Original Article

Placement of a Jejunal Feeding Tube via an Ultrasound-Guided Antral Progressive Water Injection Method

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Abstract

Background: Jejunal feeding tube allows the nutrition of critical care patients more easy and safe. However, its placement remains a challenge. This study aimed to introduce a jejunal feeding tube through an ultrasound-guided antral progressive water injection method and subsequently to examine its efficacy.

Methods: Between April 2016 and April 2017, 54 patients hospitalized in the Department of Critical Care Medicine, Peking Union Medical College Hospital, China who needed nutritional support through a jejunal feeding tube were recruited for this study. Patients who applied ultrasound-guided antral progressive water injection method were classified into the experimental group. Patients who applied conventional method were registered as control group.

Results: No significant differences were found in age, body mass index, and Acute Physiology and Chronic Health Evaluation score, but a significant difference in operation time was found between the experimental group and the control group. Of the 24 individuals in the control group, 17 displayed clear catheter sound shadows once the tube entered the esophagus. In comparison, of the 30 individuals in the experimental group, all harbored catheter sound shadows through the esophageal gas injection method. Subsequent observation revealed that in the control group (via ultrasonographic observation), 15 individuals underwent successful antral tube entry, for a success rate of 63%. In the experimental group (via antral progressive water injection), 27 individuals underwent successful antral tube entry, for a success rate of 90%. There was a significant difference between the success rates of the two groups ($\chi^2 = 5.834$, $P = 0.022$).

Conclusion: The antral progressive water injection method for the placement of a jejunal feeding tube is more effective than the traditional ultrasonic placement method.

Key words: Jejunal Feeding Tube; Nutritional Support; Ultrasound-Guided Antral Progressive Water Injection Method

Introduction

It is recommended that patients under intensive care should receive enteral nutrition within 24–48 h of hospitalization, as it is conducive to reducing patients' infection and mortality rates and the duration of hospitalization. The 2016 US clinical guidelines of nutrition support for critical care patients[1] and the SEPSIS guidelines[2] argued that nasojejunal feeding should be placed below the pylorus for patients who were at high risk of improper aspiration and who were intolerant of oral or gastric feeding.[3,4] There are multiple methods to introduce a jejunal feeding tube, including blind bedside placement,[5] fluoroscopic insertion,[6] percutaneous endoscopic insertion,[7] and electromagnetic imaging-assisted insertion.[8] Of these approaches, fluoroscopic insertion and percutaneous endoscopic insertion are not suitable for patients of intensive medicine. In recent years, ultrasonography has been applied in intensive medicine. In light of this technology, ultrasound-guided placement of jejunal feeding tubes has been attempted,[9] although its success rates vary.

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In this study, we compared two approaches of jejunal feeding tube placement: a conventional method through ultrasonographic observation with 24 individuals and an experimental method through antral progressive water injection with 30 individuals. There were two key steps of jejunal feeding tube placement: signaling tube entry into the esophagus beforehand, thereby minimizing the occurrence of complications resulting from accidental tube entry into the airway;[10] and guiding the tube through the pylorus, which is essential for tube entry into the duodenum and jejunum. Our data revealed that the conventional approach did not generate a satisfactory success rate. In addition, through experimentation and literature review, we developed an improved method of ultrasound-guided placement of a jejunal feeding tube, as detailed in the following report.

Methods

Ethical approval

This study was conducted in accordance with the procedure of disease in China and was approved by Peking Union Medical College Hospital. All patients enrolled wrote informed consent before starting the study and have their medical data used for research purposes.

Subjects

Between April 2016 and April 2017, 54 patients in the Department of Critical Care Medicine, Peking Union Medical College Hospital, who were determined to require placement of a jejunal feeding tube were recruited for this study. The inclusion criteria included the following: (i) high risks of improper aspiration, (ii) repeated vomiting, and (iii) stomach and duodenal dysfunction. The contraindications included the following: (i) facial and skull base fractures, (ii) esophageal obstruction, (iii) esophageal varices, and (iv) esophageal diverticulum. Patients who applied ultrasound-guided antral progressive water injection method were classified into the experimental group. Patients who applied conventional method were registered as control group.

Placement of jejunal feeding tube in two groups

This method required the participation of two medical professionals, whose duties were synchronized, with one responsible for the placement of the jejunal feeding tube and the other responsible for operating the ultrasound device. A Kangaroo jejunal feeding tube was employed for jejunal feeding. Ultrasonography was performed using SonoSite M-turbo and X-port machines. Vascular probes were used to monitor the esophagus; abdominal probes were used to monitor the antral sinus region [Table 1].

