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Multivariate analysis of factors associated with the successful prediction of initial blind placement of a nasointestinal tube in the stomach based on X-ray imaging: a retrospective, single-center study

Zihao Zheng[1,2†], Jiangbo Wang[3†], Ziqiang Shao[1], Hanhui Cai[1], Lihai Lu[2], Siyu Tang[3], Shuting Xu[1], Fangxiao Gong[1], Sen Ye[1], Xianghong Yang[1] and Jingquan Liu[1*]

Abstract

Background Patients in the intensive care unit (ICU) are highly susceptible to malnutrition, and while enteral nutrition via nasogastric tube is the preferred method, there is a risk of inadvertent reflux and aspiration. Therefore, clinicians have turned to nasointestinal tubes (NET) for enteral nutrition as an alternative option. But the precise localization of NET presents an ongoing challenge. We proposed an innovative approach to provide a valuable reference for clinicians involved in NET placement.

Method Data were obtained retrospectively from the medical records of adult patients with a high risk of aspiration or gastric feeding intolerance who had a NET placed in the ICU of Zhejiang Provincial People's Hospital between October 1, 2017, and October 1, 2023. The collected data were subjected to statistical analysis using SPSS and R software.

Result There were 494 patients who met the inclusion and exclusion criteria. The first-pass success rate was 81.4% ($n = 402$). The success of a patient's initial NET placement was found to be associated with Angle SPC and Distance CP, as determined by univariate analysis (25.6 ± 16.7° vs. 41.9 ± 18.0°, $P < 0.001$; 40.0 ± 26.2 mm vs. 62.0 ± 31.8 mm, $P < 0.001$, respectively). By conducting a multivariate regression analysis, we identified a significant association between pyloric types and the success rate of placing NET (OR 29.559, 95%CI 14.084–62.038, $P < 0.001$).

Conclusion Angle SPC, Distance CP, and the type of pylorus are independently associated with successful initial placement of NET. Besides, patients with the outside type of pylorus (OP-type) exhibit a higher rate of initial placement success.

†Zihao Zheng and Jiangbo Wang contributed equally to this work.

*Correspondence:
Jingquan Liu
liujqaticu@163.com

Full list of author information is available at the end of the article

Keywords Blind placement, Nasointestinal tube, Intensive care unit, Post-pyloric feeding

Background

Patients admitted to the intensive care unit (ICU) often face a heightened vulnerability to malnutrition, stemming from underlying primary diseases, prolonged absence of enteral nutrition, and various other contributing factors. The reported incidence of malnutrition in this population has been documented to range between 40% and 50% [1–3]. Therefore, enteral nutrition or parenteral nutrition is commonly employed as a means of providing nutritional therapy for patients in clinical practice, with enteral nutrition often being the preferred modality [4, 5]. According to the European and American guidelines for enteral and parenteral nutrition, enteral nutrition is the preferred method of nutritional support for patients with normal gastrointestinal function who are unable to maintain adequate oral intake [6, 7]. Currently, nasogastric tube feeding is the preferred route for enteral nutrition [8]; however, international guidelines recommend selecting the post-pyloric feeding route for patients at high risk of aspiration or gastric feeding intolerance [9, 10] .

However, the method of evaluating the position of the nasointestinal tube (NET) after placement present an ongoing challenge for ICU physicians. Currently, there are various methods for the placement of NET, primarily categorized into blind and visualization techniques. Visualization methods encompass ultrasound [11], radiographic imaging [12], electromagnetic navigation [13], endoscopy [14], among others. On the one hand, according to the statistics from relevant studies, the current preferred method for NET placement is blind placement, with reported success rates ranging from 40–90% [15–17]. On the other hand, there are also many reports of nasointestinal/nasogastric tubes entering the airway or entering the airway through the tracheoesophageal fistula, resulting in lung injury [18–20]. The placement accuracy primarily relies on abdominal X-ray imaging, with only a few centers utilizing bedside ultrasound for localization [21]; however, the experience in this regard remains limited. Therefore, considering the specific characteristics of ICU patients, bedside abdominal X-ray imaging remains the preferred modality for localization [22].

Kurisawa K et al. employed abdominal X-ray imaging to investigate the spinal level in relation to the contour of the stomach, aiming to predict the success rate of initial placement of NET [16]. The findings of this study possess significant clinical value in the prediction of the challenges associated with blind NET placement. However, the evaluation content lacks precise quantization and the description of the stomach contour is inadequate due to significant interference from gas in abdominal X-ray imaging, which hampers accurate depiction of the shape of the stomach. Therefore, we proposed an innovative approach to identify the factors that contribute to the success of initial blind NET placement by evaluating the position of the NET in the stomach using abdominal X-ray imaging. This study aims to provide a valuable reference for clinicians involved in NET placement.

Methods

Design

This retrospective study was conducted in the ICU of Zhejiang Provincial People's Hospital, a tertiary teaching hospital located in Hangzhou, China, which boasts over 3000 beds. Consecutive subjects aged ≥ 18 years with high risk of aspiration or gastric feeding intolerance [10] who underwent blind placement of the NET in the ICU of Zhejiang Provincial People's Hospital from October 1, 2017, to October 1, 2023, were included in this study. The exclusion criteria were as follows: (1) patients whose NET could not trace the shape of the stomach; (2) Patients with a history of gastrointestinal surgery; (3) Patients who underwent unblinded initial placement of the NET (Fig. 1). This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki and received approval from the Ethics Committee of Zhejiang Provincial People's Hospital (ethics approval number: QT2023423, Date of approval: 19/12/2023). Given its retrospective nature, written informed consent was waived by the ethics committee.

