside the other calibration measures (Fig. 2).

Figure 2. Calibration of the modified Caprini model

Calibration plot for the modified Caprini score. Blue points and lines represent grouped apparent estimates, the orange line represents the curve derived from the bootstrap-corrected intercept (-0.004) and slope (0.942), and the dashed line represents perfect calibration. The corrected Brier score was 0.150 and the corrected IPA was 13.7%. The grouped Hosmer–Lemeshow test yielded $P = 0.040$ and was treated as supplementary rather than definitive evidence of calibration.

Multicollinearity and nonlinearity sensitivity analyses

All VIFs were below 1.11, providing no evidence of substantial multicollinearity among the added factors. Quadratic sensitivity models found no evidence of curvature for POD1 D-dimer (P for the quadratic term $= 0.870$), whereas operative time showed significant curvature ($P = 0.002$). The estimated association with operative time increased through much of the observed range but weakened at the longest durations, where observations were sparse. We retained the 240-min cutoff for simplicity and consistency with the original framework, but it should not be regarded as a validated biological threshold (see Additional files 1 and 2).

Decision curve analysis

Decision curve analysis indicated that the modified score offered greater net benefit than the conventional score and the treat-all and treat-none strategies across most threshold probabilities from approximately 14% to 50%. At lower thresholds, the strategies performed similarly and the modified score was not consistently superior. Because clinical action thresholds were not prespecified, these findings remain exploratory (Fig. 3).

Figure 3. Decision curve analysis of the conventional and modified Caprini models

Decision curves comparing the conventional and modified Caprini scores across threshold probabilities for postoperative VTE. The modified score generally had greater net benefit above approximately 14%, while differences at lower thresholds were small or inconsistent.

Discussion

Venous thromboembolism remains a frequent and potentially life-threatening perioperative complication in patients with cancer. Cancer-associated hypercoagulability, operative injury, and perioperative stress all contribute to its development. Postoperative VTE occurred in 22.3% of patients in our cohort. This observed rate may be related to the case mix, prevalence of advanced disease, complexity of surgery, and the timing and intensity of VTE surveillance. The available database did not allow the surveillance process to be characterized fully.

The Khorana score is an established tool for assessing cancer-associated VTE risk, but it was developed mainly for patients receiving systemic anticancer therapy and may be less applicable to surgical populations [5]. The Caprini RAM is simple, broadly applicable, and widely used in surgical practice [8, 9]. Its performance may be less informative in oncological surgery because malignancy and major surgery add points for nearly every patient. As a result, many patients cluster in the high-risk category, limiting separation of those at particularly high postoperative risk.

After the conventional Caprini score had been taken into account, TNM stage III/IV, perioperative blood transfusion, and POD1 D-dimer > 5.0 mg/L provided significant incremental information. Operative time ≥ 240 min showed an association in the same direction but did not independently reach $P < 0.05$. This pattern is broadly consistent with evidence linking tumor stage, operative burden, and perioperative factors to VTE after cancer surgery [10, 13].

Several mechanisms may explain these associations. Advanced gastrointestinal adenocarcinoma can promote coagulation through tissue factor and other procoagulant mediators. Longer operations may prolong venous stasis, while anesthesia-related suppression of the skeletal-muscle pump can reduce venous return. Perioperative transfusion may contribute through inflammatory activation and altered blood rheology, although it may also reflect operative complexity or bleeding severity. Residual confounding therefore cannot be excluded [13].

Dynamic laboratory markers are increasingly considered in perioperative VTE assessment [12]. D-dimer reflects activation of coagulation and fibrinolysis and is sensitive to thrombus burden, but it is not specific for future thrombosis [6]. A POD1 D-dimer concentration > 5.0 mg/L added significant information in this cohort (OR, 2.937). The timing of VTE formation and diagnosis in relation to POD1 sampling was not available. Some of the observed association may therefore reflect an existing, possibly asymptomatic, thrombus rather than the prediction of a later event.

We addressed the limited separation produced by the conventional Caprini score by fixing its coefficient at 1 and adding four incremental, equally weighted items. This approach reduces the chance of assigning the full effect of overlapping cancer- and surgery-related information twice. The modified score improved both apparent and bootstrap-corrected discrimination, although its gain in overall prediction accuracy was modest.

Decision curve analysis suggested that the modified score might offer greater net benefit over a potentially relevant range of threshold probabilities. The thresholds were not specified before analysis, however, and a decision curve derived from a single development cohort cannot establish clinical utility. Prospective studies should determine whether score-guided surveillance or thromboprophylaxis improves outcomes without causing unacceptable bleeding.