The ultrasound methods of the two groups are summarized below. In the experimental group, the tube was inserted into the esophagus with a depth of 20–25 cm and was then observed in the esophageal cross-section [Figure 1] or longitudinal section. An ultrasonic probe was first properly positioned before it was used to inject 10 ml of gas into the feeding tube, during which ultrasonographic changes in the esophagus were monitored. If the esophagus displayed movement and/or a radiation-like hyperechoic signal that was associated with aeration, it demonstrated that the tube was inserted into the esophagus. The sign was referred as the esophageal aeration sign [Figure 2].

In conventional group, tube entry into the antrum was confirmed if tram-track signs were observed in the cross-section or the longitudinal section. In the experimental group, the tube was placed at a depth of approximately 55 cm and was ensured to be in the stomach. The ultrasound operator monitored the antral sinus to identify a cross-section, and the probe was then rotated counterclockwise to reveal a longitudinal section of the antral sinus, where the probe would remain. Water injection started at the depth of 55 cm such that 10 ml of water was injected after the tube had moved for every increment of 5 cm. During water injection, the appearance of any cloud sign, referring to microbubbles resulting in a shadow on water injection into the stomach, was monitored through ultrasonography in the longitudinal section of the antral sinus to document the location, size, orientation, and delay of the cloud sign. This approach referred as the antral progressive water injection method enabled the surgeons to determine the tube's interruption and relative position. The process of this method is illustrated in Figure 3.

The specifics of the method were as follows: if no cloud signs were found at a depth of 65 cm in the antrum, the tube needed to be reintroduced; if the cloud signs did not exhibit any changes in location, size, orientation, and delay in response to increased recorded insertion depth, the tube had not actually continue to enter and needed to be adjusted and repositioned. In general, a tube was considered to enter the horizontal portion of the duodenum if cloud signs disappeared when the tube reached a depth of 80–85 cm, after which the tube was advanced to a depth of 105–110 cm.

Statistical analysis

SPSS 19.0 (IBM, Massachusetts, USA) was used for statistical analyses. The age, body mass index (BMI), Acute Physiology and Chronic Health Evaluation (APACHE) score, and tube placement time of the patients all exhibited

Table 1: Ultrasound procedures of the two treatments

Sites	Conventional group	Experimental group
Esophagus	The catheter sound shadow was monitored in a cross-section	Esophageal gas injection
Antrum	Tram-track signs of the catheter sound shadow were observed in a cross-section of the antrum	The location, size, orientation, and delay of the cloud sign resulting from water injection were studied

normal distribution and are expressed as mean ± standard deviation (SD). A *t*-test was used to compare the data from the two groups. The success and failure numbers of the two groups were analyzed using a Chi-square test or Fisher's exact test. A value of $P < 0.05$ was considered statistically significant.

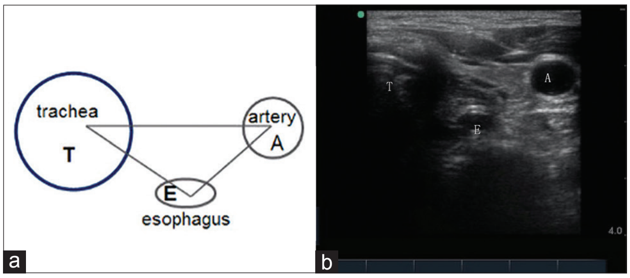

Figure 1: The location of trachea (T), carotid artery (A), and esophagus (E). (a) Schematic diagram. (b) Ultrasound image.

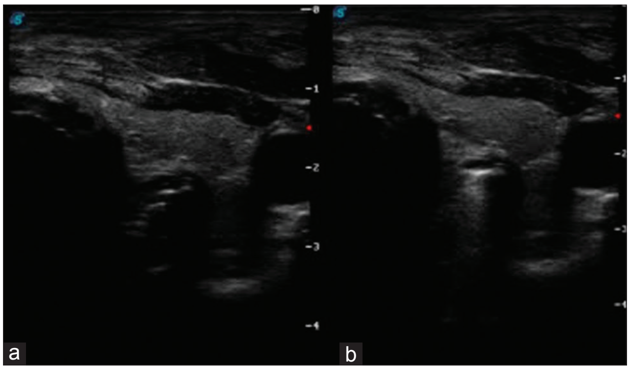

Figure 2: (a) Cross-section showing no aeration sign in the esophagus. (b) Cross-section showing the aeration sign in the esophagus.

