Prospective Clinical Research Report

Efficacy and safety of a modified method for blind bedside placement of post-pyloric feeding tube: a prospective preliminary clinical trial

Xiong Bing¹, Tang Yinshan¹, Jin Ying¹ and Shen Yingchuan²

Abstract

Objective: To compare the efficacy and safety of a new modified method of bedside post-pyloric feeding tube catheterization with the Corpak protocol versus electromagnetic-guided catheterization.

Materials and Methods: We conducted a single-center, single-blinded, prospective clinical trial. Sixty-three patients were treated with a non-gravity type gastrointestinal feeding tube using different procedures: modified bedside post-pyloric feeding tube placement (M group), the conventional Corpak protocol (C group), and standard electromagnetic-guided tube placement (EM group).

Results: The success rate in the M group, C group, and EM group was 82.9% (34/41), 70.7% (29/41), and 88.2% (15/17), respectively, with significant differences among the groups. The time required to pass the pylorus was significantly shorter in the M group (26.9 minutes) than in the C group (31.9 minutes) and EM group (42.1 minutes). The proportion of pylorus-passing operations completed within 30 minutes was significantly higher in the M group than in the C group and EM group. No severe complications occurred.

Conclusion: This modified method of bedside post-pyloric feeding tube catheterization significantly shortened the time required to pass the pylorus with no severe adverse reactions.

¹Department of Rehabilitation, The Second Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, Zhejiang, PR China
²Department of Radiology, The Second Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, Zhejiang, PR China

Corresponding author:
Xiong Bing, Department of Rehabilitation, The Second Affiliated Hospital, School of Medicine, Zhejiang University, No. 1511 Jianghong Road, Hangzhou City, Zhejiang Province 310009, PR China.
Email: 2202030@zju.edu.cn
This method is effective and safe for enteral nutrition catheterization of patients with dysphagia and a high risk of aspiration pneumonia.

Keywords
Nutritional support, catheterization, post-pyloric feeding tube, dysphagia, adverse reaction, enteral nutrition

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Introduction
Nutritional support is an important component of care for critically ill patients and patients with dysphagia. Malnutrition directly affects morbidity, mortality, the length of stay, and hospitalization costs. The gastric tube and intestinal tube are the most widely used enteral nutrition routes in the clinical setting. Previous studies have suggested that in patients with complete gastrointestinal function, enteral nutrition should be established as soon as possible to ensure a sufficient caloric supply. Enteral feeding is also considered to be patients’ preferred route. Compared with parenteral nutrition, enteral feeding is associated with fewer metabolic and septic complications. In addition, enteral feeding promotes the local immune function of the gut. However, for patients with gastric dysfunction, gastroesophageal reflux, hiccups, gastroparesis, vomiting, pyloric stenosis, and other gastric dysfunctions or consciousness and cognitive disorders, enteral nutrition through a gastric tube may significantly increase the risk of pneumonia and the difficulty or cost of treatment.

Post-pyloric feeding is an important and promising alternative to enteral and parenteral nutrition because it can significantly reduce the occurrence of pneumonia caused by reflux, thereby improving the success rate of treatment. However, the success rate of post-pyloric feeding is low and is largely affected by the operator’s technique and degree of expertise. Traditional tube placement requires the use of endoscopic or radiographic technology. During this operation, which requires the assistance of a specialist, the patient must be transferred from the ward to the endoscopic center or radiology department. Therefore, it is very likely that patients are unable to benefit from timely enteral nutrition support because of the limitations of hospital resources (especially primary medical institutions, which do not have endoscopy and radiographic examination capabilities). In addition, the transfer of critically ill patients to relevant departments to implement tube placement operations may increase unexpected risks and costs.

At present, blind bedside post-pyloric feeding tube catheterization is the main technique used in the clinical setting. The National Health Service (NHS) of the United Kingdom reported 95 cases of tube position errors within 5 years (2011–2016), and more than 3 million tubes were used in the NHS during that period. Although the error rate is low, tube malpositioning can result in serious and life-threatening consequences. X-ray examination is the gold standard technique for judging the placement of the tube; however, children and pregnant women may be at risk of excessive exposure to radiation with this approach. One study showed that among 748 critically ill patients, the nasojejunal nutritional tube was inserted into the respiratory tract in
14 patients, accounting for only 2% of the total patients. Because of the low incidence of such errors, bedside tube placement methods that do not rely on X-ray examination have been recommended. Various bedside blind post-pyloric feeding tube placement techniques not only allow the tip of the tube to cross the pylorus but also allow the operator to effectively determine the position of the catheter. The success rate of catheterization using such techniques ranges from 32% to 96%. Such wide variation might be explained by the lack of a standardized protocol of tube placement, and some methods may require the use of gastrointestinal-stimulating drugs to promote gastrointestinal activity.

Electromagnetically guided placement of a nasointestinal tube (NIT) involves the use of an electromagnetic induction device that is placed on the body surface to receive and mark the electromagnetic signal from the head end of the guidewire in the NIT on the display screen, thus providing a bedside computer trace of the tube path. In addition, the electromagnetic wire can be reused. This is a standard method of device-assisted bedside NIT placement. In January 2012, the US Food and Drug Administration approved the application of this method for the placement of small intestinal nutritional tubes, which can replace abdominal X-ray examination. The main shortcoming of this approach is that it must be completed using special equipment. Additionally, the electromagnetic guidewire has strict requirements with respect to the diameter of the nutritional tube, and the cost is high; these factors prevent its implementation in primary medical institutions.

The standards for clinical selection of NITs of different calibers vary. Small-caliber NITs have a high probability of tube blockage, and they are only applicable to the use of low-concentration nutrient solutions. Large-caliber NITs, which can remain in place for a long period of time, are used for administration of medications or nutrient solutions; however, their placement is difficult because they are not flexible. Some institutions require a radiographic examination to determine the position of a small-caliber NIT before feeding; this is because incorrect placement of a small-caliber NIT leads to no or only a few clinical symptoms, such as dyspnea and coughing.

