

Early risk prediction of necrotizing enterocolitis using 48-hour laboratory indicators and pre-symptom clinical-course variables: a single-center retrospective study

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Abstract

Background

Early identification of neonates at risk of necrotizing enterocolitis (NEC) is challenging due to nonspecific early gastrointestinal manifestations. This study aimed to develop and internally validate a nomogram for identifying neonates at increased risk of NEC using early postnatal clinical and laboratory information.

Methods

This single-center retrospective study included neonates admitted to the neonatal intensive care unit of Southwest Hospital between January 2018 and January 2024 who developed suspected NEC or feeding intolerance–related gastrointestinal manifestations. NEC was defined as Modified Bell stage II or III disease. Controls were neonates with Modified Bell stage I disease or other gastrointestinal manifestations, such as vomiting, regurgitation, or abdominal distension, without progression to NEC. Candidate predictors included perinatal characteristics, feeding-related variables, pre-symptom clinical-course variables, and routine laboratory indicators measured within 48 hours after birth. Multivariable logistic regression was used to construct the nomogram, and model performance was assessed using discrimination, calibration, decision curve analysis, and bootstrap internal validation.

Results

A total of 248 neonates were included, including 77 with NEC and 171 controls. The final nomogram incorporated five predictors: 5-minute Apgar score, parenteral nutrition, feeding advancement rate, neutrophil percentage, and procalcitonin. The model showed good discrimination, with an area under the receiver operating characteristic curve of 0.839 (95% CI, 0.785–0.893). At the optimal cutoff value of 0.353, the sensitivity and specificity were 71.4% and 86.0%, respectively. Calibration analysis indicated acceptable agreement between predicted and observed risks, and decision curve analysis suggested potential clinical usefulness.

Conclusions

A nomogram combining early postnatal laboratory indicators and pre-symptom clinical variables showed good internal performance for NEC risk stratification. External validation is required before clinical implementation.

Introduction

Necrotizing enterocolitis (NEC) is a life-threatening gastrointestinal disease in neonates and remains a major challenge in neonatal intensive care^[1-4]. The disease often begins with nonspecific manifestations, such as vomiting, regurgitation, abdominal distension, feeding intolerance, bloody stool, or systemic instability, but may progress rapidly to intestinal necrosis, perforation, sepsis, and death. In clinical practice, Modified Bell stage II or III disease is generally considered definite NEC, whereas stage I represents a suspected condition with limited diagnostic certainty^[5, 6]. Because early symptoms frequently overlap with feeding intolerance and other non-NEC gastrointestinal disorders, recognizing infants at higher risk of NEC before definite progression is difficult.

Risk assessment in this early stage usually relies on clinical judgment, serial physical examination, laboratory tests, and abdominal imaging. However, no single clinical sign or laboratory marker is sufficiently reliable for early risk stratification^[7]. Information available before definite NEC develops may help refine early risk assessment. Laboratory findings obtained soon after birth can capture early inflammatory or physiological vulnerability, whereas feeding-related and pre-symptom clinical-course variables may indicate feeding tolerance and overall clinical stability^[8]. A simple model combining these routinely available factors may therefore help clinicians identify neonates who need closer monitoring.

This study aimed to develop and internally validate a nomogram for NEC risk stratification among neonates admitted to the neonatal intensive care unit who developed suspected NEC or feeding intolerance–related gastrointestinal manifestations. Rather than focusing on neonates with established NEC, we addressed the earlier and clinically ambiguous window before definite progression. NEC was defined as Modified Bell stage II or III disease, and candidate predictors included perinatal characteristics, feeding-related factors, pre-symptom clinical-course variables, and routine laboratory indicators measured within 48 hours after birth.

Methods

Study design and population

This single-center retrospective study was conducted in the neonatal intensive care unit of Southwest Hospital, Army Medical University, Chongqing, China. Neonates admitted between January 1, 2018 and January 1, 2024 were screened.

Eligible neonates were those who developed suspected NEC or feeding intolerance–related gastrointestinal manifestations during hospitalization, including vomiting, regurgitation, abdominal distension, bloody stool, or persistent feeding intolerance. NEC was defined as Modified Bell stage II or III disease^[5, 6]. Neonates who met this definition were assigned to the NEC group, whereas neonates with Modified Bell stage I disease or other gastrointestinal manifestations who did not progress to NEC were assigned to the control group. Only neonates with complete data for all candidate predictors and outcome classification were included in the final analytical cohort. Missing values were not imputed; instead, a complete-case analysis was performed.

Neonates were excluded if they had congenital gastrointestinal malformations, spontaneous intestinal perforation, surgical emergencies unrelated to NEC, hereditary metabolic or endocrine diseases, or incomplete medical records. The diagnosis of NEC and group allocation were independently confirmed by two neonatologists according to clinical manifestations, abdominal imaging, laboratory findings, clinical course, and final diagnosis.

Candidate predictors and definitions

Data were extracted from electronic medical records. Candidate predictors included perinatal characteristics, maternal pregnancy complications, feeding-related variables, pre-symptom clinical-course variables, and routine laboratory indicators.

Perinatal and maternal variables included sex, gestational age, birth weight, small for gestational age, mode of delivery, gestational diabetes mellitus, hypertensive disorders of pregnancy, intrahepatic cholestasis of pregnancy, premature rupture of membranes, asphyxia, and 5-minute Apgar score.

Feeding-related and pre-symptom clinical-course variables included initiation time of enteral feeding, formula feeding, parenteral nutrition, and feeding advancement rate. Parenteral nutrition was defined as any intravenous administration of amino acids and/or lipid emulsions before the first gastrointestinal symptom. Feeding advancement rate was calculated as the average daily increase in enteral feeding volume (mL/kg/day) from the start of enteral feeds to the day before the first gastrointestinal manifestation, and was dichotomized as ≤ 20 or > 20 mL/kg/day based on clinical common practice.

