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Predicting postoperative nausea and vomiting after cesarean section: a nomogram model combined with gastric ultrasound

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Abstract

Background To investigate the independent risk factors associated with postoperative nausea and vomiting (PONV) following Cesarean section procedures, and establish and validate a nomogram to predict them.

Methods The clinical data of 116 adult patients who underwent Cesarean section procedures between August 2022 and February 2023 were included. Participants were randomly divided into training ($n=87$) and verification sets ($n=29$) in a 3:1 ratio. Univariate and multivariate logistic regression were used to analyze the risk factors for PONV following Cesarean sections and the independent risk factors were then used for the prediction model. Simultaneously, 29 adult patients who underwent caesarean section between February 2023 and April 2023 were included in the hospital as a test set to conduct external verification of the nomogram and Apfel scoring models, and compare their diagnostic efficacy in predicting PONV after caesarean section.

Results A history of motion sickness, systolic blood pressure reduction > 20%, and gastric volume were independent risk factors for PONV and used to construct the model. The AUC for predicting the risk of PONV in the training and validation sets was 0.814 (95% confidence interval [CI] = 0.709–0.918) and 0.792 (95% CI = 0.621–0.962), respectively. In the test set, the AUCs of the nomogram and the Apfel scoring models were 0.779 (95% CI = 0.593–0.965) and 0.547 (95% CI = 0.350–0.745), respectively, with the former being significantly higher ($Z=2.165$, $P<0.05$).

Conclusions Our nomogram model was superior to the Apfel scoring model and may be helpful in formulating appropriate individualized management strategies for nausea and vomiting following Cesarean sections, to promote the rapid recovery of patients.

Keywords Postoperative nausea and vomiting, Cesarean section, Nomogram, Gastric ultrasound

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Background

Postoperative nausea and vomiting (PONV) is a common adverse reaction following a caesarean section. Griffith et al. reported that the incidence of PONV varies from 21 to 79% [1]. Numerous studies have demonstrated that PONV after a caesarean section not only increases the risk of postoperative bleeding and wound rupture but also affects the postpartum recovery of pregnant and breastfeeding women [2, 3]. Additionally, it can elevate the risk of postpartum depression [4–6]. Therefore, caesarean section guidelines also prioritize the prevention of PONV as a key aspect of ensuring rapid postoperative recovery [3].

Current PONV prevention strategies mainly include the prophylactic use of antiemetic drugs, multimodal analgesia, and the perioperative administration of dexmedetomidine [4]. However, most current interventions carry potential risks for pregnant women and may impact newborns either through placental transplantation or during breastfeeding [7]. Therefore, it becomes crucial to perform individualized PONV risk assessments in pregnant women before a caesarean section.

The Apfel score is presently employed to assess patient susceptibility to PONV based on risk factors such as female sex, non-smoking status, opioid use, previous history of PONV, and motion sickness [8]. However, as all caesarean section recipients are female and most of them avoid smoking for the health of the fetus, the Apfel score may have limitations in predicting PONV occurrence in this population [9].

Furthermore, in addition to common anesthetic and surgical factors and the physiological changes occurring in pregnant women, such as increased gastric pressure due to the upward displacement of the uterus during pregnancy [10], Hong et al. showed that the increase in gastric volume in pregnant women compared to non-pregnant women is a significant factor contributing to the elevated risk of PONV [11]. Gastric ultrasound, a non-invasive method for evaluating gastric contents, has been extensively studied in the field of anesthesiology [12]. Chen et al. found that the gastric content and volume in pregnant women can be calculated according to the cross-sectional area (CSA) of the gastric antrum [13].

Therefore, the objective of this study was to combine gastric ultrasound assessments of pregnant women with a comprehensive collection of PONV-related risk factors for caesarean sections. This would enable us to establish a caesarean section-specific PONV prediction model, offering valuable insights for clinical prevention and intervention.

Materials and methods

Patients

This prospective observational cohort study was approved by the Research Ethics Committee of the Second Affiliated Hospital of Fujian Medical University (2022 Ethics Review No.285). This study was conducted from August 2022 to February 2023, and the data of 116 adult patients who underwent caesarean sections were continuously collected. All participants gave written informed consent to take part in the study. The studies were performed in accordance with relevant guidelines/regulations and conducted following the Helsinki Declaration and good clinical practice.

The inclusion criteria were as follows: (1) adult women who underwent caesarean section delivery under spinal anesthesia; (2) American Society of Anesthesiologists (ASA) classification: I-III; and (3) single pregnancy ≥ 36 weeks. The exclusion criteria were as follows: (1) height < 152 cm or height > 180 cm; (2) patients who received antiemetic medication within 24 h before caesarean section; (3) patients requiring emergency caesarean section; (4) pregnant women with severe hypertension during pregnancy (systolic blood pressure > 160 mmHg, diastolic blood pressure > 110 mmHg), heart disease, and diabetes; (5) patients treated with monoamine oxidase inhibitors or tricyclic antidepressants; and (6) morbid obesity (body mass index > 45 kg/m2).