Standard procedure for blind NET placement and evaluation

The NET (model NT111, specification 12) utilized in our center is manufactured by Zhejiang Jiancheng Medical Technology CO., LTD, and it belongs to the same model as Corflo NET produced by corpark company in America. The maximum scale length of the NET measures 140 cm. The outer diameter of the catheter was 3.7–4.3 mm, and the outer diameter of the feeding tube was 1.5–1.9 mm. Metoclopramide 10 mg (approval number H41021179) was routinely given intravenously to enhance gastrointestinal peristalsis before blind placement of NET [23]. The patient was positioned in a supine or slightly right-lateral decubitus position with the head of the bed elevated at an approximate angle of 30 degree (°). The clinician, who possessed expertise in blind NET placement, skillfully positioned the NET on the patient's right side. The distance from the hairline to the xiphoid process was approximately equivalent to the distance from the nose to the stomach prior to placement of the

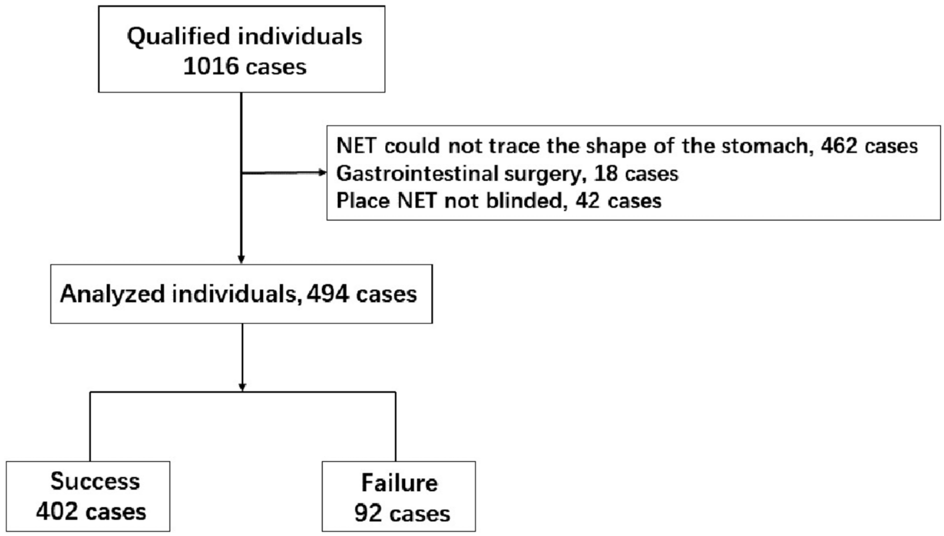

Fig. 1 Study flowchart. NET, nasointestinal tube

NET. When positioned at a predetermined distance, an air volume of 5–10 ml was forcefully introduced into the tube, and the presence of the NET in the stomach was confirmed by auscultation of gas above the gastric region. Then, the NET gradually advances by a few centimeters. The advancement of the tube was confirmed by releasing the hand after each propulsion and ensuring its stable positioning. In case of any resistance encountered during forward movement, a slight retraction of approximately 5 cm should be made, followed by readjustment and subsequent forward propulsion. The standardized procedure implemented at our center was derived from previously published protocols, with minor adjustments made to enhance its applicability and efficacy [22, 24].

Subsequently, an abdominal X-ray was performed by the radiologist at the patient's bedside, and both the radiologist and ICU physician evaluated the results, including documenting the position of the NET needle tip in the medical record. The timing for initiation of enteral nutrition via the NET following successful placement was unanimously determined by the medical team.

Definition

Line a indicates the cardia level line. Line b indicates the pylorus superior margin level line. Line c indicates the lowest point of the edge of stomach level line. The lines a, b, and c are all perpendicular to the spinal line. The Angle cardia-pylorus-line a (Angle CPA) was defined as the angle formed by the line connecting the cardia to the upper edge of the pylorus and line a. The Angle stomach-pylorus-line c (Angle SPC) was defined as the angle formed by the line connecting the lowest point of the lower edge of the stomach with the upper edge of the pylorus and line c. Distance line c-pylorus (Distance CP) was defined as the distance from the superior margin of the pylorus to line c (Fig. 2). The outside of the pylorus type (OP-type) was defined as NET distances from the body's center upon traversing through the pylorus. The inside of the pylorus type (IP-type) was defined as NET comes into close with the central region of the body upon traversing through the pylorus (Fig. 3). The measurement of intra-abdominal pressure (IAP) was conducted indirectly through the assessment of intravesical pressure.