Several limitations should be considered. The retrospective, single-center design and the 49 VTE events among 220 patients leave room for residual optimism, unmeasured confounding, and effects of local practice. The cohort also combined gastrointestinal adenocarcinomas from different anatomical sites, whose baseline risks and operative pathways may differ. Three POD1 D-dimer values were median-imputed; although the complete-case analysis produced the same point allocation, single imputation does not capture the full uncertainty associated with missing data. The exact VTE observation window, screening intensity, and timing of VTE in relation to POD1 sampling were not available, so POD1 D-dimer should be viewed as an early marker rather than a confirmed prospective predictor. Dichotomization also resulted in information loss, and operative time showed evidence of nonlinearity. Moreover, only 23.1% of bootstrap resamples reproduced the exact 1-1-1-1 point allocation, indicating that the simplified integer weights are unstable. External validation, recalibration, and prospective assessment of the sampling timeline are needed before routine use.

Conclusions

In this single-center retrospective cohort of patients undergoing gastrointestinal cancer surgery, a modified Caprini score incorporating incremental information from TNM stage, operative time, perioperative transfusion, and POD1 D-dimer discriminated postoperative VTE better than the conventional score. Calibration and overall performance were mixed, the extreme risk groups were small, and the integer weights varied across bootstrap resamples. The score remains exploratory and requires validation in larger, multicenter prospective cohorts with clearly defined VTE surveillance and sampling timelines.

Abbreviations

AUC	
area under the curve	
BMI	
body mass index	
CI	
confidence interval	
CRP	
C-reactive protein	
DCA	
decision curve analysis	
DVT	
deep vein thrombosis	
EPV	
events per variable	
IQR	
interquartile range	
IPA	
index of prediction accuracy	
OR	
odds ratio	
PE	
pulmonary embolism	
POD1	
postoperative day 1	
RAM	
risk assessment model	
ROC	
receiver operating characteristic	
SE	
standard error	
TNM	
tumor–node–metastasis	
VIF	
variance inflation factor	
VTE	
venous thromboembolism	

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Medical Ethics Committee of Huzhou Central Hospital (approval No. 202308010-01). The committee waived the requirement for informed consent because of the retrospective study design.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by the Public Welfare Applied Research Project of the Huzhou Science and Technology Bureau (Grant No. 2023GY35).

Author Contribution

Conceptualization, Z.M and H.S; methodology, Z.M; software, Z.M; validation,Z.M,H.S and X.C; formal analysis,Z.M; investigation, Z.M; resources, S.Z.; data curation,Z.M and J.Z; writing-original draft preparation, Z.M; writing-review and editing, H.S and X.C; visualization, Z.M; supervision, H.S; project administration, H.S; funding acquisition,H.S. All authors have read and agreed to the published version of the manuscript.

Acknowledgements

Not applicable.

Data Availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

References

1. Wakefield TW, McLafferty RB, Lohr JM, et al. Call to action to prevent venous thromboembolism. *J Vasc Surg.* 2009;49(6):1620–3.
2. Cronin M, Dengler N, Krauss ES, et al. Completion of the updated Caprini risk assessment model (2013 version). *Clin Appl Thromb Hemost.* 2019;25:1076029619838052.
3. Bahl V, Hu HM, Henke PK, et al. A validation study of a retrospective venous thromboembolism risk scoring method. *Ann Surg.* 2010;251(2):344–50.
4. Zhao YL, Huang Y, Zhou YQ, et al. Value of the Caprini thrombotic risk assessment model combined with plasma D-dimer for predicting venous thrombosis in patients with malignant tumors. *J Guangxi Univ Chin Med.* 2021;24(4):49–54. [Article in Chinese].
5. Key NS, Khorana AA, Kuderer NM, et al. Venous thromboembolism prophylaxis and treatment in patients with cancer: ASCO guideline update. *J Clin Oncol.* 2023;41(16):3063–71.
6. Weitz JI, Fredenburgh JC, Eikelboom JW. A test in context: D-dimer. *J Am Coll Cardiol.* 2017;70(19):2411–20.
7. Mastoraki A, Mastoraki S, Schizas D, et al. Facing the challenge of venous thromboembolism prevention in patients undergoing major abdominal surgical procedures for gastrointestinal cancer. *World J Gastrointest Oncol.* 2018;10(10):328–35.
8. Pannucci CJ, Swistun L, MacDonald JK, et al. Individualized venous thromboembolism risk stratification using the 2005 Caprini score to identify the benefits and harms of chemoprophylaxis in surgical patients: a meta-analysis. *Ann Surg.* 2017;265(6):1094–103.
9. Obi AT, Pannucci CJ, Nackashi A, et al. Validation of the Caprini venous thromboembolism risk assessment model in critically ill surgical patients. *JAMA Surg.* 2015;150(10):941–8.
10. Agnelli G, Bolis G, Capussotti L, et al. A clinical outcome-based prospective study on venous thromboembolism after cancer surgery: the @RISTOS project. *Ann Surg.* 2006;243(1):89–95.
11. Shoji M, Yamashita Y, Ishii M, et al. A predictive model for cancer-associated thrombosis in Japanese cancer patients: findings from the J-Khorana Registry. *TH Open.* 2024;8(1):e9–18.
12. Zhang X, Wang X, Li W, et al. D-dimer, a predictor of bad outcome in gastric cancer patients undergoing radical resection. *Sci Rep.* 2022;12(1):16432.
13. Li XP, Wang YY, Sun YS, et al. Preoperative and postoperative clinical signatures of postgastrectomy venous thromboembolism in patients with gastric cancer: a retrospective cohort study. *Asian J Surg.* 2023;46(4):1556–63.