Preoperative ultrasound assessment of gastric volume

Prior to surgery, ultrasonography was performed in the preparation room using a Mindray M6 ultrasonic diagnostic instrument equipped with a 3C5S convex array probe set to a frequency of 2–5 MHz. The pregnant woman was asked to assume the right position and the head of the bed was elevated to 45°. The probe was placed in the subxiphoid region, utilising the abdominal aorta and left lobe of the liver as localisation markers to obtain the sagittal plane of the scan [14]. The gastric antrum was explored through a sagittal section (Fig. 1), and the maximum anteroposterior diameter (AP) and craniocaudal diameter (CC) of the antrum were measured three consecutive times [14–16]. The average of each diameter was used to calculate the area of the gastric antrum area (CSA), $CSA\left(cm^2\right) = (AP * CC * \pi) / 4$ [16]. The gastric volume was calculated by measuring the CSA of the antrum according to the following formula [13, 17]:

$$Gastric\ volume\ (mL) = 270.76 + 13.68 * CSA - 1.20 * gestational\ age$$

Intraoperative management

The patient was placed in the supine position before the operation, and the patient ‘s blood pressure was measured every 5 minutes for three consecutive times

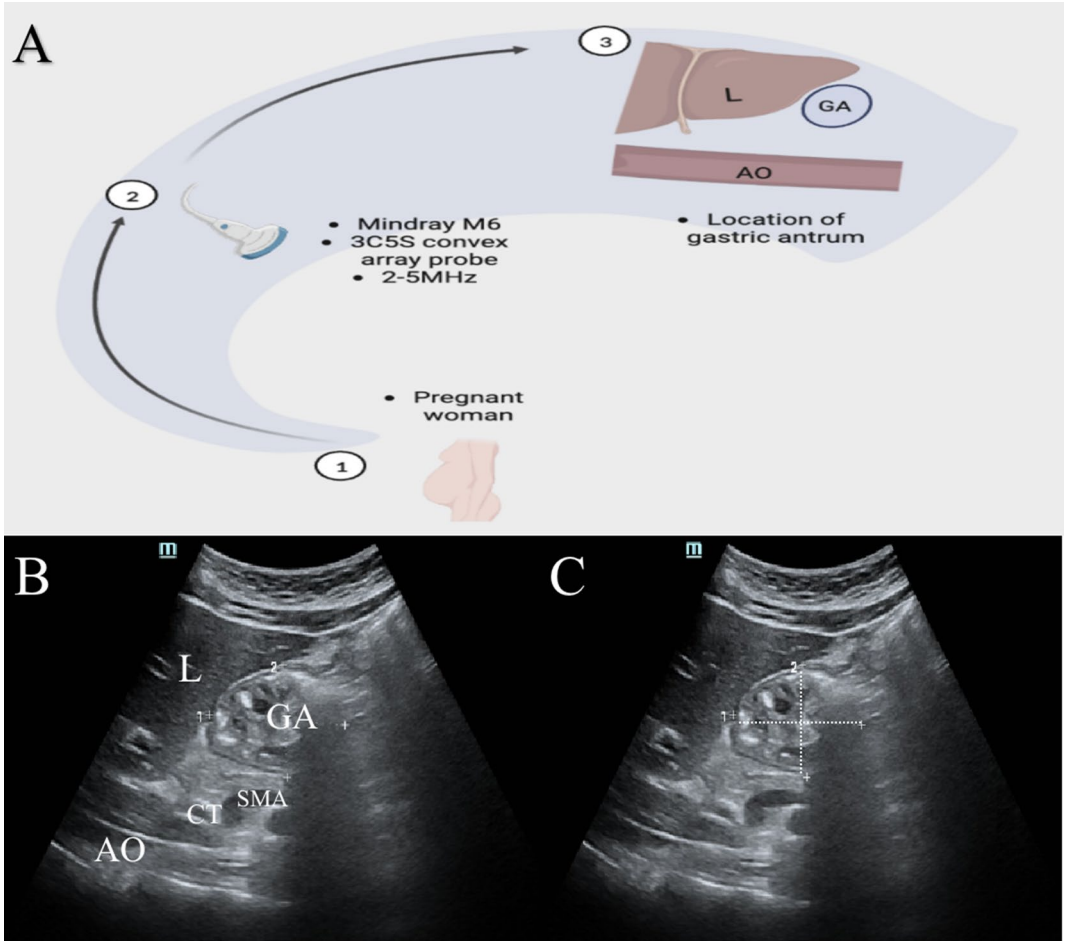

Fig. 1 (**A**) Ultrasonic positioning diagram; (**B**) Ultrasound examination of the gastric antrum. GA: gastric antrum; L: liver; SMA: superior mesenteric artery; CT: celiac trunk; and AO: aorta. (**C**) The cross-sectional area of the gastric antrum was measured by the vertical double meridian method

without interference. The baseline systolic blood pressure of the patient was determined by calculating the average of the three systolic blood pressures.