Routine laboratory indicators were obtained from blood tests performed within 48 hours after birth. These included white blood cell count, platelet count, C-reactive protein, red cell distribution width, monocyte count, absolute neutrophil count, neutrophil percentage, hemoglobin, calcium, and procalcitonin. If more than one result was available within this time window, the earliest available value was used.

Model development

Univariable logistic regression was first performed to evaluate the association between each candidate predictor and NEC. Variables associated with NEC in univariable analysis at $P < 0.05$ were considered for multivariable logistic regression. A forward conditional procedure was used to identify predictors retained in the final multivariable model.

Given the number of NEC events ($n = 77$), the final five-predictor model maintained an events-per-variable ratio greater than 10. A nomogram was constructed based on the final multivariable logistic regression model. The predicted probability of NEC was calculated from the regression equation, and each predictor was assigned a point value in the nomogram to provide an individualized risk estimate.

Model performance, internal validation, and risk threshold

Model discrimination was assessed using receiver operating characteristic curve analysis and the area under the curve. The optimal cutoff value of the predicted probability was determined using the Youden index^[9]. This cutoff was used as the model-derived risk threshold for identifying neonates who may require intensified clinical monitoring. Neonates with a predicted probability equal to or greater than this threshold were classified as high risk. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated at this threshold.

Calibration was evaluated using a calibration curve and the Hosmer–Lemeshow goodness-of-fit test^[10]. Internal validation was performed using bootstrap resampling with 1000 repetitions. Decision curve analysis was used to assess the potential clinical usefulness of the model across different threshold probabilities. A clinical impact curve was generated to estimate the number of neonates classified as high risk and the number of true NEC cases across the threshold range.

LASSO sensitivity analysis

Least absolute shrinkage and selection operator logistic regression was performed as a sensitivity analysis to assess the robustness of predictor selection. Candidate variables entered into the LASSO model were variables associated with NEC in univariable analysis at $P < 0.05$. Ten-fold cross-validation was used to determine the tuning parameter. Variables with non-zero coefficients at $\lambda_{\min}$ were considered retained by the LASSO model. This analysis was used to examine the stability of predictors identified in the primary multivariable logistic regression model.

Statistical analysis

This study was reported in accordance with the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) statement^[11]. Continuous variables were assessed for normality. Normally distributed variables are presented as mean $\pm$ standard deviation and were compared using Student's *t* test. Non-normally distributed variables are presented as median with interquartile range and were compared using the Mann–Whitney *U* test. Categorical variables are presented as number and percentage and were compared using the chi-square test or Fisher's exact test, as appropriate. Because neonates with incomplete candidate predictor data were excluded according to predefined criteria, all statistical analyses were conducted using complete cases without imputation.

All tests were two-sided, and $P < 0.05$ was considered statistically significant. Statistical analyses were performed using SPSS version 26.0 and R version 4.3.1.

Results

Patient selection and baseline characteristics

A total of 269 neonates with suspected NEC or feeding intolerance–related gastrointestinal manifestations were screened. After excluding 21 neonates because of congenital gastrointestinal malformations, surgical emergencies unrelated to NEC, or incomplete data, 248 neonates were included in the final analysis. Among them, 77 neonates were diagnosed with NEC and 171 were included in the control group (Supplementary Fig. 1).

Baseline characteristics are shown in Table 1. Compared with controls, neonates with NEC had a lower 5-minute Apgar score, a later initiation of enteral feeding, a higher proportion of parenteral nutrition, and a lower proportion of feeding advancement > 20 mL/kg/day before the first gastrointestinal manifestation. Formula feeding was also more frequent in the NEC group. Among laboratory indicators measured within 48 hours after birth, neonates with NEC had higher absolute neutrophil count, higher neutrophil percentage, lower calcium level, and higher procalcitonin level. No significant differences were observed in gestational age, birth weight, sex, mode of delivery, small for gestational age, asphyxia, or maternal pregnancy complications.

Model development

In multivariable logistic regression, five predictors were retained in the final model: 5-minute Apgar score, parenteral nutrition, feeding advancement rate, neutrophil percentage, and procalcitonin (Table 2). Lower 5-minute Apgar score, parenteral nutrition, lower feeding advancement rate, higher neutrophil percentage, and higher procalcitonin level were retained as predictors in the final model.

The final logistic regression equation was: $\text{Logit}(P) = 5.465 - 0.617 \times \text{Apgar5} + 1.049 \times \text{PN} - 1.601 \times \text{FAR} > 20 + 0.027 \times \text{NE\%} + 0.169 \times \text{PCT}$. A nomogram was constructed based on the five predictors to estimate individualized NEC risk (Fig. 1).

LASSO sensitivity analysis

LASSO logistic regression was performed to examine the robustness of predictor selection. At $\lambda_{\min}$, LASSO retained 5-minute Apgar score, parenteral nutrition, feeding advancement rate, formula feeding, absolute neutrophil count, neutrophil percentage, calcium, and procalcitonin (Supplementary Table 1). All five predictors included in the final multivariable logistic regression model were retained at $\lambda_{\min}$. In addition, LASSO selected formula feeding, absolute neutrophil count, and calcium. These additional variables were not retained in the primary multivariable logistic regression model after model selection. The LASSO results thus support the robustness of the five-predictor set without demanding their inclusion. The LASSO coefficient profile and cross-validation curve are shown in Supplementary Fig. 2.