Data acquisition

Baseline patient data were collected from the electronic medical record system, encompassing demographic information (age, gender), clinical parameters (body mass index [BMI], respiratory support method, serum albumin, lactic acid), ICU severity scores (Apache II score, SOFA score, NRS-2002 score), gastric residual volume, intra-abdominal pressure (IAP), administration of sedative and analgesic drugs, utilization of vasoactive agents and continuous renal replacement therapy (CRRT), duration between ICU admission and initiation of enteral nutrition (via nasogastric tube or NET), as well as time from NET placement to start of post-pyloric feeding. The experimental data were acquired through images of the electronic medical record system, encompassing Angle CPA, Angle SPC, and Distance CP. The angle and distance measurements were conducted by two ICU doctors who had received standardized image recognition training, and the final result was determined as the average of the measurement outcomes from both sides.

Outcome

The primary outcome examined the association between the success rate of initial NET placement and the Angle

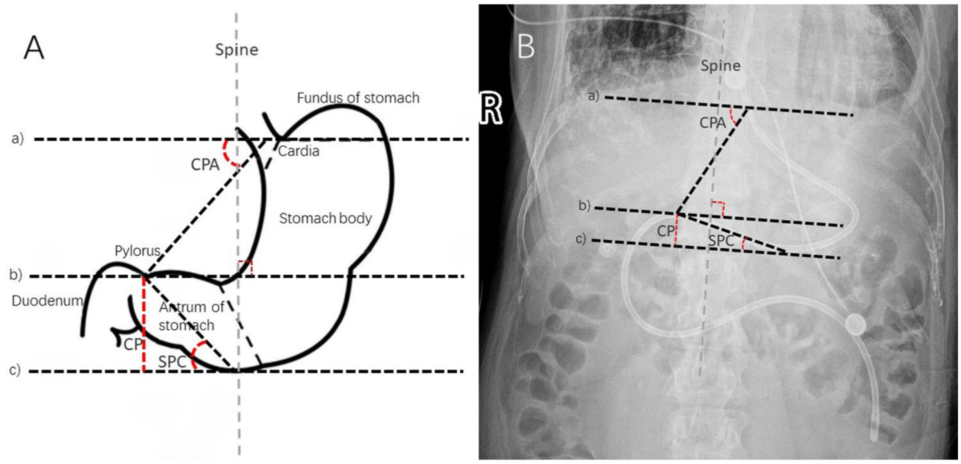

Fig. 2 Model draw of the stomach shape and the nasointestinal tube intragastric course under X-ray imaging. **(A-B)** Line **(a)** indicates the cardia level line. Line **(b)** indicates the pylorus superior margin level line. Line **(c)** indicates the lowest point of the edge of stomach level line. The lines **(a)**, **(b)**, and **(c)** are all perpendicular to the spinal line. The Angle cardia-pylorus-line a (Angle CPA) was defined as the angle formed by the line connecting the cardia to the upper edge of the pylorus and line **(a)**. The Angle stomach-pylorus-line c (Angle SPC) was defined as the angle formed by the line connecting the lowest point of the lower edge of the stomach with the upper edge of the pylorus and line **(c)**. Distance line c-pylorus (Distance CP) was defined as the distance from the superior margin of the pylorus to line **(c)**

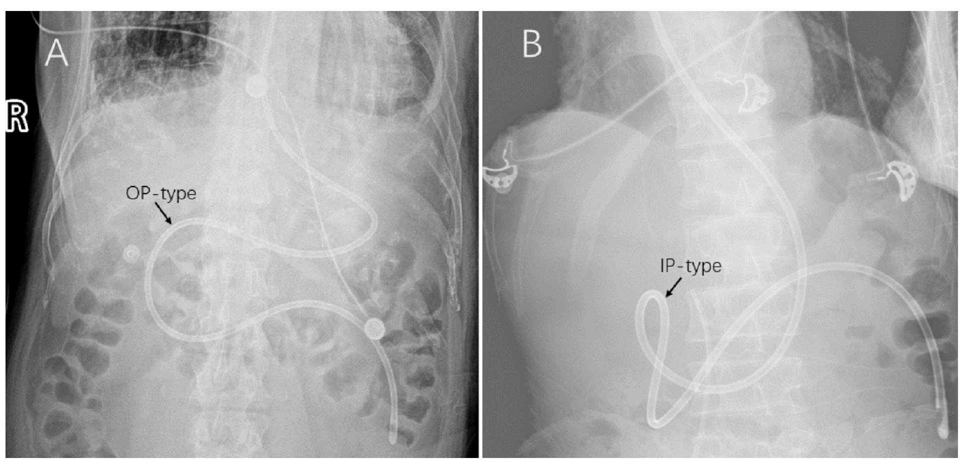

Fig. 3 The type of pylorus. **(A-B)** OP-type, the outside type of pylorus. IP-type, the inside type of pylorus

SPC. The secondary outcome measure examined the association between Angle CPA, Distance CP, pyloric type and the success rate of NET placement. The initial assessment of successful placement after the first abdominal X-ray imaging on NET involves determining the accurate positioning through the pylorus, followed by precise measurement of both angle and distance. If the determination of success or failure proved challenging, it was synthetically ascertained by the two researchers involved in the study, who relied on supplementary information such as the description of NET tip location in the medical record.