Spinal-epidural anesthesia involved puncturing the L2/L3 space and injecting 15 mg 0.75% ropivacaine hydrochloride into the subarachnoid space. The spinal needle was then removed, and a 3–4 cm catheter was inserted cephalad through the epidural puncture needle. Subsequently, the patient was immediately adjusted to the supine position, with appropriate left tilt and adjustment of the anesthesia plane to the T6–T8 range. If the patient complained of pain for more than 1 min after successful delivery of the fetus, 2 mg of morphine was injected into the epidural space. Intravenous bolus of 8 μg norepinephrine was given immediately after spinal anesthesia to maintain systolic blood pressure changes within 20% of the baseline. A systolic blood pressure fall of greater than 20% of the baseline or less than 90 mmHg was judged to be hypotension. Therefore, an additional 5 μg of norepinephrine was required, with the blood pressure monitored every 2 min, and medication was repeated accordingly until the systolic blood pressure was maintained in the expected range. If the heart rate was < 50 beats/min, 0.5 mg atropine was administered, and an additional dose were given as required. A rapid fluid infusion of 500 ml of colloidal solution immediately after spinal anesthesia and before delivery was also administered, subsequently maintaining the infusion rate. After delivery via caesarean section, 10 U of ordinary oxytocin was injected into the uterus, and 100 μg (1 ml) of carbetocin was slowly intravenously injected within 1 min. Intraoperative maternal nausea or vomiting was treated with 10 mg dexamethasone. Postoperative analgesia was performed using a postoperative analgesia pump (20 mg dezocine + 0.9% normal saline to 100 ml) and a patient-controlled intravenous analgesia mode.

Data collection

The primary outcome measure was the incidence of PONV within 24 h after surgery, as determined during follow-up on the second day after surgery. Postoperative vomiting data were collected through follow-up

with patients, patients' families, and nurses. Postoperative nausea data were collected using the visual analogue scale (VAS) [18]. A VAS score of 0–1 was considered as no nausea, and a score above 1 was considered indicative of nausea. Data on the potential risk factors for PONV were obtained from patients before surgery, the electronic medical record system of our hospital, and data recorded during surgery. Gestational age, age, hyperemesis gravidarum, PONV history, motion sickness history, smoking history, migraine history, body mass index, gastric volume, operation time, anesthesia time, intraoperative dexamethasone, intraoperative morphine, and systolic blood pressure fall > 20% were recorded.

Statistical analysis

SPSS 26.0.0.0 and R 4.2.2 were used for statistical analysis. A total of 116 patients were divided into the training and validation groups in a 3:1 ratio using a random number table. Categorical variables are expressed as an example (%), and measurement data are expressed as mean ± standard deviation ($\bar{x} \pm s$).

Categorical variables were compared using the χ^2 test, and measurement data were compared using an independent two-tailed t test. In all analyses, statistical significance was set at $P < 0.05$. The significance of each variable in the training group in the univariate analysis was included in the multivariate logistic regression analysis model to identify the independent risk factors associated with the occurrence of PONV. The "rms" package of R, version 4.2.2, was used to construct a nomogram prediction model. Internal verification of the nomogram was carried out via the random split verification method. The ROC curve was analyzed to calculate the optimal cut-off value, which was determined by maximizing the Youden index (sensitivity + specificity− 1). The accuracy of the optimal cut-off value was evaluated for sensitivity, specificity, predictive value, and likelihood ratio, and calibration and decision curves were drawn to further supplement the accuracy, predictive efficacy, and clinical practicability of the evaluation model. Using the test data set, the nomogram and Apfel scoring models were externally verified, and the ROC, clinical decision, and clinical impact curves were used to compare the predictive performances of the two models from multiple perspectives. DeLong's test was used to compare the models in terms of significant differences in their ROC curves for each data set.

Results

Baseline characteristics

A total of 116 adult patients who underwent Cesarean section procedures met the inclusion criteria. Of these, 87 formed the training group, and 24 (27.59%) of these experienced PONV following their procedures. The validation group comprised 29 patients, with 8 (27.59%) who had developed PONV. The test set included another 29 participants, of whom 12 (41.38%) had experienced PONV (Table 1). The difference between the three groups was not statistically significant ($P > 0.05$).

Analysis of PONV risk factors

The results of the univariate analysis showed that a history of motion sickness, gastric volume, and a systolic blood pressure fall > 20% were risk factors for PONV ($P < 0.05$, Table 2).

These three variables were subsequently included in the logistic multivariate regression model, revealing that a history of motion sickness, gastric volume, and a systolic blood pressure fall > 20% were independent risk factors for PONV ($P < 0.05$; Table 3).

Establishment and evaluation of the PONV nomogram

Based on the logistic analysis results, data from the three aforementioned predictors were input into the R 4.2.2 software to construct a nomogram model for predicting PONV following a caesarean section (Fig. 2).

Efficiency evaluation of the nomogram model

Predicting Performance

The model was divided into training and internal verification sets using a 3:1 random split of the data. The AUC of the training and validation nomogram models were 0.814 (95% CI = 0.709–0.918) and 0.792 (95% CI = 0.621–0.962), respectively, indicating excellent prediction performance (Fig. 3).

The Hosmer and Lemeshow goodness-of-fit test coefficient of the nomogram model was 0.076. The best diagnostic probability, sensitivity, and specificity of the training set were 0.333, 0.792, and 0.841, respectively. The optimal diagnostic probability, sensitivity, and specificity in the validation set were 0.099, 0.875, and 0.667, respectively (Table 4).

Calibration degree

In this study, calibration curves were used to evaluate the degree of fit between the predicted probability and the actual probability of PONV occurrence in the training and validation sets, using the nomogram (Fig. 4). Its calibration curve showed that the predicted and actual probabilities were in good agreement between the training and verification sets.