With the continuous development of medical technology, enteral nutritional support has become increasingly used in clinical practice and now plays an important role in disease treatment and physical rehabilitation. Many studies to date have reported on bedside catheterization. The most common blind technique of bedside post-pyloric feeding tube catheterization is the Corpak 10-10-10 protocol, which involves 10-minute standard blind placement, administration of 10 mg of metoclopramide, and a 10-mL saline flush. This method does not require special equipment or a specific site, can be performed as a bedside hands-free operation, and is convenient for clinical application. We developed an improved bedside catheterization technique based on the Corpak protocol to reduce the use of drugs during the operation, shorten the operation time, and improve the success rate of tube placement. In this study, a modified post-pyloric feeding tube placement technique was adopted and compared with both the standard Corpak 10-10-10 protocol and electromagnetic-guided catheterization. A large-caliber NIT was selected to implement blind insertion of a nasojejunal feeding tube at the bedside.

**Materials and methods**

**General information**

This prospective preliminary clinical trial involved patients with dysphagia from the
Department of Rehabilitation, the Second Affiliated Hospital of Zhejiang University School and was performed from 1 January 2017 to 1 January 2019. All patients included in this study were managed in accordance with the current diagnostic and treatment guidelines of swallowing disorders.\textsuperscript{18}

At the beginning of the trial, all enrolled patients were asked to perform a face-to-face interview. A random number table was then generated to divide the participants into the Corpak protocol group (C group) and modified bedside post-pyloric feeding tube placement group (M group) in 1:1 ratio using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). Patients who underwent a failed operation or developed tube blockage were assigned to the electromagnetic-guided tube placement group (EM group). Randomization numbers were sealed in opaque envelopes with the patients’ screening sequence numbers printed on the outside. All envelopes were numbered consecutively. Another researcher, who screened the eligible patients after baseline, opened the envelopes and then assigned the patients to either the treatment group or the control group.

The contents of this study were reported to the ethics committee of our hospital for approval, and the trial was registered in ClinicalTrials.gov (NCT number 04608071). All patients and their families provided informed consent. Before the NIT placement procedure, the patients were informed of the risk of tube placement, and all patients then provided written informed consent and participated voluntarily.

**Inclusion and exclusion criteria**

The inclusion criteria were (1) dysphagia that could not be alleviated within 48 hours; (2) a high-risk status with aspiration pneumonia, including consciousness disorders caused by various diseases, severe dementia, bed rest, gastroesophageal reflux, hiccups, gastric retention, or pyloric achalasia; and (3) an inability to undergo nasogastric tube feeding.

The exclusion criteria were (1) a history of upper abdominal surgery; (2) gastroduodenal ulcers and esophagogastric varices; (3) severe sinusitis and nasal bone fracture; (4) recent gastrointestinal bleeding, intestinal obstruction, ischemic bowel disease, and epistaxis; and (5) an implantable cardiac defibrillator, implantable cardiac pacemaker, or diaphragm pacemaker in patients undergoing electromagnetic-guided catheterization.

**Intervention methods**

The patients in all three groups (M group, C group, and EM group) were treated with a non-gravity type CORFLO gastrointestinal feeding tube (Production batch number, 0002985061; Specifications, 12FR 43\textsuperscript{109} CM; Halyard Health, Inc., Alpharetta, GA, USA). The guidewire in the EM group contained a signal-generating ability, whereas the metal guidewire in the M group and C group did not contain a signal-generating function. All required equipment was prepared before the operation (Table 1).

In all three groups, the NIT was first placed into the stomach through the nose. Before passing the tube through the pylorus, the position of the tip of the tube was confirmed using pH test paper and subxiphoid auscultation as recommended by the NHS National Patient Safety Agency.\textsuperscript{6} When the pH of the gastric liquid was <5.5 and the sound of air passing through water (similar to a gurgling sound) under the xiphoid process was heard, the position of the end of the NIT in the stomach was confirmed. If the pH was >5.5 or if no sound was heard, the position was confirmed by bedside X-ray examination.
It was also necessary to observe the patient for the development of any respiratory symptoms to determine whether the tube had entered the respiratory tract.

After the NIT tip was confirmed to have reached the stomach, the NIT tip was advanced through the pylorus in all three groups according to different operating procedures. We recorded the success rate of catheterization, the total operation time of catheterization, the time required to pass the pylorus, the depth of tube insertion, the three determining factors of advancement through the pylorus (described below), and adverse reactions related to catheterization and tube placement. X-ray examination was used as the criterion for successful catheterization. Successful catheterization was defined as placement of the catheter tip behind the pylorus. We measured time with a chronometer. The total operating time of catheterization was defined as the time from readiness of the catheterization-related items to the beginning of the bedside operation. The time required to pass the pylorus was defined as the time required to push the feeding tube forward from the stomach to the post-pylorus position. The depth of tube insertion was defined as the length of the NIT that entered the body after successful tube insertion. Adverse effects included both operation-related and catheter-related adverse effects. All measured variables were recorded by the researchers during the operation and within 72 hours after the tube was placed and were judged according to the patient-reported symptoms or physical examination findings.

In all patients, the NIT was placed by a single clinician to eliminate other interference factors.

**Modified protocol**

**Step 1.** The tip of the NIT was lubricated with a hydrophilic lubricant, and the length of tube insertion was estimated using the nose–ear–xiphoid (NEX) measurement method.

**Step 2.** The patient was placed in the semi-supine position at 30°. The NIT was inserted through the nose to the expected length of the stomach (NEX + 10 cm), and the end of the tube was confirmed to be located in the stomach. If the pH of the gastric liquid was <5.5 and the sound of air passing through water under the xiphoid process was heard, tube placement was considered successful.