Statistical analyses

The data were analyzed using IBM SPSS Statistics v.25.0 (IBM Corp., Armonk, NY, USA). The data were presented as mean ± standard deviation or median (quartile) based on the results of a normality test. Unpaired t-tests, Mann-Whitney U tests, or Fisher's exact tests were employed as appropriate for univariate analyses of patient characteristics between the success and failure groups. A nomogram was developed using R software v.4.3.1 to predict the initial success rate of placement, aiming to facilitate doctors in comprehending and implementing the predictive model. The Receiver Operating Characteristic curve (ROC) was utilized to determine the optimal threshold for the angle and distance of abdominal X-ray imaging in predicting the success of the initial placement. The cut-off value was determined based on the Youden index. The variables with a significance level of $P<0.1$ in the univariate analysis were included in the multivariate regression model for further investigation. According to the P values < 0.05, the difference was statistically significant (two-tailed).

Result

A total of 1016 patients were enrolled in this study, with exclusion criteria applied to 522 patients (including 462 patients whose NET could not trace the shape of the stomach, 18 patients with a history of gastrointestinal surgery and 42 patients with an unblinded placement). The basic characteristics of the patients are presented in Table 1, indicating a median age and BMI of 72 (58–81) years and 22.2 (19.8–24.4) kg/m^2, respectively. The male patients accounted for 62.1% of the total population. Mechanical ventilation was administered to 395 patients, while High-Flow oxygen therapy was provided to 75 patients. In terms of nutritional status, the mean serum albumin level was 31.0 ± 6.9 g/dL and the median NRS-2002 score was 4 (3–5). The median Apache II score and SOFA score were 21 (16–26) and 8 (6–10), respectively. The initial success rate of NET placement was 81.4% (*n* = 402). The median placement depth reached 110 (105–110) cm.

Among the failure patients, 22 cases (23.9%) received CRRT, which demonstrated a statistically significant difference compared to the success group in terms of NET placement (*P* = 0.041). Regarding the outcome indicators, Angle SPC exhibited an average of 25.6 ± 16.7° and 41.9 ± 18.0° in successful and unsuccessful patients,

Table 1 Patient characteristics and results of the univariate analysis

Characteristic	Overall (*n* = 494)	Success (*n* = 402)	Failure (*n* = 92)	*P*-value
Age (years)	72 (58–81)	72 (59–81)	70 (57–80)	0.460
Sex, n (%)				0.905
Male	307 (62.1)	249 (61.9)	58 (63.0)	
Female	184 (37.9)	153 (38.1)	34 (37.0)	
Body mass index (kg/m^2)	22.2 (19.8–24.4)	22.5 (19.8–24.8)	21.2 (11.0-26.6)	0.129
Clinical presentation, n (%)				
Sepsis	33 (6.7)	25 (6.2)	8 (8.7)	0.486
Septic shock	17 (3.4)	13 (3.2)	4 (4.3)	0.751
Severe pneumonia	79 (16.0)	65 (16.2)	14 (15.2)	0.876
Hypertension	174 (35.2)	144 (35.8)	30 (32.6)	0.629
Diabetes	76 (15.4)	64 (15.9)	12 (13.0)	0.527
Respiratory support way, n (%)				0.804
Mechanical ventilation	395 (80.0)	320 (79.6)	75 (81.5)	
High-Flow oxygen therapy	75 (15.2)	63 (15.7)	12 (13.0)	
Others	24 (4.9)	19 (4.7)	5 (5.4)	
Serum albumin (g/dL)	31.0 ± 6.9	30.6 ± 6.2	32.7 ± 9.0	0.042
Serum lactate (mmol/L)	1.7 ± 1.2	1.7 ± 1.2	1.8 ± 1.0	0.764
Use of sedatives, n (%)	361 (73.1)	293 (72.9)	68 (73.9)	0.897
Use of a vasopressor, n (%)	172 (34.8)	138 (34.3)	34 (37.0)	0.716
Renal replacement therapy, n (%)	81 (16.4)	59 (14.7)	22 (23.9)	0.041
Apache II score	21 (16–26)	21 (16–26)	21 (15–25)	0.430
SOFA score	8 (6–10)	8 (6–10)	7 (5–10)	0.256
NRS-2002 score	4 (3–5)	4 (3–5)	4 (3–5)	0.126
Gastric drainage volume (mL)	0.0 (0.0–70.0)	0.0 (0.0–50.0)	0.0 (0.0-100.0)	0.141
Intra-abdominal pressure (cmH_2O)	9.1 ± 2.2	9.0 ± 2.2	9.3 ± 1.9	0.265
NET placement depth (cm)	110 (105–110)	110 (105–110)	110 (105–110)	0.385
Time from ICU admission to the start of enteral feeding (days)	1 (0–2)	1 (0–2)	1 (0–2)	0.736
Time from NET placement to the start of post-pyloric feeding (days)	1.0 (0.0–1.0)	0.0 (0.0–1.0)	2.0 (1.0-2.8)	< 0.001
Outcomes				
Angle CPA (°)	49.2 ± 13.1	49.0 ± 12.4	50.3 ± 15.9	0.457
Angle SPC (°)	28.7 ± 18.1	25.6 ± 16.7	41.9 ± 18.0	< 0.001
Distance CP (mm)	44.0 ± 28.6	40.0 ± 26.2	62.0 ± 31.8	< 0.001
Type of pylorus, n (%)				< 0.001
IP-type	111 (22.5)	36 (9.0)	75 (81.5)	
OP-type	383 (77.5)	366 (91.0)	17 (18.5)	