Model discrimination and risk threshold

The nomogram showed good discrimination, with an area under the receiver operating characteristic curve of 0.839 (95% CI, 0.785–0.893) (Fig. 2). The optimal cutoff value of the predicted probability, determined by the Youden index, was 0.353. This cutoff was used as the model-derived risk threshold for

identifying neonates who may require intensified clinical monitoring. Neonates with a predicted probability ≥ 0.353 were classified as high risk.

At this threshold, the sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy were 71.4%, 86.0%, 69.6%, 87.0%, and 81.5%, respectively (Table 3). In total, 79 neonates were classified as high risk, of whom 55 were true NEC cases.

Calibration, internal validation, and clinical usefulness

The calibration curve showed acceptable agreement between predicted and observed NEC risk (Fig. 3). The Hosmer–Lemeshow goodness-of-fit test showed no significant lack of fit ($\chi^2 = 5.348$, $P = 0.720$). Bootstrap internal validation with 1000 resamples showed that the bias-corrected calibration curve remained close to the ideal reference line.

Decision curve analysis showed that the nomogram provided greater net benefit than the treat-all or treat-none strategies across a range of threshold probabilities (Fig. 4). The clinical impact curve showed that the standardized number of neonates classified as high risk per 1000 decreased as the threshold increased, and the gap between predicted and observed high-risk cases narrowed at higher thresholds (Fig. 5).

Discussion

In this single-center retrospective study, we developed and internally validated a nomogram for early NEC risk stratification in neonates who developed suspected NEC or feeding intolerance–related gastrointestinal manifestations during hospitalization. The final model incorporated five routinely available predictors: 5-minute Apgar score, parenteral nutrition, feeding advancement rate, neutrophil percentage, and procalcitonin. The nomogram demonstrated good discrimination and calibration, and may provide clinically relevant risk estimates. At the model-derived risk threshold of 0.353, the model achieved a specificity of 86.0% and a negative predictive value of 87.0%, suggesting that it may help identify neonates who require closer monitoring and repeated assessment.

A major challenge in NEC management is that early gastrointestinal manifestations are often nonspecific. Vomiting, regurgitation, abdominal distension, bloody stool, and feeding intolerance may represent early NEC, transient feeding intolerance, or other non-NEC gastrointestinal conditions^[12, 13]. Modified Bell stage I disease is particularly difficult to interpret because clinical and radiographic findings are not yet definitive^[2, 12, 14]. In this uncertain clinical window, clinicians usually rely on repeated physical examination, serial abdominal imaging, laboratory trends, and clinical judgment. Recent work using routinely collected physiological data also supports the clinical value of earlier risk recognition in high-risk neonates^[15]. The present study focused on this stage rather than on neonates with already established NEC. Therefore, the purpose of the model is not to replace clinical diagnosis, but to provide an individualized estimate of NEC risk before definite progression.

The predictors retained in the model are clinically plausible and readily available in routine neonatal care. A lower 5-minute Apgar score may reflect perinatal compromise and early physiological instability, both of which can increase intestinal vulnerability^[16, 17]. Parenteral nutrition before the first gastrointestinal manifestation may indicate delayed enteral tolerance or a more fragile clinical course. This association should not be interpreted as evidence that parenteral nutrition causes NEC; rather, it may capture underlying illness severity and nutritional dependence before symptoms become evident^[18].

Feeding advancement rate also requires cautious interpretation^[8, 19]. In this cohort, a feeding advancement rate > 20 mL/kg/day was associated with lower odds of NEC. We emphasize that this association should not be interpreted causally. Infants who tolerated faster advancement likely had greater clinical stability and fewer early signs of feeding intolerance; conversely, slower advancement may have been a consequence, not a cause, of underlying vulnerability^[20]. Thus, feeding advancement rate in this context serves as an indicator of pre-symptom clinical status rather than a modifiable target for intervention^[21]. This interpretation is consistent with the observational nature of our data and the absence of a randomized feeding protocol.

The inclusion of neutrophil percentage and procalcitonin suggests that early inflammatory status may contribute to NEC risk before definite clinical progression^[22]. Both indicators were obtained within 48 hours after birth, which strengthens the temporal relationship between predictor measurement and subsequent clinical classification. However, neither marker is specific for NEC^[7]. Their value lies in their integration with perinatal and pre-symptom clinical-course variables. Rather than relying on a single laboratory abnormality, the model combines early biological signals with information from the preceding clinical course. This concept is consistent with emerging evidence that biological alterations may precede clinically apparent NEC^[23]. Such an approach is consistent with the multifactorial nature of NEC and may be more useful in daily NICU practice.

Compared with models designed to predict severe outcomes after NEC has been diagnosed, such as intestinal perforation, fulminant disease, or surgical intervention, the present model addresses an earlier and more ambiguous clinical scenario^[24–26]. Existing prediction tools often focus on neonates with established NEC or on highly selected populations, especially very preterm or very-low-birth-weight infants^[27]. In contrast, our study focused on neonates who presented with suspected NEC or feeding intolerance–related gastrointestinal manifestations, using laboratory information obtained within 48 hours after birth together with clinical-course variables recorded before the first gastrointestinal manifestation. This design separates early risk information from symptom-time diagnostic information and makes the model more relevant to bedside risk assessment when the clinical picture is still evolving. The model may support decisions about intensified abdominal assessment, closer observation of feeding tolerance, repeated laboratory evaluation, and timely imaging reassessment.

The relatively high gestational age of the cohort deserves attention. Although NEC is most strongly associated with prematurity and very low birth weight, it may also occur in late preterm and term

neonates with perinatal stress, impaired intestinal perfusion, infection, or feeding-related vulnerability^[28, 29]. Our cohort reflected the real case mix of a single neonatal intensive care unit and included neonates with suspected NEC or feeding intolerance–related gastrointestinal manifestations, rather than a population restricted to extremely preterm or very-low-birth-weight infants. Therefore, the model should be applied to a symptomatic NICU population with a similar gestational age profile. Its performance in extremely preterm or very-low-birth-weight infants remains to be validated.