Clinical decision curve analysis

DCA curve analysis showed that when the threshold probabilities of the training set and the validation set were 8.9-61.4% and 12.1-67.2%, respectively, the prediction of PONV occurrence probability after cesarean section based on the nomogram had more clinical benefits

Table 1 Participant characteristics

	Cohort			
Variable	**Training set (*n* = 87)**	**Validation set(*n* = 29)**	**Test set (*n* = 29)**	**P Value**
Age [mean ± s], y	30.26 ± 4.23	31.10 ± 3.52	30.59 ± 3.95	0.622
Gestational age [mean ± s], weeks	38.07 ± 1.13	38.52 ± 1.40	38.28 ± 1.16	0.205
BMI [mean ± s], kg/m2	26.95 ± 2.96	25.92 ± 4.11	26.57 ± 3.43	0.345
History of smoking, %				0.999
Yes	6 (6.90%)	2 (6.90%)	2 (6.90%)	
No	81 (93.10%)	27 (93.10%)	27 (93.10%)	
History of motion sickness, %				0.821
Yes	22 (25.29%)	6 (20.69%)	8 (27.59%)	
No	65 (74.71%)	23 (79.31%)	21 (72.41%)	
History of PONV, %				0.191
Yes	17 (19.54%)	2(6.90%)	7(21.14%)	
No	70 (80.46%)	27 (93.10%)	22(75.86%)	
History of migraine, %				0.571
Yes	20 (22.99%)	4 (13.79%)	6(20.69%)	
No	67 (77.01%)	25 (86.21%)	23(79.31%)	
Hyperemesis Gravidarum, %				0.721
Yes	13 (14.94%)	4 (13.79%)	6(20.69%)	
No	74 (85.06%)	25 (86.21%)	23(79.31%)	
Gastric volume [mean ± s], ml	290.21(50.92)	286.14(18.15)	287.88(55.37)	0.819
Operation time, %				0.195
≤ 60 min	58 (66.67%)	14(48.28%)	19(65.52%)	
> 60 min	29 (33.33%)	15 (51.72%)	10(34.48%)	
Anesthesia time, %				0.731
≤ 90 min	64 (73.56%)	23 (79.31%)	23(79.31%)	
> 90 min	23 (26.44%)	6 (20.69%)	6(20.69%)	
Use of morphine, %				0.175
Yes	25 (28.74%)	4 (13.79%)	5 (17.24%)	
No	62 (71.26%)	25 (86.21%)	24 (82.76%)	
Intraoperative dexamethasone, %				0.246
Yes	17 (19.54%)	9(31.03%)	4(13.79%)	
No	70 (80.46%)	20(68.97%)	25(86.21%)	
Systolic blood pressure fall > 20%, %				0.525
Yes	16 (18.39%)	3 (10.34%)	6(20.69%)	
No	71 (81.61%)	26 (89.66%)	23(79.31%)	
Postoperative nausea and vomiting, %				0.352
Yes	24 (27.59%)	8(27.59%)	12(41.38%)	
No	63 (72.41%)	21 (72.41%)	17(58.62%)	

BMI, body mass index; PONV: Postoperative Nausea and Vomiting

than that of all patients receiving targeted interventions or none receiving targeted interventions, indicating its strong clinical practicability (Fig. 5).

Clinical impact curve analysis

The clinical impact curve was used to assess the ability of the nomogram model to identify patients at high risk of developing PONV (Fig. 6).

Diagnostic efficacy comparison: nomogram model vs. Apfel model

We used clinical data from 29 adult patients who underwent Cesarean section procedures at another hospital as a test set. The test set was used to externally validate both the nomogram and Apfel models, as well as compare their levels of diagnostic efficacy.

In the test set, the AUCs of the nomogram and Apfel models were 0.779 (95% CI = 0.593–0.965) and 0.547 (95% CI = 0.350–0.745), respectively (Fig. 7). Delong's test showed that the AUC of the nomogram model was significantly higher than that of the Apfel one (Z = 2.165, $P < 0.05$). In the test set, the highest diagnostic probability, sensitivity, and specificity measurement for the nomogram model were 0.449, 0.700, and 0.842, respectively, while the corresponding scores for the Apfel model were 0.500, 0.600, and 0.526, respectively (Table 4). In the

Table 2 Univariate logistic regression analysis in the training set

Variable	β Value	OR (95% CI)	*P* Value
Age, y	-0.011	0.989(0.884–1.106)	0.849
Gestational age, weeks	0.153	1.165 (0.765–1.774)	0.476
BMI, kg/m2	0.031	1.031 (0.880–1.208)	0705
History of smoking, yes or no	-0.293	1.341(0.229–7.845)	0.745
Hyperemesis Gravidarum, yes or no	0.981	2.667(0.793–8.968)	0.113
History of motion sickness, yes or no	1.110	3.036 (1.087–8.475)	**0.034**
History of PONV, yes or no	0.780	0.458 (0.151–1.390)	0.168
History of migraine, yes or no	0.532	1.702 (0.505–5.732)	0.391
Gastric volume, ml	0.014	1.014 (1.003–1.025)	**0.012**
Operation time > 60 min, yes or no	0.749	2.115(0.801–5.588)	0.131
Anesthesia time > 90 min, yes or no	0.742	2.100(0.759–5.810)	0.153
Intraoperative dexamethasone, yes or no	-0.78	2.182 (0.719–6.620)	0.168
Use of morphine, yes or no	0.916	0.400(0.121–1.321)	0.133
Systolic blood pressure fall > 20%, yes or no	1.915	6.786 (2.109–21.838)	**0.001**