Apache, Acute Physiology and Chronic Health Evaluation; SOFA, Sequential Organ Failure Assessment; NRS, Nutritional Risk Screening; NET, nasointestinal tube; ICU, Intensive care unit; OP-type, the outside type of pylorus. IP-type, the inside type of pylorus; Angle CPA, Angle cardia-pylorus-line a; Angle SPC, Angle stomach-pylorus-line c; Distance CP, Distance line c-pylorus (the definitions of angles and distance are shown in Fig. 2)

Table 2 Multivariate analysis of the initial success rate of NET placement

Variable	Odds ratio	95%CI	*P*-value
Serum albumin (each 1- g/dL increment)	1.025	0.985–1.068	0.227
Renal replacement therapy	0.495	0.209–1.173	0.110
Angle SPC (each 1-° increment)	1.007	0.970–1.044	0.729
Distance CP (each 1-mm increment)	1.012	0.990–1.035	0.275
Type of pylorus	29.559	14.084–62.038	< 0.001
Time from NET placement to the start of post-pyloric feeding (each 1-day increment)	2.250	1.663–3.043	< 0.001

Factors with an odds ratio > 1.0 are associated with successful NET placement. CI, confidence interval. NRS, Nutritional Risk Screening; NET, nasointestinal tube; Angle SPC, Angle stomach-pylorus-line c; Distance CP, Distance line c-pylorus (the definitions of both are shown in Fig. 2)

Table 3 Patient characteristics of different type of pylorus

Characteristic	Overall (*n* = 494)	OP-type (*n* = 383)	IP-type (*n* = 111)	*P*-value
Male, n (%)	307 (62.1)	247 (64.5)	60 (54.1)	0.059
Age (years)	72.0 (58.0–81.0)	72.0 (59.0–81.0)	72.0 (57.0–81.0)	0.987
Body mass index (kg/m^2)	22.2 (19.8–24.4)	22.5 (20.0-24.8)	21.5 (19.5–24.1)	0.037
Respiratory support way, n (%)				0.910
Mechanical ventilation	395 (80.0)	306 (79.9)	89 (80.2)	
High-Flow oxygen therapy	75 (15.2)	59 (15.4)	16 (14.4)	
Others	24 (4.9)	18 (4.7)	6 (5.4)	
Serum albumin (g/dL)	30.3 (27.5–33.0)	30.4 (27.6–32.9)	30.3 (27.3–34.9)	0.892
Serum lactate (mmol/L)	1.4 (1.0-2.1)	1.4 (1.0-2.1)	1.5 (1.1–2.2)	0.184
Use of sedatives, n (%)	361 (73.1)	280 (73.1)	81 (73.0)	1.000
Use of a vasopressor, n (%)	172 (34.8)	135 (35.2)	37 (33.3)	0.736
Renal replacement therapy, n (%)	81 (16.4)	59 (15.4)	22 (19.8)	0.308
Gastric drainage volume (mL)	0.0 (0.0–70.0)	0.0 (0.0–50.0)	0.0 (0.0-100.0)	0.235
Intra-abdominal pressure (cmH_2O)	9.1 ± 2.2	9.1 ± 2.2	9.2 ± 2.1	0.750
Apache II score	21.0 (16.0–26.0)	21.0 (16.0–26.0)	22.0 (17.0–26.0)	0.916
SOFA score	8.0 (6.0–10.0)	8.0 (6.0–10.0)	8.0 (5.0–10.0)	0.222
NRS-2002 score	4.0 (3.0–5.0)	4.0 (3.0–5.0)	4.0 (4.0–5.0)	0.006
NET placement depth (cm)	110 (105–110)	110 (105–110)	110 (105–110)	0.348
Time from ICU admission to the start of enteral feeding (days)	1.0 (0.0–2.0)	1.0 (1.0–2.0)	1.0 (0.0–2.0)	0.390
Time from NET placement to the start of post-pyloric feeding (days)	1.0 (0.0–1.0)	0.0 (0.0–1.0)	1.0 (0.9-2.0)	< 0.001
Angle CPA (°)	49.2 ± 13.1	49.4 ± 12.3	48.5 ± 15.5	0.390
Angle SPC (°)	24.5(14.0–41.0)	21.0 (12.0–35.0)	45.0 (30.0–54.0)	< 0.001
Distance CP (mm)	38.2 (20.7–63.2)	33.1 (18.9–58.3)	59.3 (35.0-86.2)	< 0.001

BMI, body mass index; Apache, Acute Physiology and Chronic Health Evaluation; SOFA, Sequential Organ Failure Assessment; NRS, Nutritional Risk Screening; NET, nasointestinal tube; ICU, Intensive care unit; OP-type, the outside type of pylorus. IP-type, the inside type of pylorus; Angle CPA, Angle cardia-pylorus-line a; Angle SPC, Angle stomach-pylorus-line c; Distance CP, Distance line c-pylorus (the definitions of angles and distance are shown in Fig. 2)

respectively ($P<0.001$). Similarly, Distance CP demonstrated an average of 40.0 ± 26.2 mm and 62.0 ± 31.8 mm in successful and unsuccessful patients, respectively ($P<0.001$). The type of pylorus exhibited a statistically significant difference ($P<0.001$), with 383 cases (77.5%) demonstrating an OP-type during the initial successful NET placement.