The model-derived risk threshold of 0.353 offers a practical reference for identifying neonates who may benefit from intensified monitoring. This threshold should be interpreted as a provisional risk-stratification cutoff rather than a mandatory treatment cutoff^[30]. In practice, high-risk classification may support more cautious feeding decisions, closer observation of abdominal signs, and earlier reassessment when symptoms change. It should not be used alone to determine specific therapeutic interventions or surgical consultation. Because the threshold was derived from a single-center retrospective cohort, external and prospective validation is needed before it can be used as a clinical decision threshold.

The LASSO sensitivity analysis supported the robustness of the main predictors. Although LASSO additionally selected formula feeding, absolute neutrophil count, and calcium, these variables were not included in the final nomogram to preserve model parsimony and clinical interpretability in the primary logistic regression. The five-variable nomogram was therefore retained as the final model. The final nomogram was based on multivariable logistic regression because it provides a more interpretable structure for bedside risk estimation.

This study has several limitations. First, it was a single-center retrospective study, and selection bias could not be fully avoided. In addition, the complete-case design may have introduced selection bias if neonates with missing data differed systematically from those included in the analysis. Second, although bootstrap resampling was used for internal validation, no external validation cohort was included. The generalizability of the model to other NICUs, different feeding protocols, and populations with different gestational age distributions remains uncertain. In particular, because the cohort had a relatively high gestational age distribution, the model may not be directly generalizable to extremely preterm or very-low-birth-weight infants. Third, some predictors, such as parenteral nutrition and feeding advancement rate, are influenced by clinical condition and local management practice. These variables may reflect pre-symptom clinical vulnerability, but causal inference should not be made. Fourth, laboratory indicators were extracted from tests performed within 48 hours after birth, and dynamic changes after symptom onset were not incorporated. Finally, the proposed risk threshold was derived from the same cohort used for model development and should be considered provisional.

Conclusion

In summary, we developed an interpretable nomogram that integrates early postnatal laboratory indicators and pre-symptom clinical-course variables for NEC risk stratification among neonates with

suspected NEC or feeding intolerance–related gastrointestinal manifestations. The model showed good discrimination, acceptable calibration, and potential clinical usefulness, suggesting that early biological signals and the preceding clinical course can be combined to support individualized risk assessment. With further external and prospective validation, this tool may help clinicians identify high-risk neonates during the early and uncertain phase before definite NEC progression.

Abbreviations

AUC

area under the receiver operating characteristic curve

CI

confidence interval

CRP

C-reactive protein

DCA

decision curve analysis

LASSO

least absolute shrinkage and selection operator

NEC

necrotizing enterocolitis

NICU

neonatal intensive care unit

OR

odds ratio

PCT

procalcitonin

PLT

platelet count

RDW

red cell distribution width

ROC

receiver operating characteristic

SE

standard error

WBC

white blood cell count.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Southwest Hospital, Army Medical University (Approval No. [B] KY2024234). The Ethics Committee of Southwest Hospital, Army Medical University waived the requirement for informed consent because this was a retrospective study using de-identified clinical data collected during routine care. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available because they contain clinical information from neonates and are subject to institutional privacy and ethical restrictions. De-identified data may be available from the corresponding author upon reasonable request and with permission from Southwest Hospital, Army Medical University.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

YL and LS conceived and designed the study. YL and YH collected and organized the clinical data. YL performed the statistical analyses and interpreted the results. YL drafted the manuscript. LY and LS critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Tables

Table 1. Baseline characteristics of neonates with and without NEC

Variable	Control group (n = 171)	NEC group (n = 77)	P value
Sex			0.469
Male	87 (50.9)	43 (55.8)	
Female	84 (49.1)	34 (44.2)	
Gestational age, weeks	35.61 ± 3.13	35.76 ± 3.60	0.754
Birth weight, g	2383.87 ± 761.30	2379.22 ± 768.07	0.965
Small for gestational age	17 (9.9)	11 (14.3)	0.317
Cesarean delivery	108 (63.2)	53 (68.8)	0.386
Gestational diabetes mellitus	41 (24.0)	22 (28.6)	0.442
Hypertensive disorders of pregnancy	22 (12.9)	11 (14.3)	0.761
Intrahepatic cholestasis of pregnancy	12 (7.0)	7 (9.1)	0.570
Premature rupture of membranes	27 (15.8)	18 (23.4)	0.151
Asphyxia	8 (4.7)	6 (7.8)	0.493
5-minute Apgar score	10.00 (10.00, 10.00)	10.00 (8.00, 10.00)	<0.001
Initiation time of enteral feeding			0.001
<1 h	158 (92.4)	59 (76.6)	
≥1 h	13 (7.6)	18 (23.4)	
Parenteral nutrition	61 (35.7)	51 (66.2)	<0.001
Feeding advancement rate			<0.001
≤20 mL/kg/day	34 (19.9)	45 (58.4)	
>20 mL/kg/day	137 (80.1)	32 (41.6)	
Formula feeding	68 (39.8)	43 (55.8)	0.018
Postnatal age at first gastrointestinal manifestation, days	8.00 (5.00, 16.00)	11.00 (5.50, 19.00)	0.169
WBC, ×10 ⁹ /L	10.15 (7.18, 13.11)	9.95 (7.21, 13.55)	0.818
PLT, ×10 ⁹ /L	306.84 ± 130.35	300.55 ± 104.28	0.686
CRP, mg/L	5.00 (2.79, 5.00)	5.00 (1.88, 10.85)	0.105