Figures

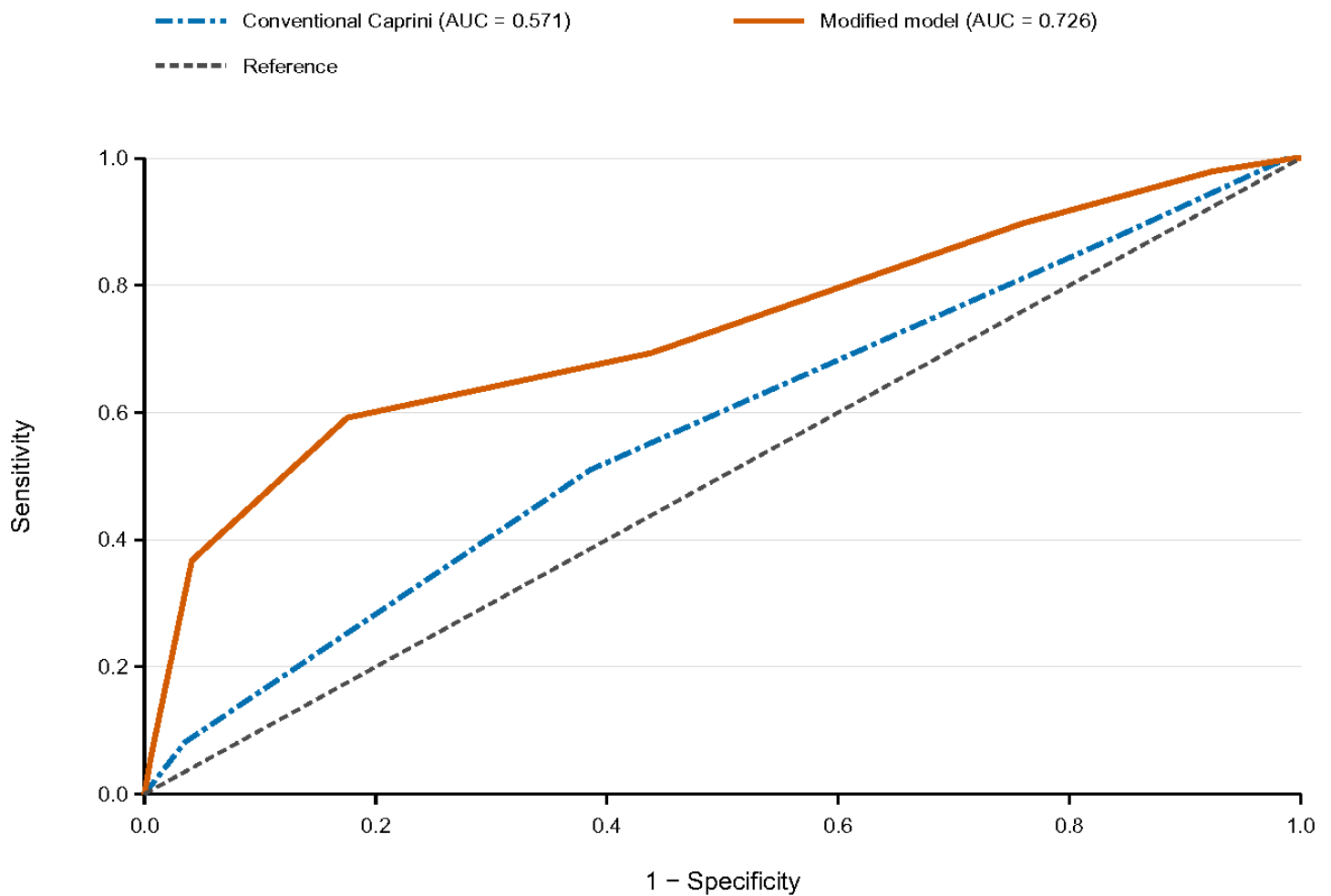


Figure 1

Receiver operating characteristic curves for the conventional and modified Caprini models