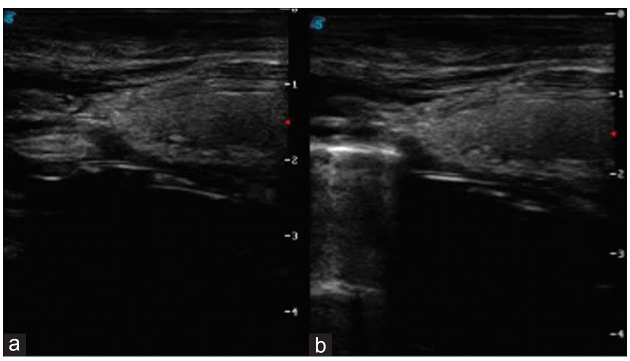

Figure 3: (a) Longitudinal section showing no aeration sign in the esophagus. (b) Longitudinal section showing the aeration sign in the esophagus.

Results

General information

An independent sample *t*-test was used to analyze the patients' general information. There were no significant differences in age (54.4 ± 22.50 years, 60.1 ± 18.4 years, $P > 0.05$), BMI (23.78 ± 4.46 kg/m^2, 25.21 ± 3.26 kg/m^2, $P > 0.05$), or APACHE score (21.92 ± 10.07, 20.58 ± 8.26, $P > 0.05$) between the conventional group and the experimental group, but there was a significant difference in operation time (28.68 ± 14.15 min, 34.96 ± 9.58 min, $P < 0.05$) [Table 2].

Esophagus

In the conventional group, 17 individuals displayed explicit tube sound shadows in the esophageal cross-section, yielding an identification rate of 71%. In comparison, of the 25 individuals in the experimental group, whether the tube entered into the esophagus was determined by esophageal aeration signs [Figure 4]; the tube entered the airway in only one patient, evidenced by its mobility correlated with aeration. After adjustment, the tube was reintroduced into the esophagus, where aeration signs were identified. As such, the identification rate of the tube entering the esophagus was 100%.

Antrum sinus

In the conventional group, the antral cross-section was monitored through ultrasonography to determine whether the tube entered the antrum based on the tube sound shadow. Subsequently, the tube was advanced to a depth of 105–110 cm.

In the experimental group, a progressive water injection method was employed to determine the spatial relationship between the jejunal feeding tube and the antrum. Specifically, the tube was first positioned at a depth of 55 cm. Then, water was injected through the tube for every advancement of 5 cm, during which the cloud sign in the antral longitudinal section was examined in terms of location, orientation, size, and delay after water injection.

Cloud signs were identified in the antrum in 60% of the patients when the tube was advanced to a depth of 65 cm. On the basis of this result, attention was paid to ensure that the landmarks visible through ultrasound probe matched the correct side of the body. The right side (or the left side) was defined as the right side (or the left side) of each individual in the image of the antral longitudinal section. Size referred to the dimensions relative to the cloud sign in the antrum. Delay was defined as the temporal gap between water injection and the appearance of the cloud sign. Observation continued until

Table 2: Patient characteristics of the two groups

Variables	Conventional group (*n* = 24)	Experimental group (*n* = 30)	*t*	*P*
Age (years)	54.4 ± 22.5	60.1 ± 18.4	−1.031	>0.05
BMI (kg/m^2)	23.78 ± 4.46	25.21 ± 3.26	−1.395	0.180
APACHE score	21.92 ± 10.07	20.58 ± 8.26	0.535	0.595
Procedure time (min)	28.68 ± 14.15	34.96 ± 9.58	−1.934	0.046

BMI: Body mass index; APACHE: Acute Physiology and Chronic Health Evaluation.