RDW, %	15.40 (14.60, 16.40)	15.20 (14.40, 16.45)	0.526
Monocyte count, $\times 10^9/L$	1.17 (0.89, 1.58)	1.14 (0.79, 1.48)	0.443
Absolute neutrophil count, $\times 10^9/L$	4.53 (2.95, 6.65)	5.36 (3.36, 9.20)	0.048
Neutrophil percentage, %	48.57 $\pm$ 17.04	56.63 $\pm$ 17.20	0.001
Hemoglobin, g/L	146.67 $\pm$ 33.29	140.26 $\pm$ 35.45	0.170
Calcium, mmol/L	1.23 $\pm$ 0.17	1.15 $\pm$ 0.23	0.008
Procalcitonin, ng/mL	0.22 (0.07, 0.89)	1.08 (0.26, 3.10)	<0.001

Data are presented as mean $\pm$ standard deviation, median (interquartile range), or *n* (%), as appropriate. NEC, necrotizing enterocolitis; SGA, small for gestational age; WBC, white blood cell count; PLT, platelet count; CRP, C-reactive protein; RDW, red cell distribution width; PCT, procalcitonin.

Table 2. Multivariable logistic regression model for NEC

Predictor	β	SE	Wald χ^2	P value	OR (95% CI)
5-minute Apgar score	-0.617	0.180	11.811	0.001	0.539 (0.379–0.767)
Parenteral nutrition	1.049	0.342	9.415	0.002	2.856 (1.461–5.584)
Feeding advancement rate					
≤ 20 mL/kg/day	Reference	—	—	—	1.000
>20 mL/kg/day	-1.601	0.349	21.009	<0.001	0.202 (0.102–0.400)
Neutrophil percentage	0.027	0.010	6.840	0.009	1.027 (1.007–1.048)
Procalcitonin	0.169	0.070	5.894	0.015	1.184 (1.033–1.357)
Constant	5.465	1.741	9.854	0.002	—

OR, odds ratio; CI, confidence interval. Feeding advancement rate ≤ 20 mL/kg/day was used as the reference category.

Table 3 Performance of the nomogram at the model-derived risk threshold

Measure	Value
Area under the curve	0.839
95% CI	0.785–0.893
Model-derived risk threshold	0.353
Sensitivity	71.4%
Specificity	86.0%
Positive predictive value	69.6%
Negative predictive value	87.0%
Accuracy	81.5%
True positives	55
False positives	24
True negatives	147
False negatives	22

The risk threshold was determined using the Youden index. Neonates with a predicted probability ≥ 0.353 were classified as high