BMI, body mass index; CI, confidence interval; OR, odds ratio; PONV, postoperative nausea and vomiting

Table 3 Multivariate logistic regression analysis in the training set

Variable	β Value	OR (95% CI)	*P* Value
History of motion sickness, yes or no	1.628	5.091 (1.474–17.581)	0.010
Gastric volume, ml	0.018	1.018 (1.005–1.032)	0.009
Systolic blood pressure fall > 20%, yes or no	2.061	9.515 (2.410-37.563)	0.001

CI, confidence interval; OR, odds ratio;

test set, DCA results showed that the nomogram model had a higher benefit when the threshold probability was 14.1–62.1% and the Apfel model had a higher benefit when the threshold probability was 31.5–37% (Fig. 8).

Discussion

PONV is a common adverse reaction following surgery, including caesarean Sect. [1]. PONV not only increases the risk of other postoperative complications but also often causes discomfort to patients with nausea and vomiting, leading to reduced patient satisfaction and extended discharge time, imposing a substantial burden on patients [4].

In non-obstetric surgery, patient susceptibility to PONV is evaluated using the Apfel simplified risk score [8]. In the Apfel score, patient and anesthesia factors contribute most to the risk of vomiting. For instance, the ORs for postoperative opioid use in women were reported as 4.78 and 2.44, respectively [8]. However, in patients undergoing spinal anesthesia, these two factors generally exist by default, potentially limiting their predictive value for caesarean sections. In contrast, some maternal physiological and caesarean section-related factors may be associated with PONV risk; however, their predictive performance has not been integrated into the risk score prediction model. In addition, when evaluating the efficacy of the Apfel score, it was found that the AUC ROC of obstetric patients was 0.59, while that of non-obstetric patients was 0.753, further indicating the limited predictive performance of the Apfel score in the obstetric population [8].

To establish a specific risk prediction model for caesarean section, this study collected information on potential perioperative risk factors such as patients' basic conditions, surgical factors, anesthesia factors, and gastric ultrasound. In this study, a total of 32 patients developed PONV, accounting for 27.59% of the total sample size. Analysis of the collected data revealed that a history of motion sickness, gastric volume, and systolic blood pressure fall > 20% were independent risk factors for nausea and vomiting after caesarean section. Based on these three factors, a predictive model for nausea and vomiting after the caesarean section was established using R software and visualized as a nomogram. The model underwent verification and evaluation using the area under the ROC curve, calibration curve, DCA and CIC analysis. The model demonstrates good predictive performance and clinical application value.

Among the included indicators, a history of motion sickness has been widely confirmed to possess a high predictive value for PONV. Apfel and Koivaranta included it in their studies, constructing PONV prediction models that have found widespread use in clinical practice [8, 19]. The results highlighted that a history of motion sickness stands as an independent risk factor for PONV during caesarean section, with the incidence of PONV being 5.08 times higher in patients with this history than in those without [20]. Lee et al. further demonstrated the efficacy of prophylactic dexamethasone administration in reducing the incidence of PONV in patients with a history of motion sickness [21]. Horn et al. found that after spinal anesthesia, hypotension caused by vasodilation, whether postural hypotension or hypotension caused by other factors, can stimulate the receptors of the central nervous system to release emetic neurochemical transmitters, resulting in nausea and vomiting [22]. This is consistent with the results of the present study, illustrating that intraoperative hypotension is an independent risk factor for PONV during caesarean Sect. [22]. The use of gastric ultrasound has become increasingly prevalent in obstetric anesthesia in recent years [23, 24]. Hong et al. observed that pregnant women had larger gastric volumes than non-pregnant women, while Cozza