Table 3: Case numbers according to the tube insertion distances when cloud signs first appeared

Cloud sign	55 cm	60 cm	65 cm	70 cm
Case number	2	5	18	5
Proportion (%)	6.6	16.7	60.0	16.7

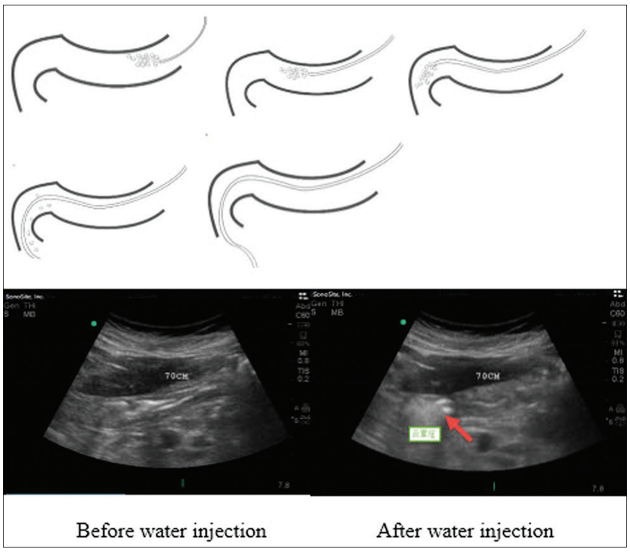

Figure 4: Determination of the relative position between the tube tip and the antral sinus via cloud signs (arrow). Antral progressive water injection method.

the cloud sign disappeared, after which the tube was advanced to a depth of 105–110 cm [Table 3]. The experimental group had a significantly higher rate of successful tube insertion than that of the conventional group ($P < 0.05$).

Discussion

The placement of a jejunal feeding tube started using a guide wire and was first reported in 1991.[11] The success rate of placement of the jejunal feeding tube was between 25% and 92%.[11,12] Such tremendous variation in the success rate was associated with the operator's proficiency and hand feeling.[13] Gastroscopic or intervention guidance is not suitable for Intensive Care Unit (ICU) applications due to various objective reasons. It has been reported in the literature that during ultrasound-guided placement of a jejunal feeding tube, the tube's sound shadow is visible only in the antrum.[9] However, advancing the jejunal feeding tube through the pylorus is only the first step toward successful delivery because the occurrence of improper aspiration could only be minimized once the tube reaches the ascending part of the duodenum and passes the ligament of Treitz.[14] It is recommended that the feeding tube be positioned in the ascending part of the duodenum and its distal end.

A comparison of the general information between the two groups revealed that they only differed in operation time, as the antral progressive water injection method required repeated manipulation and observation, which caused increased operation time. Nevertheless, this method ensured an improved success rate.

The esophageal aeration sign is conducive for the swift determination of the presence of the feeding tube in the esophagus.

Two sites crucial for delivering a jejunal feeding tube are the esophagus and the pylorus. For patients in ICUs who are in comas or who are being given sedative medicine, a severe complication known as pneumothorax may occur if, during delivery of the jejunal feeding tube, the tube is accidentally inserted into the airway. Although the incidence of pneumothorax is low (0.38–1.41%), it can be life-threatening if it occurs. To prevent this complication, some special techniques have been attempted.[15] The traditional method of auscultation can only be performed at a given distance and location. As such, auscultation is not suitable for monitoring tube advancement because if the tube enters the airway, complications may already have occurred. Ultrasonography can identify the esophagus on the left side of the patient's neck. If the tube is advanced into the esophagus, its hyperechoic shadow can be observed. However, it is common in a clinical setting that a patient has received a nasogastric feeding tube before a jejunal feeding tube is introduced. As a consequence, gas appearing in the esophagus may compromise any ultrasonography of the esophageal tube. Therefore, conventional ultrasonographic methods do not yield satisfactory results in tube identification. In particular, mistakes are common in patients who have already received a nasogastric tube. Our observation indicated that during tube delivery, gas injection (10 ml) could better reveal the feeding tube in the esophagus when the tube reached a depth of 20–25 cm (i.e., the appearance of the hyperechoic area and esophagus motions correlated with gas injection). Using this approach, the positive identification rate of the experimental group was 100%. Of note, the distance of the tube from the tip of the nose to the glottis is 25 cm; if this distance is sufficient for determining the tube presence in the esophagus, it can minimize the occurrence of pneumothorax resulting from the accidental introduction of the tube into the airway.[10] In addition, it is important to pay attention to the tube entry depth; if the depth is excessive, no aeration signs can be observed. In the experimental group, only one subject experienced airway tube entry during delivery, which was observed due to esophagus airway motion during gas injection. Esophageal aeration signs reappeared after adjustment. As this group had only one individual who experienced airway tube entry during delivery, more patients are needed to verify whether there is corresponding mobility of the airway after the tube enters the esophagus.