**Step 3.** The patient was placed in the left lateral position at >45°, and 200 mL of air was injected into the NIT with a 50-mL syringe. The tube was then slowly and

| Table 1. Placement checklist for post-pyloric nutritional tube placement. |
|-----------------------------|------------------|---------------------------|
| **Apparatus**               | **Source**       | **Details**               |
| Nasointestinal tube         | Halyard Health, Inc. | CORFLO 1FR 43 "109 CM    |
| Electromagnetism guide device | Halyard Health, Inc. | CORTRAK 2 Enteral Access System |
| Injection syringe           | Zhejiang Longde Pharmaceutical, Inc. | 50 mL, Reg. certificate 20193141951 |
| pH test paper               | ASONE, Japan     | pH 5.5–9.0                |
| Water-soluble lubricant     | Heilongjiang Yunja Medical Technology, Co., Ltd. | 10 mL, Production license 20170012 |
| Normal saline               | China Otsuka Pharmaceutical Co., Ltd. | 10 mL: 0.09 g, Batch number 0B74B3 |
gently pushed forward for 10 to 15 cm (total depth of tube placement, 60–65 cm). The operation was stopped for a 5-minute rest period. Auscultation of the sound of air passing through water under the xiphoid process, the right lower abdomen, and the left lower abdomen was performed. If significant resistance was encountered during propulsion, the feeding tube length was returned to the starting position for further propulsion.

**Step 4.** The patient was restored to a 30° semi-supine position, and the feeding tube was slowly advanced at a speed of 5 cm/minute, confirming the head position at 65, 70, 75, 80, and 85 cm. Correct tube placement was confirmed as follows: the sound of air passing through water in the lower xiphoid, right lower abdomen, and left lower abdomen was auscultated; the syringe was repeatedly withdrawn; and resistance of the tube was felt. If the following three conditions were simultaneously met, the feeding tube was considered to have passed the pylorus. (1) Compared with Step 3, the sound of air passing through water under the xiphoid process was significantly weakened and distant, and the sound in the right lower abdomen or left lower abdomen was significantly increased. (2) The withdrawal syringe could not obtain air or >5 mL of liquid. (3) No obvious advancement resistance was encountered, or the catheter was retracted only ≤5 cm after the catheter was released. If the tube placement did not exceed 85 cm and the above three conditions were not met, the advancement was continued to the next 5 cm, after which it was checked again. If the tube placement exceeded 85 cm and did not meet the above three conditions, the tube was returned to the starting position of Step 4, and Step 4 was repeated (Figure 1).

**Step 5.** Advancement of the NIT was slowly continued until obvious resistance was felt or a length of >90 cm had been reached. The NIT was then fixed, the

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**Figure 1.** Modified bedside post-pyloric feeding tube catheterization, Step 4. The dotted red line is the outline of the stomach. The solid blue line indicates the position of the NIT in the stomach at the greater curvature. As shown in the figure, the feeding tube was advanced slowly at a speed of 5 cm per minute, and three locations identified by auscultation are marked with ①, ②, and ③. The flowchart on the right side indicates that if the tube placement did not exceed 85 cm and the three conditions were not met, the advancement was continued to the next 5 cm, after which it was checked again. NIT, nasointestinal tube.
guidewire was withdrawn, and an abdominal X-ray was used to determine the position of the catheter tip.

**Corpak 10-10-10 protocol**

**Step 1.** Ten minutes before tube placement, an intramuscular injection of metoclopramide (10 mg) was administered. The tip of the NIT was lubricated with a hydrophilic lubricant, and the length of tube insertion was estimated using the NEX measurement method.

**Step 2.** The patient was placed in a semihorizontal position. The NIT was then inserted at $30^\circ /C14$ through the nose into the stomach. Placement of the catheter tip in the stomach was determined by checking the pH of the liquid and ausculting the sound of air passing through water under the xiphoid process. Determination of whether the tube had passed the pylorus was performed in the same way as in the above-described modified protocol.

**Step 3.** After lubricating the catheter with a 10-mL saline flush, the catheter was pushed forward in 5-cm increments, and the depth of the tube was adjusted by feeling the change in resistance until the tube exceeded 95 cm.

**Step 4.** The head position was confirmed by X-ray examination.

**Step 5.** If the catheterization time exceeded 20 minutes, 200 mL of air was injected into the stomach. Finally, we determined whether the tip of the catheter was located beyond the pylorus according to the pH and volume of withdrawn liquid.

**Electromagnetic-guided placement protocol**

**Step 1.** Contraindications for electromagnetic-guided placement were excluded.

**Step 2.** Metoclopramide was injected 10 minutes before tube placement. The components of the device were connected, the guidewire with signal-generating capability was inserted into the feeding tube, and the blue receiver was fixed in the correct position of the patient’s xiphoid process.

**Step 3.** The patient was placed in a semisupine position at $30^\circ$. The feeding tube was then inserted through the nose to the expected length of the stomach ($NEX + 10\, \text{cm}$). The location of the feeding tube in the stomach was confirmed. The track of the tip of the tube could be seen on the monitoring screen.

**Step 4.** The catheter was pushed slowly forward while observing the head-end trajectory on the monitoring screen. Turning of the catheter was observed from the left of the midline to the right side. Advancement of the tip of the catheter through the pylorus was tracked during repeated, slow insertions, and the catheter was retracted if resistance or kinking and rotation of the tube occurred. If the procedure was longer than 90 minutes, the catheterization was terminated.

**Step 5.** The catheter was fixed, the guidewire was pulled out, and an abdominal X-ray examination was performed to determine the position of the catheter tip.

**Statistical analysis**

All data were analyzed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp.). Measurement data are presented as mean $\pm$ standard deviation, and one-way analysis of variance was used for comparison between groups. A P value of $<0.05$ was considered statistically significant.