Figures

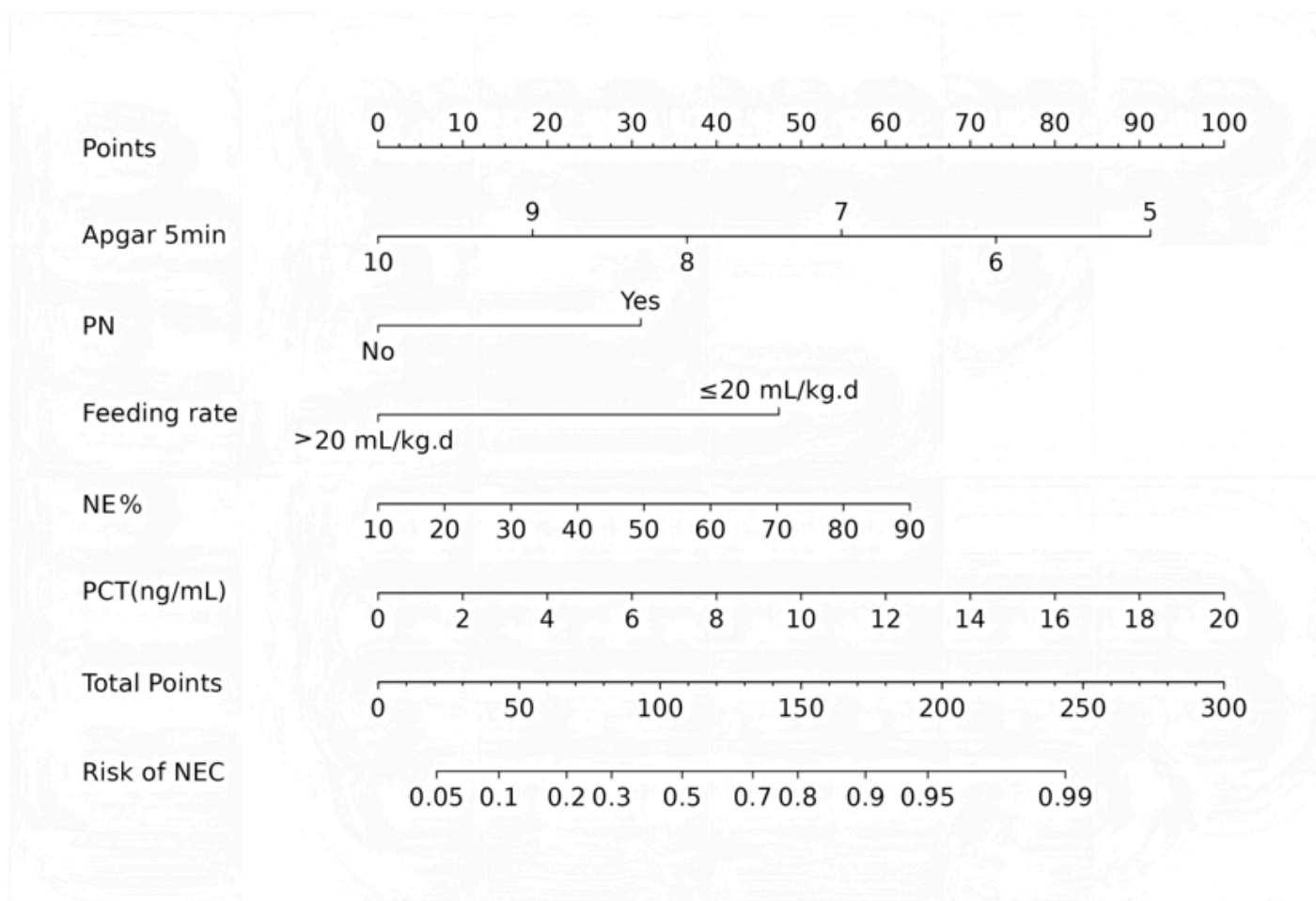


Figure 1

Nomogram for individualized NEC risk estimation. The nomogram was constructed using five predictors retained in the final multivariable logistic regression model: 5-minute Apgar score, parenteral nutrition, feeding advancement rate, neutrophil percentage, and procalcitonin.

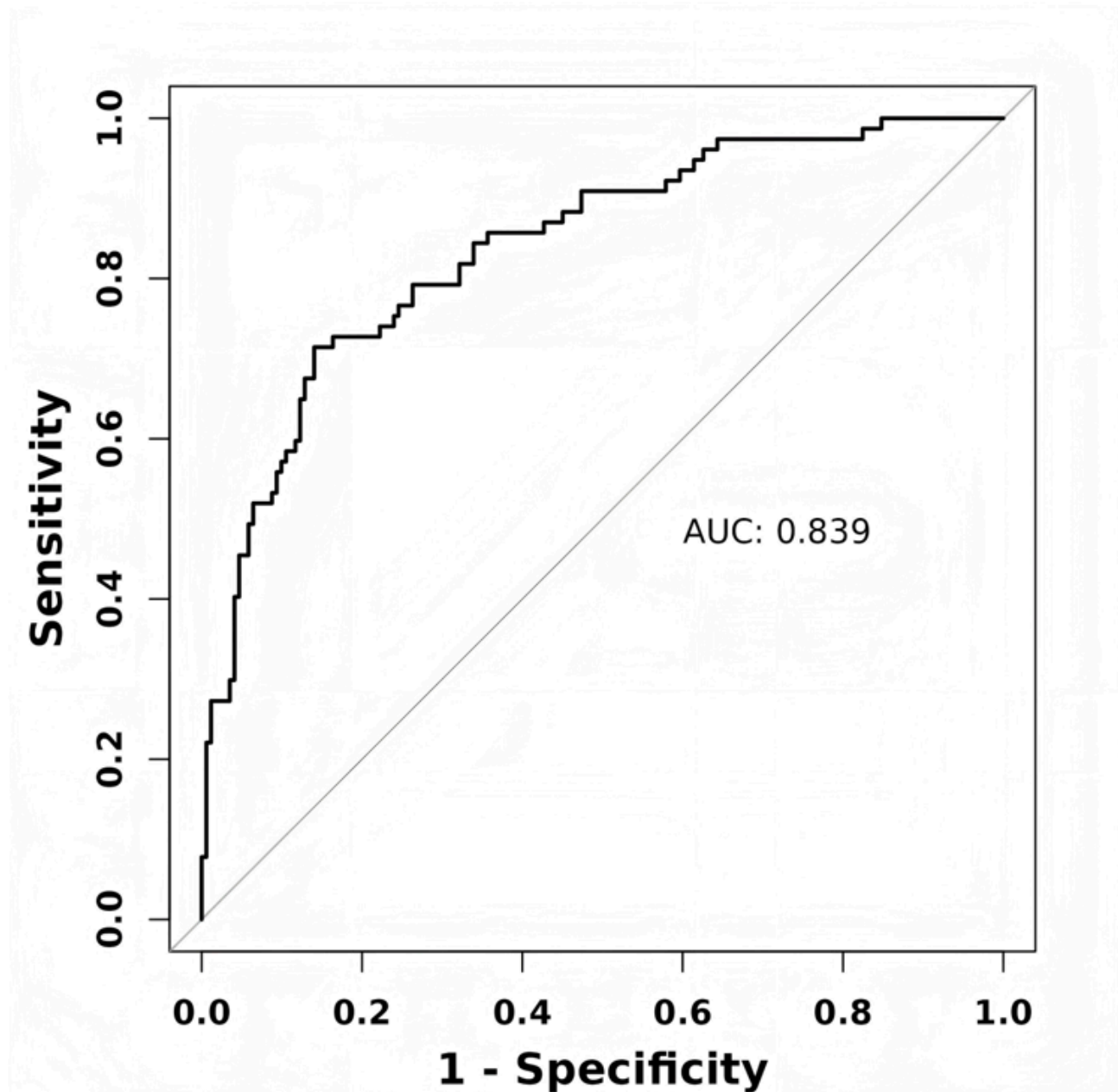


Figure 2

Receiver operating characteristic curve of the nomogram. The area under the curve was 0.839 (95% CI, 0.785–0.893). The optimal cutoff value of the predicted probability was 0.353.