Receiver operating characteristic curves comparing the conventional and modified Caprini scores for postoperative VTE after gastrointestinal cancer surgery. The AUC was 0.571 (95% CI, 0.484–0.658) for the conventional score and 0.726 (95% CI, 0.638–0.815) for the modified score. The paired difference was statistically significant (DeLong Z = 3.983; P < 0.001).

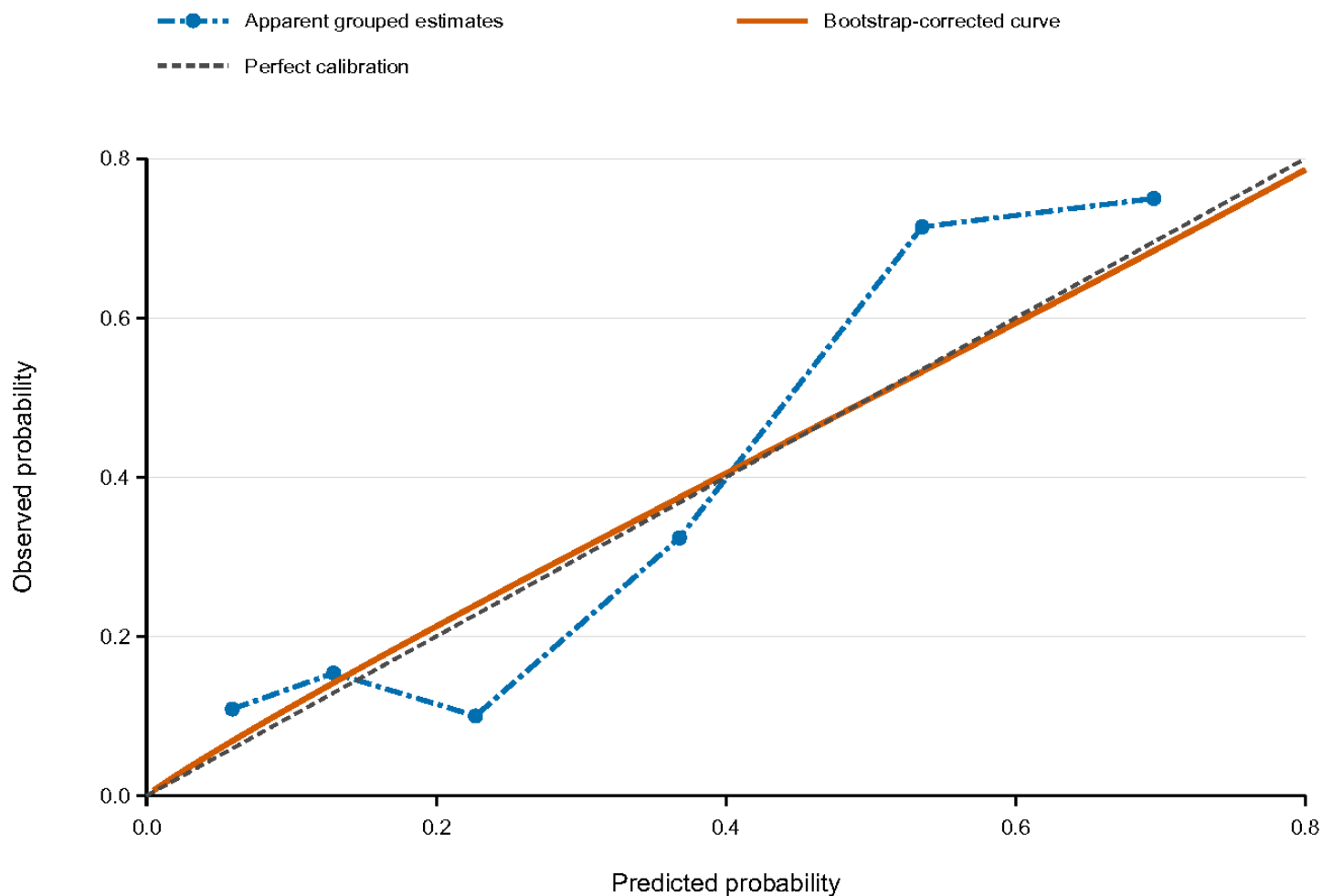


Figure 2

Calibration of the modified Caprini model

Calibration plot for the modified Caprini score. Blue points and lines represent grouped apparent estimates, the orange line represents the curve derived from the bootstrap-corrected intercept (-0.004) and slope (0.942), and the dashed line represents perfect calibration. The corrected Brier score was 0.150 and the corrected IPA was 13.7% . The grouped Hosmer–Lemeshow test yielded $P = 0.040$ and was treated as supplementary rather than definitive evidence of calibration.