**Results**

**Patients’ age, sex, and diagnosis**

This study involved 99 NIT placement procedures that were performed in 63 patients.
Among them, 41 procedures were performed in the C group (29 men, 12 women; mean age, 65.7 years), 17 procedures were performed in the EM group (13 men, 4 women; mean age, 66.8 years), and 41 procedures were performed in the M group (31 men, 10 women; mean age, 65.4 years).

**Comparison of tube placement success rate, operation time, time required to pass pylorus, and depth of insertion among the groups**

The time required to pass the pylorus and the tube placement success rate were the main variables, whereas the operation time and depth of insertion were secondary variables. The time required to pass the pylorus and the depth of insertion were significantly different among the groups (P < 0.05), and both were lowest in the M group. The operation time was shortest in the M group, but it was not significantly shorter than that in the C group. The operation time, the time required to pass the pylorus, and the depth of insertion were statistically different between the EM group and C group and between the EM group and M group (P < 0.05) (Table 2 and Figure 2).

**Success rate of NIT placement**

X-ray examination of the abdomen confirmed that the catheterization was completed in all cases; successful catheterization was defined when the catheter tip was placed behind the pylorus. The success rate in the M, EM, and C groups was 82.9% (34/41), 88.2% (15/17), and 70.7% (29/41), respectively. In the EM group, endoscopic catheter placement was used for two cases of failed catheterization. In the two groups of patients who underwent bedside catheterization, catheterization was successfully performed after the first tube placement failure in three patients, and four patients received partial enteral nutrition and partial parenteral nutrition by a gastric tube instead of placing the tip of the catheter behind the pylorus.

**Operation time of tube insertion**

The mean operation time in the M group was 36.9 ± 10.9 minutes, which was significantly shorter than that in the EM group (52.4 ± 24.7 minutes, P = 0.0015), but not significantly shorter than that in the C group (40.8 ± 11.7 minutes). There was also a significant difference between the C group and the EM group (P = 0.0184). Moreover, in the EM group, the shortest time was 25 minutes and the longest time

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**Table 2.** Comparison of tube placement success rate, operation time, and tube placement depth of each group of tube placement methods.

|                          | C group | EM group | M group |
|--------------------------|---------|----------|---------|
| Successful cases, n      | 29/41   | 15/17    | 34/41   |
| Success rate             | 70.70%  | 88.2%    | 82.9%   |
| Operation time, minutes  | 40.8 ± 11.7*# | 52.4 ± 24.7*# | 36.9 ± 10.9*# |
| Time required to pass pylorus, minutes | 31.9 ± 9.5*# | 42.1 ± 25*# | 26.9 ± 8.8*## |
| Depth of insertion, cm    | 80.9 ± 7.9*# | 85.8 ± 9.7*# | 76.6 ± 6.9*## |

Data are presented as mean ± standard deviation unless otherwise indicated.

*P < 0.05 compared with C group; #P < 0.05 compared with EM group.

C group, Corpak protocol group; EM group, electromagnetic-guided tube placement group; M group, modified bedside post-pyloric feeding tube placement group.
was 97 minutes; in the C group, the shortest time was 24 minutes and the longest time was 77 minutes; and in the M group, the shortest time was 22 minutes and the longest time was 76 minutes.

The most critical indicator was the time required to pass the pylorus. The mean time required to pass the pylorus in the M group was 26.9 ± 8.8 minutes, which was significantly shorter than that in the EM group (42.1 ± 25 minutes, P = 0.0011) and C group (31.9 ± 9.5 minutes, P = 0.0160). There was also a significant difference between the C group and EM group (P = 0.0267).

The rate of pylorus-passing operations completed within 30 minutes was significantly higher in the M group (65.9%) than in the other two groups (EM group, 41.2%; C group, 46.3%) (P < 0.05). The proportion of operations that were completed in >40 minutes was 7.3%, 47.1%, and 19.5% in the M, EM, and C group, respectively (Figure 3).

**Depth of insertion**

The M group had a lower mean depth of tube insertion (76.6 ± 6.9 cm) than the EM group (85.8 ± 9.7 cm, P = 0.0001) and C group (80.9 ± 7.9 cm, P = 0.0107). There was also a significant difference between the EM group and C group (P = 0.0469).

**Safety**

Misplacement of the tube into the airway did not occur in any of the groups. The probability of nosebleeds was higher in the C group than in the EM and M groups. The probability of refractory hiccups was higher in the M group than in the EM group. The risk of accidental extubation was lower in the EM group than in the C and M groups.

No serious complications occurred among the 99 tube insertion procedures, such as asphyxiation, hemoptysis, or exacerbation of aspiration pneumonia due to accidental insertion into the trachea. A nosebleed was the most common
complication associated with catheterization, and the incidence was not statistically significant among the groups. The incidence of sore throat was 14.6% in the M group. The highest incidence of subxiphoid pain was observed in the EM group (23.5%). The M group had a significantly higher incidence of abdominal distension than the other two groups (34.1%) ($P < 0.05$). The incidence of refractory hiccups was significantly higher in the EM group than in the other two groups (17.6%), with the lowest incidence of 4.9% observed in the M group. After successful catheterization, catheter-related adverse effects occurred in all three groups with little difference in probability. Two accidental extubations of the NIT occurred in M group, and four occurred in the C group (Table 3).