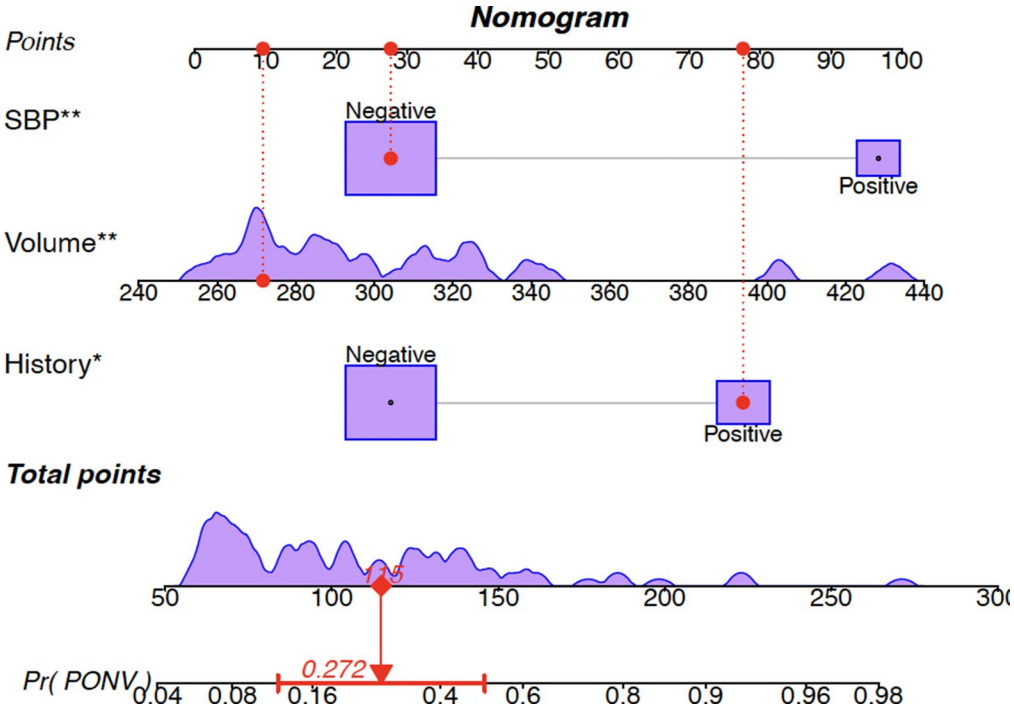

Fig. 2 A nomogram model for predicting postoperative nausea and vomiting based on gastric volume (red arrow shows a patient with a preoperative ultrasound-measured gastric volume of 270 mL, no history of motion sickness, and no hypotension during the Cesarean section procedure. The total score was 115 points, and according to the model, the probability of PONV was 0.272)

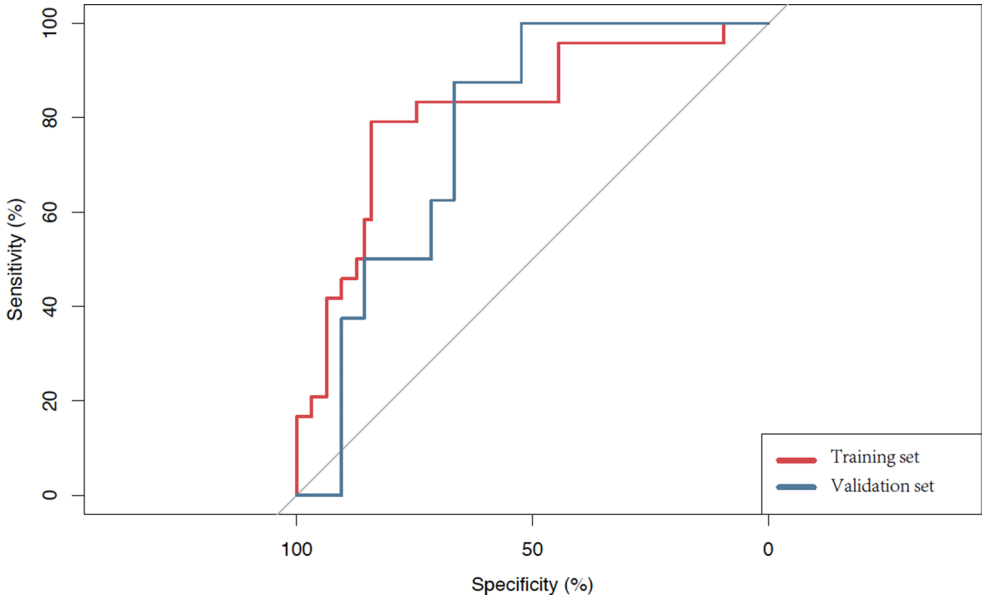

Fig. 3 ROC curve of nomogram model for training set and validation set

Table 4 Accuracy of predicting PONV using nomogram models and the Apfel score models

	Nomogram model			Apfel score
	Training set	Validation set	Test set	Test set
AUC	0.814 (0.709–0.918)	0.792 (0.621–0.962)	0.779 (0.593–0.965)	0.547 (0.350–0.745)
Cut-off probability	0.333	0.099	0.449	0.500
Youden index	0.633	0.541	0.542	0.126
Sensitivity	0.792	0.875	0.700	0.600
Specificity	0.841	0.667	0.842	0.526
Positive predictive value	0.655	0.500	0.700	0.400
Negative predictive value	0.914	0.933	0.8642	0.714
Positive likelihood ratio	4.988	2.623	4.433	1.267
Positive likelihood ratio	0.248	0.188	0.356	0.760

AUC: area under curve

et al. found that increased gastric volume corresponds to a higher incidence of PONV [25]. Hamed et al. showed that preoperative metoclopramide administration could effectively reduce the incidence of PONV by decreasing gastric volume, further substantiating these findings [11, 25, 26]. The results of this study also suggest that increased stomach volume is an independent risk factor for PONV in caesarean sections.

The nomogram and Apfel scoring models were externally verified using the test dataset, and an ROC curve was drawn to compare their levels of diagnostic efficacy for predicting PONV following Cesarean section procedures. The AUCs of the two models were 0.779 and 0.547, respectively. DCA curves for the two models show that the nomogram had a wider threshold probability range and higher clinical net return rate, further confirming its superiority for predicting PONV following Cesarean section procedures.