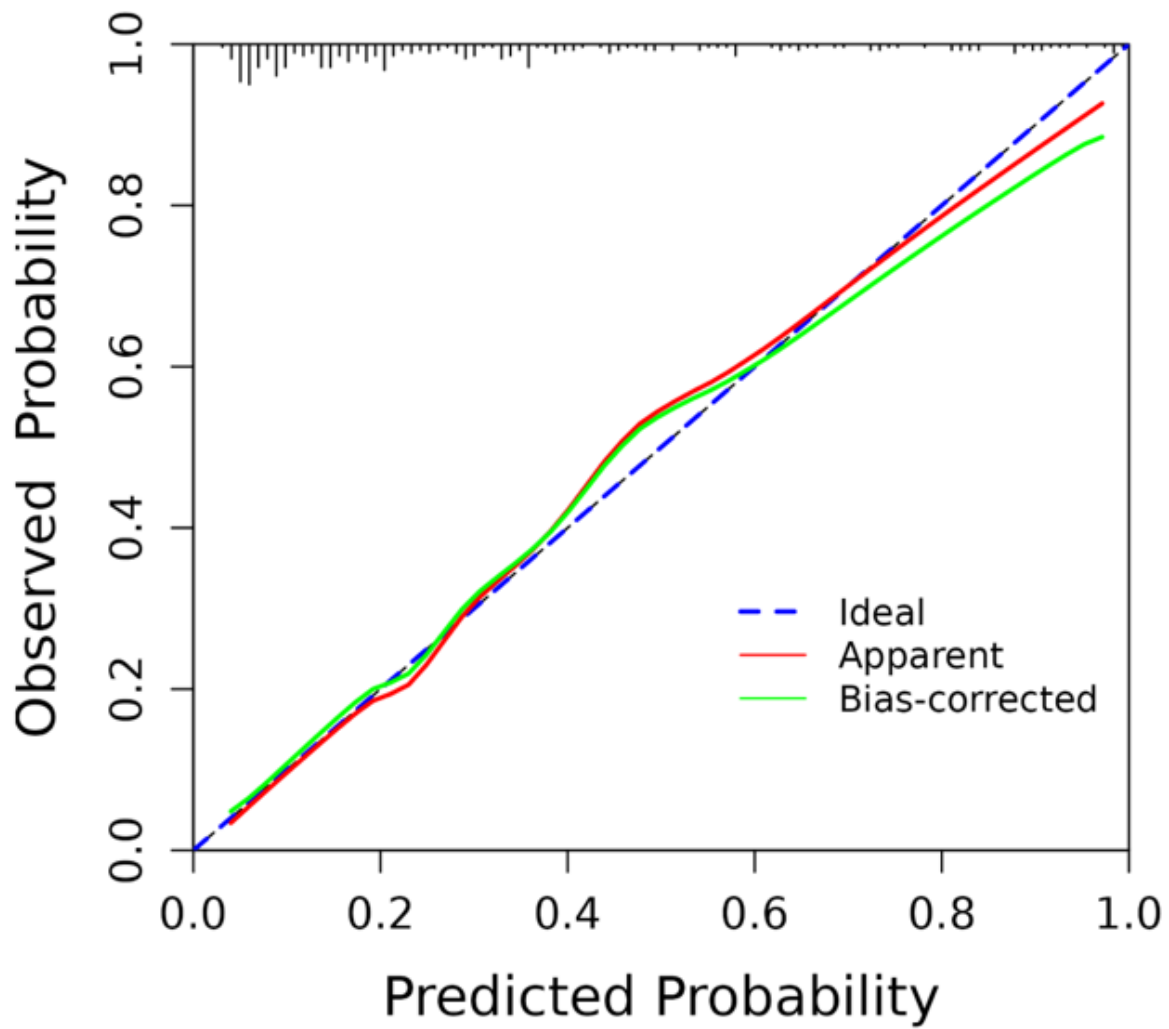


Figure 3

Calibration curve of the nomogram. Apparent and bias-corrected calibration curves were generated using bootstrap resampling with 1000 repetitions.