Discussion

Appropriate nutritional support, which is essential for a good prognosis in critically ill patients,\textsuperscript{19} should be applied as early as possible in such patients.\textsuperscript{20,21} Appropriate nutritional support can effectively reduce bacterial complications, improve intestinal function, achieve nutritional goals, reduce mortality and medical expenses, and shorten the hospital stay.\textsuperscript{22} A meta-analysis conducted by Zhang et al.\textsuperscript{5} suggested that the post-pyloric nutritional pathway can provide a higher proportion of predicted energy requirements while significantly reducing gastric residues. In patients with energy requirements or a high risk of reflux aspiration pneumonia, the use of post-pyloric enteral nutrition can reduce gastric residue and the risk of pneumonia.\textsuperscript{23,24} In the clinical setting, it has been found that application of the Corpak method for catheterization has introduced substantial confusion among clinicians. Therefore, in the present study, we compared the efficacy and safety of a new modified bedside post-pyloric feeding tube catheterization technique using the Corpak 10-10-10 procedure and electromagnetic-guided catheterization for treatment of patients with dysphagia and a high risk of aspiration pneumonia (Figure 4).
The modified method described in this report is an improvement of the Corpak method and is a type of bedside blind catheterization. The first two steps of the modified method and the traditional Corpak method are basically the same. In the latter three steps, the modified method achieved a higher success rate and shortened operation time by changes in the auscultation and posture, control of the advancement speed, and use of intestinal motility drugs. The advantages of this modified method compared with the other two methods are as follows. (1) It does not require the use of metoclopramide, erythromycin, or any other drugs to promote intestinal motility. (2) It does not require lubrication with 10 mL of saline before tube placement. (3) It increases the requirements for patient posture: the patient is placed in the left lateral position at >45°, 200 mL of air is injected into the stomach, the NIT is pushed forward 60 to 65 cm, and the patient is rested for 5 minutes. (4) It increases the requirements for the advancement speed: before passage of the pylorus,
the 30° semi-recumbent position is restored, and the 5-cm/minute NIT propulsion speed is controlled. (5) The criteria used to judge passage of the pylorus is increased by two items: first, the sound of air passing through water under the xiphoid process is significantly weakened and distant, and the sound under the right lower abdomen or left lower abdomen is significantly increased; second, the syringe cannot obtain air or more than 5 mL of liquid. Notably, the modified method does not involve determination of NIT passage through the pylorus by the pH of the extracted liquid. However, the following evaluation item is unchanged: no obvious advancement resistance is encountered or the catheter is retracted no more than 5 cm after its release.

The most significant advantage of electromagnetic-guided catheterization is the visual interface. With this approach, it is possible to accurately determine whether the head end of the tube has been placed in the post-pylorus position by monitoring the position of the NIT end. At the same time, inadvertent placement of the catheter into the airway is avoided.25 In this study, as expected, electromagnetic-guided catheterization had the highest catheterization success rate (88.2%), which is consistent with previous studies.26 Bedside blind tube placement does not rely on special equipment. The Corpak protocol is the most commonly used method in the clinical setting. However, it is relatively difficult to adjust the depth of the tube with the change in resistance until it reaches 95 cm.

The first major advantage of the modified method is that when the catheter reaches the position behind the pylorus, the Corpak protocol relies on the pH of the extraction fluid to determine whether the insertion was successful. However, this approach is not easy to perform. Because the length of the catheter is >1 m, residual gastric fluid is present in the lumen, and little fluid and no air are present in the duodenum and jejunum. Thus, the extraction can be fully achieved, and reliance on the pH may lead to a large error in judgment. The modified method does not require pH measurement to judge achievement of the post-pylorus position. Instead, the judgment standard is the inability of the withdrawal syringe to obtain air or more than 5 mL of liquid. During the operation, the NIT frequently becomes bent and reflexed and sometimes even returns to the esophagus. Therefore, the change in the resistance of the inlet tube is still used as one of the three evaluation criteria. Studies have also shown that the auscultation method can be used to judge the location of the catheter.27 The modified method emphasizes the role of auscultation. Auscultation of the catheter behind pylorus is combined with the acoustic changes in the sound of air passing through water under the xiphoid when the catheter is in the stomach. Different patients have different strengths of the sound of air passing through water because of the positioning of the catheter tip in the stomach and the presence of gas or liquid in the stomach. However, when the NIT enters the duodenum, the sound of air passing through water under the xiphoid process inevitably weakens. Additionally, because of the sound transmission effect of the intestinal tract, the sound from the right or left lower abdomen clearly increases. Because the alimentary canal is an interconnecting channel, the sound of air passing through water under the xiphoid process was still heard; we still observed changes in relative loudness in the present study. Kohata et al.28 confirmed the catheter position by palpating vibration changes to prove that the relative change can be used to determine the catheter position. In the present study, three criteria were used to determine that the tip of the tube was behind the pylorus in the M group, which was more reliable than the criteria used in
the C group. The success rate was 82.9%, which was significantly higher than that in the C group.

The second major advantage of the modified method is the posture change. When using the electromagnetic-guided method to place the catheter, we found that in 82.4% of successful cases, the catheter tip had turned from the left to the right as shown by the monitor, and the catheter trajectory deepened when passing through the pylorus (Figure 5). These findings suggest that in most successful cases of blind NIT placement, the non-gravity catheter advances along the greater curvature of the stomach. Therefore, when the NIT reached 65 cm in the M group, the patient was lying on the left side and remained in that posture for 5 minutes so that the catheter could be placed along the large bend of the stomach; the tip was directed from left to right in the direction of the pylorus, which is important for fixing the direction of the catheter. After 5 minutes of inactivity, the half-lying posture was restored and Step 4 was initiated. Some NIT placement methods also utilize the impact of the body position on the success rate of catheterization; these only involve the right lateral position. The purpose of the right lateral position is to enable the NIT to enter the pylorus, which is located on the right side of the stomach body, through gravity. This differs from the direct placement achieved by the modified method.

The third major advantage of the modified method is the ability to control the advancement speed of the NIT at 5 cm/minute during passage of the pylorus. The normal gastrointestinal motility frequency is three to five times/minute, and the pylorus also exhibits rhythmic opening. Pushing the catheter tip toward the pylorus too quickly, even if the direction of the tip is correct, may result in a lost chance to enter the pylorus. Slowing down the NIT advancement rate could thus increase the success rate of tube placement. However, waiting too long could delay the start of enteral nutrition. Therefore, it is necessary to slow down the tube advancement speed when placing the tube directly near the pylorus.