The nomogram prediction model constructed in this study effectively foresees the risk of PONV in caesarean sections. Internal verification shows that the model exhibits good discrimination, consistency, and clinical utility. In the era of individualized precision medicine, which is gaining increasing attention, the ability to promptly identify caesarean section patients at risk of PONV and implement targeted preventive measures, such as preoperative antiemetic drugs administration, intraoperative management of blood pressure stability, adjustment of opioid dosage, auxiliary support, and other treatment measures, is invaluable. These measures can significantly enhance postoperative recovery speed and patient satisfaction.

However, this study has some limitations. First, this was conducted at a single center with a relatively small sample size, potentially introducing selection bias. As such, further verification using larger, multicenter datasets is warranted to validate the study's results. Second, the scope of relevant factors considered in this study was limited, potentially overlooking certain risk factors associated with PONV. Follow-up studies can further expand patient data based on this study, identifying screen indicators with stronger correlations to PONV to establish a more precise prediction model. In this study, a nomogram model for predicting PONV was constructed by combining three independent risk factors identified through multivariate regression analysis. This model serves to optimize the preoperative evaluation system for caesarean sections, formulate individualized perioperative management strategies, accelerate recovery, and improve prognosis.

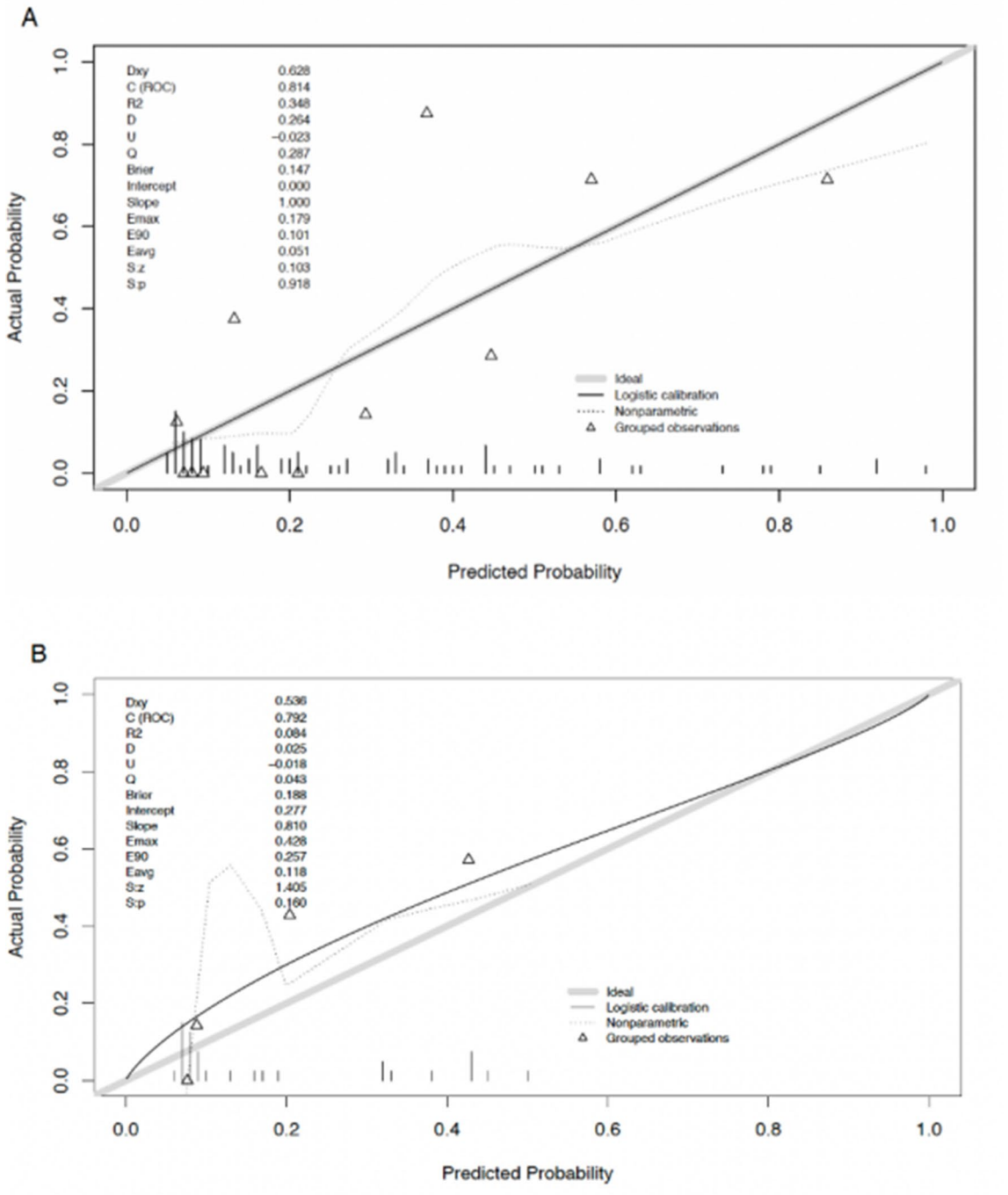

Fig. 4 (**A**) Calibration curves of the nomogram model for the training set and (**B**) validation set