Multivariate analysis of six indicators with $P<0.1$ in univariate analysis such as albumin and the type of pylorus showed that IP-type patients had a higher failure rate of NET placement (OR 29.559, 95%CI 14.084–62.038, $P<0.001$), indicating a substantial 28.6-fold increase. The duration of post-pyloric feeding was significantly prolonged in patients with initial NET placement failure (OR 2.25, 95% CI 1.663–3.043, $P<0.001$). Although variables such as Distance CP and CRRT exhibit a certain correlation with the success rate of placement, the statistical findings do not yield significant differences (Table 2).

The univariate analysis of pyloric types revealed that there were 383 patients with an OP-type, while the BMI of patients with an IP-type was significantly lower compared to those with an OP-type ($P=0.037$) (Table 3). In patients with different type of pylorus, the median Angle SPC was found to be 21.0 (12.0–35.0) ° for the OP-type and 45.0 (30.0–54.0) ° for the IP-type, showing a statistically significant difference between them ($P<0.001$). Similarly, the median Distance CP differed significantly between the two groups, measuring at 33.1 (18.9–58.3) mm for the OP-type and at 59.3 (35.0–86.2) mm for the IP-type ($P<0.001$).

Multivariate analysis of six indicators with $P<0.1$ in univariate analysis such as sex and Angle SPC showed

Table 4 Multivariate analysis of the type of pylorus

Variable	Odds ratio	95%CI	*P*-value
Sex	1.363	0.815–2.278	0.238
Body mass index (each 1- kg/m^2 increment)	0.996	0.932–1.064	0.907
NRS-2002 score (each 1- increment)	1.163	0.959–1.410	0.125
Time from NET placement to the start of post-pyloric feeding (each 1-day increment)	1.840	0.1.473–2.298	< 0.001
Angle SPC (each 1-° increment)	1.075	1.046–1.105	< 0.001
Distance CP (each 1-mm increment)	0.983	0.967-1.000	0.052

Factors with an odds ratio > 1.0 are associated with the inside type of pylorus. CI, confidence interval. NRS, Nutritional Risk Screening; NET, nasointestinal tube; Angle SPC, Angle stomach-pylorus-line c; Distance CP, Distance line c-pylorus (the definitions of both are shown in Fig. 2)

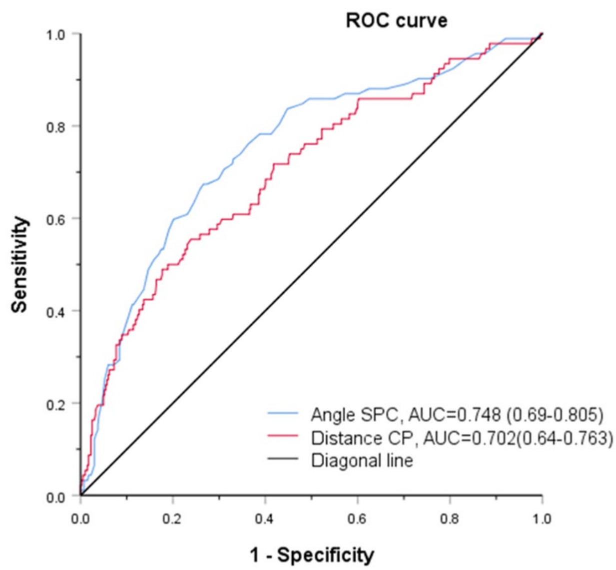

Fig. 4 Receiver operating characteristic curve (ROC) of the Angle SPC and Distance CP in predicting the failure of nasointestinal tube placement. Angle SPC, Angle stomach-pylorus-line c; Distance CP, Distance line c-pylorus (the definitions of both are shown in Fig. 2)

that patients with the bigger degree are associated with the pylorus type transition, from OP-type to IP-type (OR 1.075, 95%CI 1.046–1.105, $P<0.001$) (Table 4).

The cut-off values of Angle SPC and Distance CP to predict the failure of the first NET placement were 35.5° (sensitivity 0.674, specificity 0.734) and 59.6 mm (sensitivity 0.554, specificity 0.761). The AUC was 0.748 (0.690–0.805) and 0.702 (0.640–0.763), respectively (Fig. 4).

Based on the aforementioned results, a total of 6 variables were selected for multivariate analysis, including, serum albumin, CRRT, etc. These variables were incorporated into the final model to construct a nomogram that predicts the success rate of first placement. Additionally, a calibration curve was included in this model (Fig. 5). The model demonstrates a high level of predictive efficacy in determining the success of NET placements (R^2 0.640, C-index 0.943).