Drugs that promote bowel movements can increase the success rate of post pyloric feeding tube placement by

![Figure 5. Trajectory of the NIT on the screen monitor in the EM group.](image)

NIT, nasointestinal tube; EM group, electromagnetic-guided tube placement group.
increasing peristalsis and pyloric opening. Metoclopramide, erythromycin, and domperidone are commonly used drugs administered by intramuscular injection or intravenous injection before the operation.\textsuperscript{32} Rhubarb is another drug that is orally administered before NIT placement.\textsuperscript{33} However, certain toxicities and adverse reactions have been associated with intestinal motility drugs. For example, erythromycin has been associated with cardiotoxicity and bacterial resistance, and metoclopramide has been associated with neurological reactions. Moreover, repeated administration of prokinetic drugs in patients with gastroparesis may result in superposition of doses.\textsuperscript{34} Such drugs should be cautiously administered to children and pregnant women.\textsuperscript{35} One advantage of the modified method is that it does not require the use of intestinal motility drugs before catheter placement, which further increases the safety of the procedure.

The tube placement time was relatively long in all three methods of the present study. In some cases, nasal and laryngeal discomfort or bleeding was observed. In other cases, the operation time was prolonged because of the difficulty of entering the esophagus with the NIT. The EM group had a significantly longer mean operation time than the other two groups, which is not completely consistent with the findings of a previous study.\textsuperscript{36} We considered that this might have been related to the time spent on the arrangement of the machine equipment. The operation time in the M group was shorter than that in the C group. However, repeated evaluation of the sound of air passing through water and measurement of the pH of gastric juice extraction also took a certain amount of time; thus, there was no significant difference between the two methods. The best indicator of efficiency was the time needed to pass the pylorus, which showed significant differences among the three groups. The time required to pass the pylorus in the M group was significantly shorter than that in the other two groups because of improved posture, advancement speed, and judgment methods. Meanwhile, the proportion of operations completed within 30 minutes in the M group was 65.9\%, which was significantly higher than that in the other groups. Notably, it is easier to gain the necessary expertise to perform the modified operation through training, which is conducive to its promotion.\textsuperscript{37}

Although the electromagnetic-guided method involves visual tube placement, the direction of the catheter head end after entering the stomach is uncontrollable. When preforming electromagnetic-guided catheterization, it is necessary to continuously enter, withdraw, and rotate the catheter slowly and repeatedly to ensure that the head-end trajectory crosses the pylorus, and this increases the time required to perform the procedure. Moreover, the electromagnetic-guided catheterization procedure does not involve intragastric gas injection, which is consistent with the commonly performed electromagnetic-guided protocol.\textsuperscript{26} The NIT is more difficult to control in the direction of the gastric catheter without expansion. Consistently, we found that the time required to pass the pylorus was the longest in the EM group in the present study. The gastric air injections enable effortless completion of the catheterization process.\textsuperscript{38,39} In patients with no structural abnormalities of the gastrointestinal tract, injecting the appropriate amount of gas causes no serious adverse reactions. Therefore, we chose air injections to perform the modified method.

We found the highest mean depth in the EM group (85.8 ± 9.7 cm) (Figure 6) and the lowest mean depth in the M group (76.6 ± 6.9 cm) (Figure 7); the mean depth in the C group was 80.9 ± 7.9 cm (Figure 8). The observed differences were statistically
significant. Because of the visual factors of the electromagnetic-guided method, the operator might be able to safely push the catheter forward and even reach the position of the proximal jejunum after confirming that the catheter has passed through the pylorus. Thus, patients who have undergone successful catheterization can be treated with a long tube indwelling time behind the pylorus, which is consistent with previous studies.26 The M group inevitably has a shallower tube placement depth because the head position is judged every 5 cm and the NIT advancement is stopped after 65 cm once the three factors determining advancement through the pylorus have been satisfied. We believe that as long as the head of the NIT is placed behind the pylorus, it can effectively prevent gastric retention and reduce the incidence of gastroesophageal reflux. The relationship between the depth of tube insertion and the incidence of tube-related complications has been rarely reported.

The safety and efficacy of the NIT operation are the most important indexes with which to evaluate whether the method is suitable for clinical application. In the
In the present study, we recorded operation-related and catheter-related complications of three methods. Our data indicated no serious fatal complications due to malpositioning of the catheter. Therefore, the catheter tip positioning method adopted in the modified method is safe. Sore throat, subxiphoid pain, and abdominal distension were the most common adverse reactions observed in this study. The M group had the lowest incidence of sore throat, which may have been related to the limitation of the advancement speed of the operation. The EM group had the highest incidence of subxiphoid pain, which may have been related to the recurrent insertion and re-entry of the catheter in the stomach and the rotation of the catheter during the pyloric stenting procedure. The incidence of abdominal distension in the M group was significantly higher than that in the other two groups, which may have been due to the intragastric injection of 200 mL of air during the catheterization process. Increased gas in the gastrointestinal tract was caused by repeated gas injection during auscultation for tube positioning assessment. The EM group also had a high incidence of hiccups, which was related to the depth of catheter insertion. These complications resolved within 24 to 48 hours. The tube-related complications included tube blockage and accidental extubation, which were related to the daily care of the nasoenteric nutritional tube.

This study has a few limitations. First, the operations were independently completed by one operator. The modified method requires further research to verify whether other medical staff can achieve similar success rates of catheterization and whether medical workers can master the necessary skills through simple training. Second, the number of cases in the EM group was small because of the requirement for special equipment. To decrease the NIT operation time and avoid aggravating the patients’ discomfort, the catheterization was stopped when the operation time exceeded 90 minutes, and the procedure was declared a failure. Neither gas injection nor body position changes were used in the catheterization process, and the tube placement time may not accurately reflect the true situation. Third, in this study, no serious complications caused by incorrect tube placement occurred in this study. The incidence of serious complications caused by bedside methods of post-pyloric feeding tube catheterization reportedly ranges...
from 1% to 2%. Therefore, the 99 operations in this study do not reflect the overall probability of serious complications, and additional operative cases must be accumulated. Finally, many bedside methods of post-pyloric feeding tube catheterization are available, such as ultrasound technology, endoscopy technology, and radiographic imaging technology. The modified NIT placement technique needs to be compared with other methods to more accurately judge its clinical value.