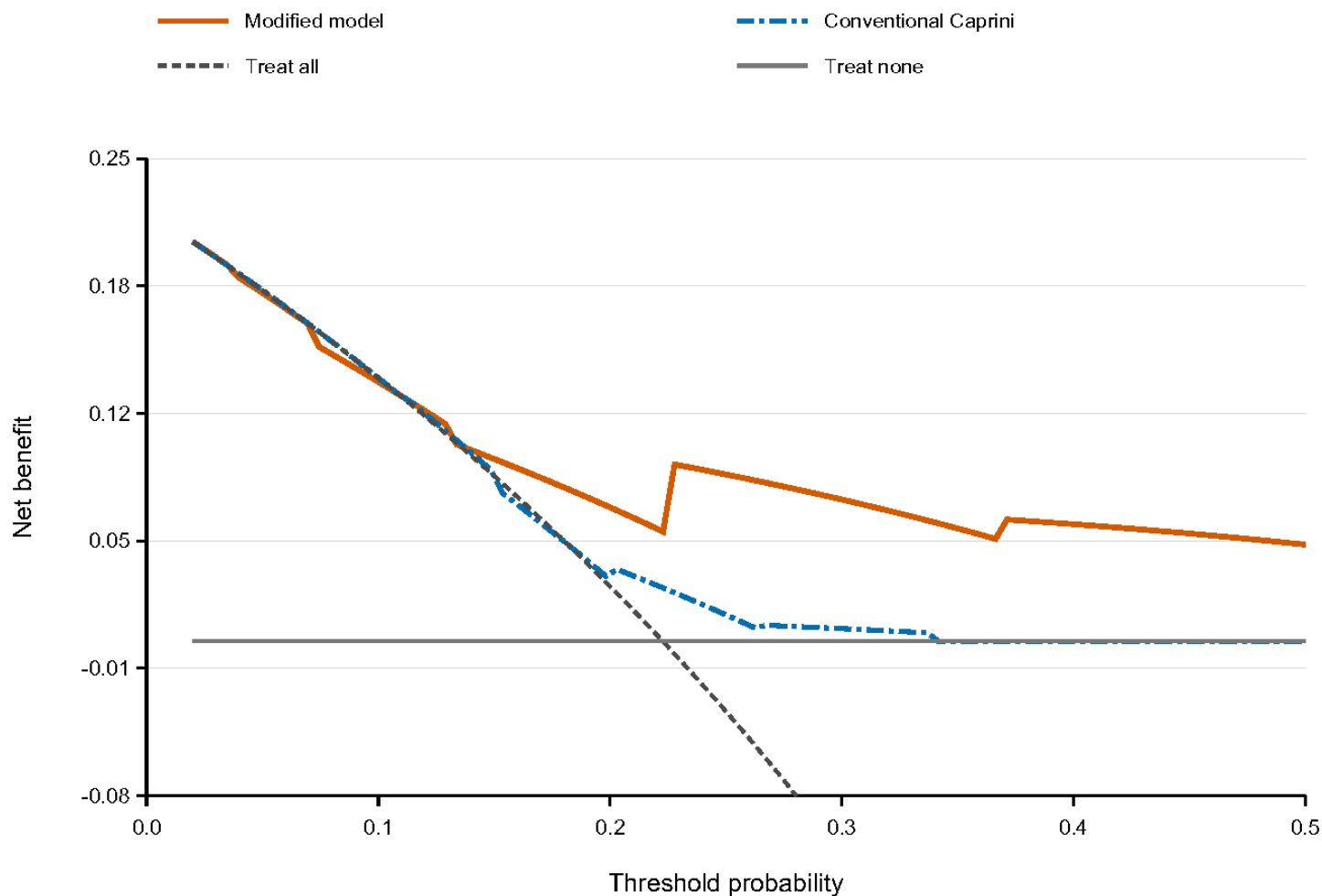


Figure 3

Decision curve analysis of the conventional and modified Caprini models

Decision curves comparing the conventional and modified Caprini scores across threshold probabilities for postoperative VTE. The modified score generally had greater net benefit above approximately 14%, while differences at lower thresholds were small or inconsistent.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Additionalfile1.pdf](#)
- [Additionalfile2.pdf](#)