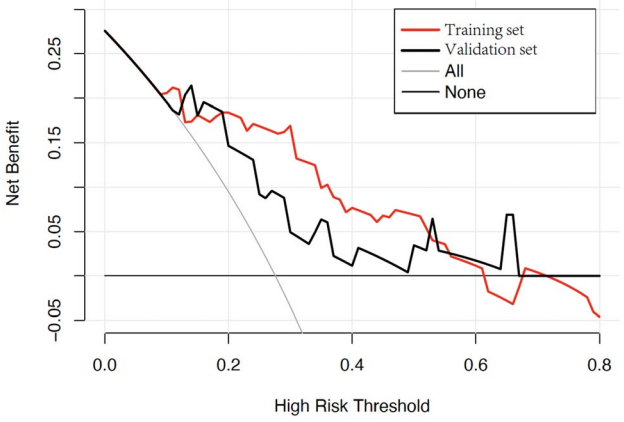

Fig. 5 DCA curves for the nomogram model in the training and validation sets with regard to predicting the occurrence of PONV in adult patients undergoing emergency Caesarian section surgeries

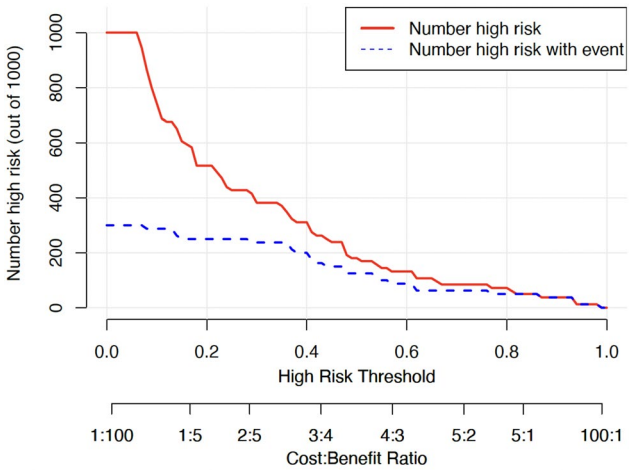

Fig. 6 The clinical impact curve for the nomogram model

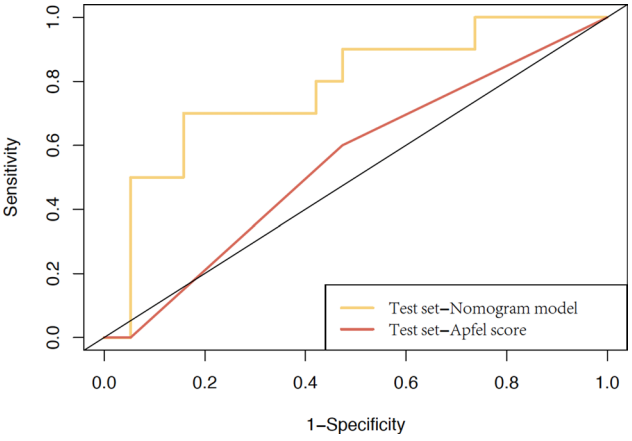

Fig. 7 Test sets were used to construct ROC curves for both the nomogram and Apfel scoring models

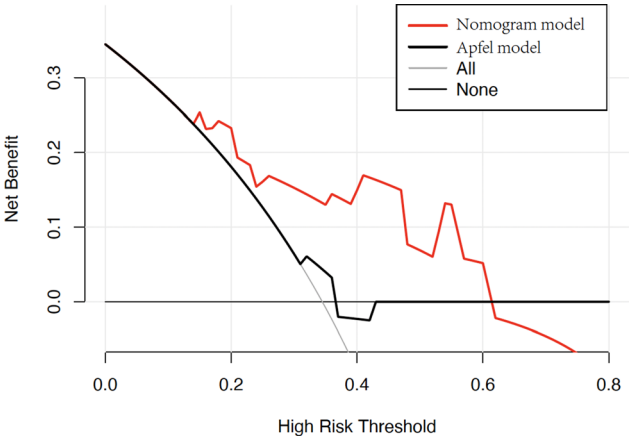

Fig. 8 Test sets were used to construct DCA curves for both the nomogram and Apfel scoring models

Conclusions

Using a multivariate logistic regression analysis, we found that a previous history of motion sickness, intraoperative hypotension, and stomach volume were independent risk factors for the development of PONV following Cesarean section procedures. We also confirmed that our nomogram model constructed using these three independent risk factors had higher levels of predictive performance and clinical practicability, and was significantly more accurate than a similarly-constructed Apfel scoring model for this application. This model may help to further optimize preoperative evaluation systems for Cesarean section procedures, develop individualized perioperative management strategies, achieve more rapid recoveries for patients undergoing Cesarean sections, and improve their prognoses.

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Author contributions
Conceptualization, Y.L. and H.Z.; methodology, Y.H., and Z.D.; software, H.Z., and Z.D.; validation, Y.L. and H.Z.; formal analysis, Y.L.; investigation, H.H.; resources, Y.L.; data curation, Y.L.; writing—original draft preparation, Y.L.; writing—review and editing, W.L.; visualization, Y.L.; supervision, W.L. All authors have read and agreed to the published version of the manuscript.

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Data availability
Data is provided within the manuscript.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of the Second Affiliated Hospital of Fujian Medical University on August 15, 2022 [No.285] and performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments. Verbal informed consent was obtained from all the participants which was approved by the Ethics Committee of the Second Affiliated Hospital of Fujian Medical University.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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