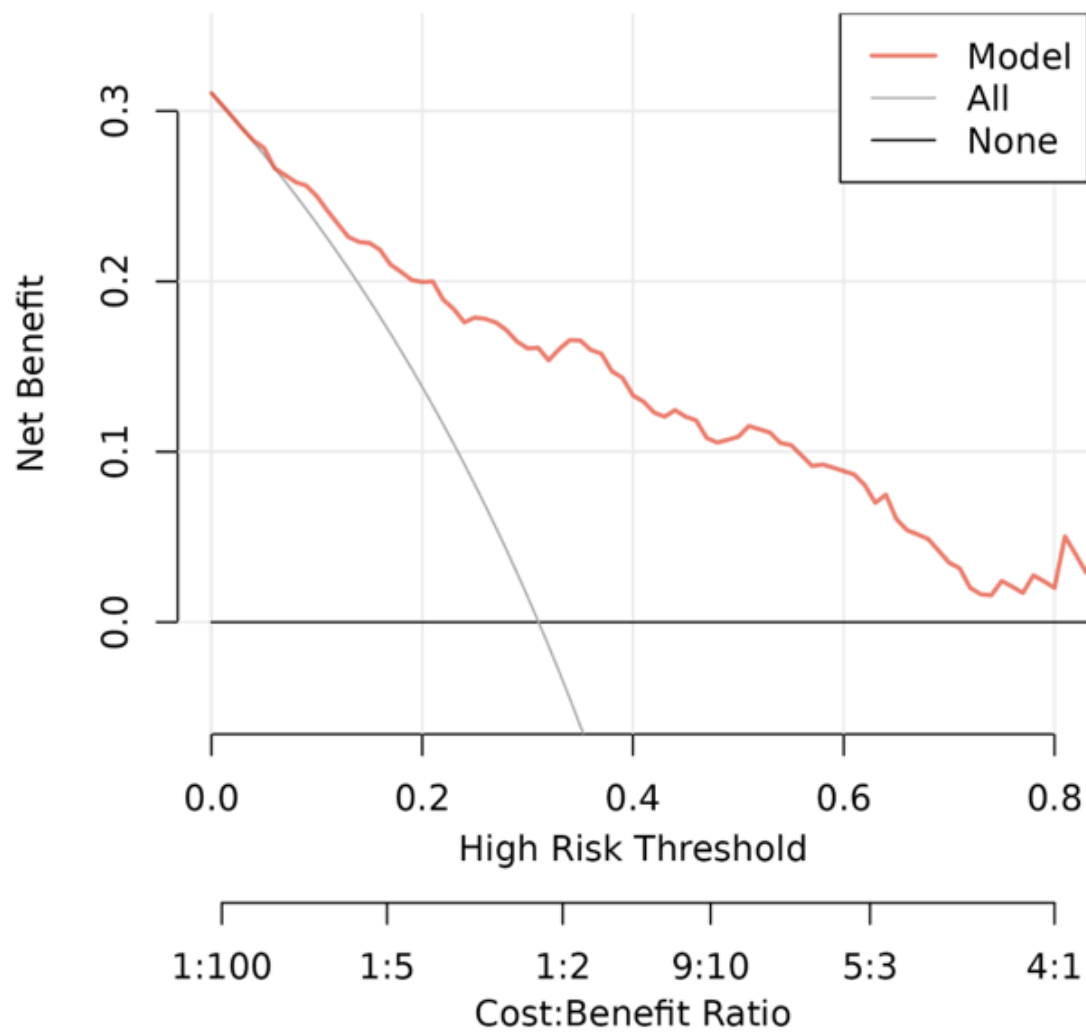


Figure 4

Decision curve analysis of the nomogram. The decision curve shows the net benefit of the nomogram across threshold probabilities compared with treat-all and treat-none strategies.

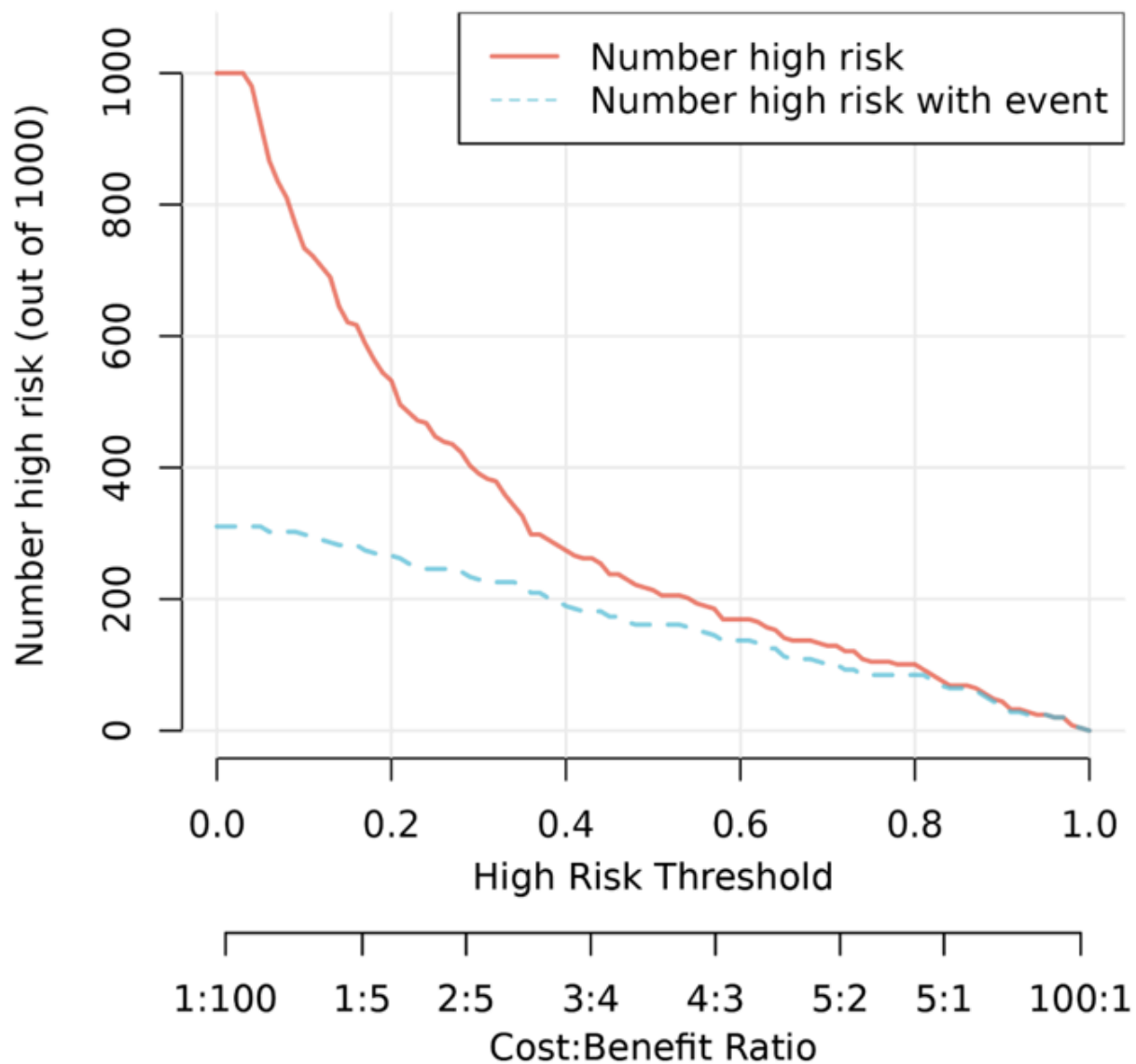


Figure 5

Clinical impact curve of the nomogram. The curve shows the standardized number of neonates classified as high risk per 1000 and the number of high-risk neonates with observed NEC across threshold probabilities.

Supplementary Files

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

- [SupplementaryFigs.docx](#)

- [SupplementaryTable.docx](#)