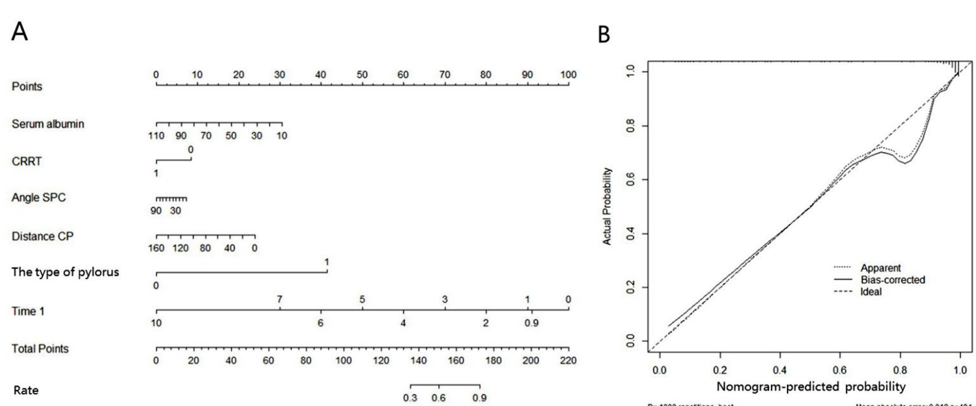

Fig. 5 Constructed nomogram and performance of the model for predicting NET success rate of placement. (**A**) Nomogram according to clinical indices for predicting NET success rate of placement. The nomogram is used by adding up points identified on the points scale for each variable. The points of the six predictors should be added to calculate the total points. The straight edge should be aligned to the "total points," and the predicted value would be visible on the last line. (**B**) Calibration curve of nomogram in the training cohort. The x-axis is the predicted probability from the nomogram, and the y-axis is the actual probability. The dashed line represents performance of the ideal nomogram (predicted outcome perfectly corresponds with actual outcome). The dotted line represents the apparent accuracy of our nomogram without correction. The solid line represents bootstrap-corrected performance of our nomogram. CRRT, continuous renal replacement therapy, 1 means yes, 0 means no; The type of pylorus, 1 means OP-type, 0 means IP-type; Time 1, the time from nasointestinal tube placement to the start post-pyloric feeding; Angle SPC, Angle stomach-pylorus-line c; Distance CP, Distance line c-pylorus (the definitions of both are shown in Fig. 2)

Discussion

Our research demonstrates that in ICU patients, the success rate of blinded placed NET for the first time is associated with the size of Angle SPC, Distance CP, and pyloric types. Furthermore, multifactor analysis reveals a significant increase in difficulty of NET placement with the change in pyloric type (from OP-type to IP-type).

A study conducted by Kurisawa K et al. demonstrated the success of NET placement correlated with the stomach and spinal level in X-ray imaging, with spinal level L1-L2 identified as the critical position [16]. The recent study conducted by the same research group demonstrated that, according to computed tomography imaging, the optimal cutoff point for gastric large curvature to predict first attempt failure was found caudal to spine L2-L3 [17]. Both of findings aligns with our own investigation closely, which also explored the association between gastric contour and the success rate of initial NET placement under imaging. However, our study offers several advantages compared to the study conducted by Kurisawa K et al. On the one hand, while X-ray imaging may not clearly display the shape of the stomach, we are able to approximate it by tracing the shape of the NET within the stomach. This approach provides a more accurate representation of the stomach's shape. On the other hand, we conducted a quantitative evaluation of the angle and distance, which provided more detailed information compared to spinal level assessment. Additionally, by employing ROC curve analysis, we established cut-off values for the angle and distance that significantly influenced the success rate of initial NET placement. Our study does not provide a prediction for the success rate of initial blinded placement in patients who have not undergone NET placement or abdominal X-ray imaging; however, it is important to consider the following points. Firstly, patients with a larger gastric curvature (Angle SPC) are more prone to retention in the stomach during NET placement, whereas patients with a lower curvature exhibit a smoother trajectory and are more likely to pass through the pylorus. Secondly, regarding the classification of stomach shape, it encompasses four types: horn, hook, weak and waterfall [25]. The weak-type stomach has a low position and tension. The upper stomach cavity is narrow and wide like a water bag, while the lower part of the stomach is often below the level of the iliac crest [25]. This anatomical arrangement contributes to an increased curvature of the stomach, thereby posing challenges for NET placement. Based on the cut-off value obtained from the ROC curve, we observed that placement failure rates were significantly higher for Angle SPC > 35.5° and Distance CP > 59.6 mm. Consequently, blind placement of NET is not recommended; instead, visualization techniques such as endoscopy and ultrasound should be employed due to documented complications like pneumothorax and gastric perforation [26, 27] associated with blind NET placement. Repeated blind placement in the same patient inevitably escalates the likelihood of complications.

The success rate of blinded NET placement has been reported to range from 40 to 90% in previous studies [15–17], with an overall success rate of 81.4% observed after screening at our center. In addition, we propose for the first time that the success rate of placement is largely related to the type of pylorus. After screening, 366 patients (91%) were successfully classified as having the OP-type, while 75 patients (81.5%) failed to place successfully and were categorized as having the IP-type, with a statistically significant difference ($P < 0.001$). In addition, a subgroup analysis was conducted based on pylorus type, revealing that Angle SPC ($P < 0.001$) and Distance CP ($P < 0.001$) emerged as the two primary independent factors. Yamamichi N et al. [28]. investigated the correlation between satiety and gastroduodenal shape using gastric barium radiography. They categorized the gastroduodenal shape into four forms: V type (in the stomach), V-H type (in the proximal half of the duodenal bulbs), H-V type (in the distal half of the duodenal bulbs), and H type (in the descending part of the duodenum). According to the barium radiography, the position of the duodenal bulb is superior to that of the pylorus, and its medial displacement predisposes to barium retention. This observation closely aligns with our investigation on different type of pylorus. Anatomically [29], it can be observed that the duodenum typically originates on the right side of the pylorus (OP-type), aligning with the normal anatomical position of the human body, thereby facilitating smoother placement of the NET. Conversely, at the IP-type, there is a tendency for the initial part of the duodenum to incline towards the medial side of the body. The larger values for Angle SPC and Distance CP indicate an increased likelihood for this inclination towards the medial side, resulting in greater navigational challenges and a higher rate of placement failure for NET. Through multifactor analysis, we have found consistent evidence supporting the relationship between increased angle and transition of pylorus from the outside type to the inside type. Moreover, with the transition of pylorus from the outside type to the inside type, the failure rate of NET placement increases.