Conclusions
Modified bedside post-pyloric feeding tube catheterization, as an optimized bedside free-hand blind post-pyloric catheterization technique, is safe and effective for placement of enteral nutritional tubes in patients with dysphagia with a high risk of aspiration pneumonia. By changing the patient’s posture, slowing the advancement speed, and adjusting the judgment criteria, this new method improves the success rate of tube placement, shortens the operation time, and eliminates the use of drugs. This protocol contains five clear steps, basically eliminating the differences caused by subjective factors. This might reduce the difficulty of training and learning and thus facilitate clinical promotion.

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Author contributions
All authors are members of the swallowing treatment group in the hospital. In this study, Dr. Xiong Bing was responsible for the experimental design, literature search, and operation of all cases. Dr. Tang Yinshan was responsible for the data processing and statistical analysis. Dr. Jin Ying was responsible for case collection, preparation of catheterization materials, acquisition of written informed consent, and observation of adverse effects after catheterization. Technician Shen Yinchuan was responsible for taking the bedside flat abdominal films.

Authorship statement
Xiong Bing and Tang Yinshan equally contributed to the conception and design of the research. Jin Ying and Shen Yinchuan contributed to the acquisition and analysis of the data. Tang Yinshan contributed to the interpretation of the data. Xiong Bing and Tang Yinshan drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

ORCID iD
Xiong Bing https://orcid.org/0000-0002-9249-3388

Supplemental material
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References
1. Aeberhard C, Birrenbach T, Joray M, et al. Simple training tool is insufficient for appropriate diagnosis and treatment of malnutrition: a pre-post intervention study in a tertiary center. *Nutrition* 2016; 32: 355–361. https://doi.org/10.1016/j.nut.2015.09.012
2. Felder S, Lechtenboehmer C, Bally M, et al. Association of nutritional risk and adverse medical outcomes across different medical inpatient populations. *Nutrition* 2015; 31: 1385–1393. https://doi.org/10.1016/j.nut.2015.06.007
3. Elke G, Van Zanten ARH, Lemieux M, et al. Enteral versus parenteral nutrition in critically ill patients: an updated systematic review and meta-analysis of randomized controlled trials. *Crit Care* 2016; 20: 117. https://doi.org/10.1186/s13054-016-1298-1

4. Alhazzani W, Almasoud A, Jaeschke R, et al. Small bowel feeding and risk of pneumonia in adult critically ill patients: a systematic review and meta-analysis of randomized trials. *Crit Care* 2013; 17: R127. https://doi.org/10.1186/cc12806

5. Zhang Z, Xu X, Ding J, et al. Comparison of postpyloric tube feeding and gastric tube feeding in intensive care unit patients: a meta-analysis. *Nutr Clin Pract* 2013; 28: 371–380. https://doi.org/10.1177/0884533613485987

6. National Health Service. Nasogastric tube misplacement: continuing risk of death and severe harm. Patient Safety Alert. 2016. NHS/PSA/RE/2016/006. Available at: https://improvement.nhs.uk/news-alerts/nasogastric-tube-misplacement-continuing-risk-of-death-severe-harm/. (accessed 7 November 2017).

7. Rassias AJ, Ball PA and Corwin HL. A prospective study of tracheo-pulmonary complications associated with the placement of narrow-bore enteral feeding tubes. *Crit Care* 1998; 2: 25–28. https://doi.org/10.1186/cc120

8. Chau JP, Lo SH, Thompson DR, et al. Use of end-tidal carbon dioxide detection to determine correct placement of nasogastric tube: a meta-analysis. *Int J Nurs Stud* 2011; 48: 513–521. https://doi.org/10.1016/j.ijnurstu.2010.12.004

9. Irving SY, Rempel G, Lyman B, et al. Pediatric nasogastric tube placement and verification: best practice recommendations from the NOVEL project. *Nutr Clin Pract* 2018; 33: 921–927. https://doi.org/10.1002/ ncp.10189

10. National Health Service. Placement devices for nasogastric tube insertion do not replace initial position checks. Patient Safety Alert. 2013. NHS/PSA/W/2013/001. Available at: https://www.england.nhs.uk/wp-content/uploads/2013/12/psa-ng-tube.pdf.

11. Metheny NA and Meert KL. Monitoring feeding tube placement. *Nutr Clin Pract* 2004; 19: 487–495. https://doi.org/10.1177/0115426504019005487

12. Meyer R, Harrison S, Cooper M, et al. Successful blind placement of nasojejunal tubes in paediatric intensive care: impact of training and audit. *J Adv Nurs* 2007; 60: 402–408. https://doi.org/10.1111/j.1365-2648.2007.04401.x

13. U.S. Food and Drug Administration. 510(k) Premarket notification. Cortrak enteral access device. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm?ID=K113351. Updated October 16, 2017. (accessed 8 March 2017).