The antral progressive water injection method enables dynamic observation of the relative position between the tube and antrum, thereby improving the success rate of tube placement.

Another key step of a jejunal feeding tube is to advance the tube through the pylorus. There are multiple methods to help determine whether the tube has entered the duodenum: examination of the color and pH of the drainage fluid, determination of carbon dioxide,[9] and palpation.[16] However, these methods can be difficult to apply due to a variety of factors, such as administration of gastric acid inhibitors, under nutritional feeding, sputum obstruction, and unequal volume and force of gas injection.

Clinically, the identification rate of the antrum under ultrasonography is very high. In this study, the antrum was observed in all individuals. For the conventional group, the antrum was observed after the tube sound shadow was noted. However, this method is unable to determine whether the tube enters the ascending part of the duodenum or passes the ligament of Treitz. Furthermore, our observations suggested that monitoring the tube sound shadow was not always reliable, as mistakes can occur due to the tube's complete adherence to the digestive tract wall or the presence of gas in the antrum.

The antral progressive water injection method prevented observation mistakes in the conventional group because antral water injection could help to determine the relative position between the tube tip and the antrum: (1) no cloud sign indicates that the tube did not pass the antrum; (2) if, as the tube is inserted, the cloud sign appears and undergoes changes in size, location, and delay, it suggests that the tube has passed through the antrum and has entered the duodenum and its distal end; (3) if, as the tube is inserted to a depth of 80–85 cm, the cloud sign disappears and does not appear again during continuous observation, it suggests that the tube has entered the duodenum and its distal end; and (4) if, as the tube is being inserted, the cloud sign does not exhibit any changes in location, size or delay with the changes in the insertion depth, it suggests that the tube has not advanced and that readjustment needs to be made. Finally, after the cloud sign disappears, the tube is continued to be delivered to until it reaches a depth of 105–110 cm.

The analysis of placement failure in the two groups: The conventional group had 9 cases of failure, including 5 cases of tube folding in the stomach and 4 cases entering the descending or horizontal portion of the duodenum. The main reason for failure was that after the tube had reached the antrum, it was impossible to make a sound judgment.

The experimental group, which used antral progressive water injection, had 3 cases of failure. The possible causes for these failures are analyzed below: First, for one patient, it was observed that during the placement, the tube reached the antrum but could not pass the pylorus. In addition, repeated position changes, corroborated by changes in the cloud sign, did not allow the tube to pass the pylorus. Therefore, the failure was determined during the operation, which allowed the patient to avoid receiving a radiation-based examination. Second, one patient experienced tube folding in the stomach. It was discovered that the patient had a relatively narrow acoustic window in the antral longitudinal section, which made it difficult for an accurate assessment if the tube was returned to be made. In addition, a too-early disappearance of the cloud sign might suggest that the tube was folded in the stomach.

The study has limitations, such as a small sample size. Furthermore, it is a single-center study.

In conclusion, this new method of ultrasound-guided jejunal feeding tube placement involved two crucial techniques: the esophageal aeration sign and the antral progressive water injection method. The esophageal aeration sign can inform the surgeons that the tube has entered the esophagus, thus avoiding its introduction into the airway and the resulting complications. The antral progressive water injection method enables the relative position between the tube tip and the antrum to be identified. As such, this new procedure is an improvement over the conventional method and increases the success rate of feeding tube placement.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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超声引导胃窦渐进式注水法放置空肠营养管研究

摘要

背景：空肠营养管使得重症患者营养支持更安全和更容易，但是放置空肠管有一定难度。本文介绍超声引导胃窦渐进式注水法放置空肠营养管并证明其有效性

方法：纳入2016年4月~2017年4月入住北京协和医院重症医学科54名需要放置空肠营养管的患者，患者分两组进行空肠营养管放置。

结果：两组患者年龄、体重指数、急性生理及慢性病评分没有差别，但是操作时间上有差别，对照组（24例）：导管进入食道后，能够通过超声确切判断导管声影的患者有17例；而实验组（30例）采用食道注气法判断导管在食道内的患者有30例。对照组通过观察导管进入胃窦成功15例，失败9例，成功率63%；实验组：通过胃窦渐进注水法成功27例，失败3例，成功率90%。两组成功例数存在差异(χ^2=5.834, P =0.022)。

结论：采用超声引导渐进式注水法放置空肠营养管比传统的超声方法更有效。