The residual stomach and IAP may emerge as two prominent factors influencing the success rate of NET placement for the first time. However, it is worth noting that our findings did not yield statistically significant results, with P values of 0.141 and 0.265, respectively. The acute gastrointestinal dysfunction resulting from elevated IAP is a prevalent clinical manifestation observed in critically ill patients within the ICU [30]. Furthermore, mechanical ventilation, commonly employed among ICU patients, exacerbates IAP elevation and subsequently intensifies gastrointestinal dysfunction [30, 31]. The clinical manifestations of patients, such as delayed gastric emptying, gastroesophageal reflux, vomiting, and abdominal distension [31–33], exert an impact on the process of NET placement to a certain extent. This influence includes reducing the success rate of blind NET placement and delaying the initiation time of enteral nutrition. As shown in our study, patients with placement failure had a significantly longer time to start post-pyloric feeding via NET ($P<0.001$).

However, it is important to note that in assessing gastric shape, we conducted a rough evaluation of the position of the cardia, body, greater curvature, and antrum based on the X-ray NET's shape after placement in the stomach. This allowed us to measure angles and distances; however, it should be acknowledged that these measurements may differ from the actual gastric shape [29]. But the trajectory of NET in the stomach reflects the contour of the stomach based on the direction of force transmission in an ideal scenario. Our study holds significant value for the subsequent expansion of ultrasound-guided NET placement [21]. Although ultrasound may not offer the same level of precision in locating and visualizing NET implantation as endoscopy, utilizing routine ultrasound enables us to identify the cardia, pylorus, the lowest point of the stomach, and duodenum on its surface [21, 34]. Furthermore, by measuring angle and distance, we can proactively predict the challenges associated with NET placement. Moreover, contrast-enhanced ultrasound serves as an additional modality for evaluating gastric contour [35]. The administration of oral contrast agent enhances the visualization of gastrointestinal contour during ultrasound examination, enabling clinicians to identify early signs of difficult blind placement in patients, select appropriate nutritional methods, and prevent nutrition-related complications.

Our study has several limitations. Firstly, due to the retrospective nature of this study, we were unable to account for potential confounding factors that remain unknown. Secondly, we did not have a secondary validation of the placement results. Experienced clinicians only evaluate the success of placement by abdominal X-ray imaging, but lack abdominal computed tomography and endoscopic direct vision to verify. Thirdly, the determination of the cardia, the lowest point of the stomach, and the pylorus position was obtained through abdominal X-ray imaging. However, it is important to note that there may be discrepancies between these measurements and their actual anatomical positions. Although our study exhibits a temporal delay in investigating the success rate of NET placement, it offers a valuable reference for subsequent utilization of ultrasound to assess the complexity of NET placement.

Conclusion

Angle SPC, Distance CP, and the type of pylorus are independently associated with successful initial placement of NET. Besides, patients with the OP-type exhibit a higher rate of initial placement success.

Abbreviations

ICU	Intensive care unit
NET	Nasointestinal tube
IAP	Intra-abdominal pressure
BMI	Body mass index
Apache	Acute Physiology and Chronic Health Evaluation
SOFA	Sequential Organ Failure Assessment
NRS	Nutritional Risk Screening
CRRT	Continuous renal replacement therapy
Angle CPA	Angle cardia-pylorus-line a
Angle SPC	Angle stomach-pylorus-line c
Distance CP	Distance line c-pylorus
ROC	Receiver operator characteristic

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Author contributions

Z.Zheng and J.Wang: Data curation; Formal analysis; Investigation; Methodology; Validation; Writing—original draft. L.Lu, S.Xu, F.Gong and S.Tang: Data curation; Formal analysis; Writing—review & editing. Z.Shao, H.Cai, X.Yang and J.Liu: Investigation; Methodology; Resources; Supervision; Validation; Writing—review & editing. J.Liu and S.Ye: Project administration; Resources; Supervision; Writing—review & editing. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board and the Ethics Committee of the of Zhejiang Provincial People's Hospital, which complies with the Declaration of Helsinki (ethics approval number: QT2023423, Date of approval: 19/12/2023). And individual consent for this retrospective analysis was waived.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Emergency and Critical Care Center, Intensive Care Unit, Affiliated People's Hospital, Zhejiang Provincial People's Hospital, Hangzhou Medical College, No. 158 Shangtang Road, Gongshu District, Hangzhou 310014, Zhejiang Province, China
[2]The Fourth School of Clinical Medicine, Zhejiang Chinese Medical University, Hangzhou 310053, Zhejiang Province, China
[3]The Second School of Clinical Medicine, Zhejiang Chinese Medical University, Hangzhou 310053, Zhejiang Province, China

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