14. Marino LV, Ramchandra P and Nathoo N. Blind transpyloric nasojejunal versus nasogastric tube intubation in severe head injuries: a preliminary report. *J Clin Neurosci* 2005; 12: 435–437. https://doi.org/10.1016/j.jocn.2004.04.009

15. Gatt M and MacFie J. Bedside postpyloric feeding tube placement: a pilot series to validate this novel technique. *Crit Care Med* 2009; 37: 523–527. https://doi.org/10.1097/CCM.0b013e3181959836

16. Taylor B and Schallom L. Bedside small bowel feeding tube placement in critically ill patients utilizing a dietitian/nurse team approach. *Nutr Clin Pract* 2001; 16: 258–262. https://doi.org/10.1177/088453360101600410

17. Lee AJ, Eve R and Bennett MJ. Evaluation of a technique for blind placement of postpyloric feeding tubes in intensive care: application in patients with gastric ileus. *Intensive Care Med* 2006; 32: 553–556. https://doi.org/10.1007/s00134-006-0095-8

18. Gallegos C, Brito-De La Fuente E, Clavé P, et al. Nutritional aspects of dysphagia management. *Adv Food Nutr Res* 2017; 81: 271–318. https://doi.org/10.1016/bs.afnr.2016.11.008

19. Heyland DK, Dhaliwal R, Drover JW, et al. Canadian clinical practice guidelines for nutrition support in mechanically ventilated, critically ill adult patients. *JPEN J Parenter Enteral Nutr* 2003; 27: 355–373. https://doi.org/10.1177/014860710327005355

20. Kreymann KG, Berger MM, Deutz NE, et al. ESPEN Guidelines on Enteral Nutrition: Intensive care. *Clin Nutr* 2006;
21. Martindale RG, McClave SA, Vanek VW, et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition: executive summary. *Crit Care Med* 2009; 37: 1757–1761. https://doi.org/10.1097/CCM.0b013e3181a40116

22. Marik PE and Zaloga GP. Early enteral nutrition in acutely ill patients: a systematic review. *Crit Care Med* 2001; 29: 2264–2270. https://doi.org/10.1097/00003246-200112000-00005.

23. Mosier MJ, Pham TN, Klein MB, et al. Early enteral nutrition in burns: compliance with guidelines and associated outcomes in a multicenter study. *J Burn Care Res* 2011; 32: 104–109. https://doi.org/10.1097/BCR.0b013e318204b3be

24. Chiang YH, Chao DP, Chu SF, et al. Early enteral nutrition and clinical outcomes of severe traumatic brain injury patients in acute stage: a multi-center cohort study. *J Neurotrauma* 2012; 29: 75–80. https://doi.org/10.1089/neu.2011.1801

25. Gerritsen A, Van Der Poel MJ, De Rooij T, et al. Systematic review on bedside electromagnetic-guided, endoscopic, and fluoroscopic placement of nasoenteral feeding tubes. *Gastrointest Endosc* 2015; 81: 836–847.e2. https://doi.org/10.1016/j.gie.2014.10.040

26. McCutcheon KP, Whittet WL, Kirsten JL, et al. Feeding tube insertion and placement confirmation using electromagnetic guidance: a team review. *JPEN J Parenter Enteral Nutr* 2018; 42: 247–254. https://doi.org/10.1002/jpen.1015

27. Xiao J, Mao Z, Hua M, et al. Auscultation-assisted bedside postpyloric placement of feeding tube in critically ill patients: a prospective, observational study. *Asia Pac J Clin Nutr* 2019; 28: 435–441. https://doi.org/10.6133/apjcn.201905_28(3).0002

28. Kohata H, Okuda N, Nakataki E, et al. A novel method of post-pyloric feeding tube placement at bedside. *J Crit Care* 2013; 28: 1039–1041. https://doi.org/10.1016/j.jcrc.2013.06.018

29. Sun JK, Wang X and Yuan ST. A novel method of blind bedside placement of post-pyloric tubes. *Crit Care* 2018; 22: 62. https://doi.org/10.1186/s13054-018-1986-0

30. Rajamani A. Description of a simple technique of non-endoscopic insertion of a post-pyloric feeding tube in critically ill patient. *J Intensive Care Soc* 2019; 20: NP21–NP22. https://doi.org/10.1177/175143719843425

31. Gokhale A, Kantoor S, Prakash S, et al. Bedside placement of small-bowel feeding tube in intensive care unit for enteral nutrition. *Indian J Crit Care Med* 2016; 20: 357–360. https://doi.org/10.4103/0972-5229.183909

32. Hu B, Ouyang X, Lei L, et al. Erythromycin versus metoclopramide for post-pyloric spiral nasoenteric tube placement: a randomized non-inferiority trial. *Intensive Care Med* 2018; 44: 2174–2182. https://doi.org/10.1007/s00134-018-5466-4

33. Li J, Gu Y and Zhou R. Rhubarb to facilitate placement of nasojejunal feeding tubes in patients in the intensive care unit. *Nutr Clin Pract* 2016; 31: 105–110. https://doi.org/10.1177/0884533615608363

34. Li G, Ke L, Tong Z, et al. Is it necessary for all patients to use prokinetic agents to place a trans-pyloric tube? *Intensive Care Med* 2019; 45: 751–752. https://doi.org/10.1007/s00134-019-05548-7

35. Clifford P, Ely E and Heimall L. Bedside placement of the postpyloric tube in infants. *Adv Neonatal Care* 2017; 17: 19–26. https://doi.org/10.1097/ANC.0000000000000364

36. Shadid H, Keckeisen M and Zarrinpar A. Safety and efficacy of electromagnetic-guided bedside placement of nasoenteral feeding tubes versus standard placement. *Am Surg* 2017; 83: 1184–1187.

37. Sun C, Lv B, Zheng W, et al. The learning curve in blind bedside postpyloric placement of spiral tubes: data from a multicentre, prospective observational study. *J Int Med Res* 2019; 47: 1884–1896. https://doi.org/10.1177/0300060519826830

38. Salasidis R, Fleisher T and Johnston R. Air insufflation technique of enteral tube insertion: a randomized, controlled trial.
39. Tiancha H, Jiyong J and Min Y. How to promote bedside placement of the postpyloric feeding tube: a network meta-analysis of randomized controlled trials. *JPEN J Parenter Enteral Nutr* 2015; 39: 521–530. https://doi.org/10.1177/0148607114546166

40. Halloran O, Grecu B and Sinha A. Methods and complications of nasoenteral intubation. *JPEN J Parenter Enteral Nutr* 2011; 35: 61–66. https://doi.org/10.1177/0148607110370976