Review Article

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Application of Electromagnetic-Guided Intubation in Post-Pyloric Feeding Patients

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ABSTRACT

The accuracy of the nasoenteral tube tip position is the most crucial factor for ensuring the safety and effectiveness of enteral nutritional support in patients after pyloric feeding. Electromagnetic-guided is a new positioning technology used for nasal gut tube catheterization and endoscopy. It is both safe and effective, allowing for accurate positioning. Additionally, and has been well evaluated domestically and internationally. This review focuses on the technical principles of electromagnetic -guided and positioning system, as well as the effectiveness, safety, and economic benefits of electromagnetic-guided and nasal gut catheterization to provide a reference for clinical practice and research.

Keywords: Electromagnetic-Guided, Posterior Pyloric Feeding, Nasoenteral Canal, Tip Positioning

Introduction

Malnutrition is one of the main factors leading to adverse clinical outcomes in patients with severe diseases. Enteral nutrition is more physiological than parenteral nutrition, which is economical and convenient. Furthermore, enteral nutrition is preferred for patients with a functional and safe gastrointestinal tract and nutritional risk and/or malnutrition [1,2]. The 2023 guidelines for the clinical application of parenteral nutrition in Chinese adult patients recommend post-pyloric feeding for patients with severe gastric retention and inability to tolerate gastric feeding [3]. This is crucial for improving their nutritional status as early as possible as well as reducing the incidence of aspiration pneumonia. Nasoenteral tube feeding is the primary method of achieving post-pyloric feeding [4]. Currently, there is no uniform standard or evident benefit for the nasoenteral tube implantation method.

The electromagnetic-guided and positioning system employs magnetic guidance to dynamically display the process of the nasoenteral canal through the pylorus and confirm the location of the nasoenteral canal tip through the track map. Over recent years, the electromagnetic-guided and positioning system has been successfully used in hospitals domestically and internationally to locate the nasal tube tip. Electromagnetic-guided features a high success rate of catheterization, positioning accuracy aligning with X-ray results, and fewer complications, all of which have been highly praised [5]. Many scholars believe that electromagnetic-guided is the preferred alternative to nasoenteral catheterization. Nonetheless, strong evidence supporting this conclusion is lacking. The progress of electromagnetic-guided for nasal catheterization is summarized as follows.

Composition and Technical Principles of the Electromagnetic-Guided

The electromagnetic-guided utilizes the constant speed of electromagnetic waves propagating in space to determine the location of targets by measuring their propagation times and signal strengths. Subsequently, through an intelligent analysis system, the electromagnetic signal changes and is displayed as trajectories. The operator dynamically tracks and locates with precision based on whether the trajectory follows the correct path [6]. The equipment comprises four parts-a display, a magnetic field generator, a scaler, and a tracking sensor (guidewire) [7]. The magnetic field generator is placed on one side of the patient's trunk, generating a certain range of magnetic fields (600 × 600 × 500 mm) to cover the body. The tip of the scaler faces the head of the patient and is smoothly fixed at the xiphoid (the position of the gastric area) to ensure accurate positioning. When the tip of the nasoenteral tube with the sensor enters the magnetic field

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through the esophagus, a yellow track line moving vertically along the "Y" axis appears on the screen. When the track line is displayed below the "X" axis, the nasal tube enters the stomach through the gastroesophageal junction, presenting a "J" -like curve in the stomach. When passing through the pylorus, the trajectory line shows a similar "C" curve after rising, confirming that the nasal canal is passing through the horizontal site of the duodenum. When the track line appears stacked, one can see whether the nasal gut tube is discounted in three-dimensional orientation. If recatheterization is required, a guidewire can be inserted directly into the nasal gut tube for repositioning.

Overview of the nasoenteral Catheterization Technique

Nasoenteral catheterization involves catheter placement in the duodenum or jejunum through the esophagus to provide enteral nutrition. The depth of catheterization in adults generally ranges from 95 to 100 cm. Indications for nasoenteral tube insertion include mechanically ventilated patients, patients who cannot tolerate intragastric feeding and gastric retention, patients with a high risk of reflux and aspiration, and patients with severe pancreatitis and gastroesophageal fistulas. Relative contraindications include complete obstruction of the mouth, nose, or esophagus, severe and uncorrectable coagulopathy, and anatomical deformities in the digestive tract [8].

Frequently used clinical nasoenteric tube placement methods include blind insertion, which requires high technical skills and X-ray positioning of the catheter tip; fluoroscopic placement, which allows direct positioning of the catheter tip but carries risks of transport and radiation; endoscopic placement, which can be performed bedside without the need for positioning, but the waiting time is uncertain and there are more complications related to tube placement; ultrasound-guided placement, which allows real-time bedside guidance, is non-invasive, and radiation-free, but has strong operator dependency [9]. Currently, there is no unified standard for nasoenteral catheterization; clinical catheterization methods are selected according to the patient's condition and existing medical resources.

Application effect of the Electromagnetic-Guided

Current Situation of Foreign Electromagnetic-Guided and Tube Setting:

Success Rate of Electromagnetic-Guided and Tube Setting

The key to the success of the nasal tube is whether the tip of the catheter reaches the duodenum or the jejunum [10]. Currently, national and international guidelines and expert consensus do not unify the position of the tip of the nasoenteral tube, and there are different criteria for the success of nasoenteral tube catheterization in various diseases [11]. Therefore, the success rates of catheterization are also vastly different and cannot be effectively compared. The majority of foreign studies have involved severely ill patients in gastrointestinal surgery [12]. utilized electromagnetic-guided for nasoenteral catheterization in ordinary patients and indicated a success rate of 89.4% [13]. Obtained consistent results (88%) and then performed electromagnetic-guided catheterization for severe patients, with a success rate of 72% [14]. Selected 81 ICU patients with bedside electromagnetic-guided, with a success rate of 78%. In the studies conducted by Akers and Pinsky and Taylor et al., nasoenteral tubes were placed under electromagnetic-guided in mechanically ventilated patients, with a tube placement success rate of 87%. Kaffarnik et al. reported a success rate of 79%, which increased to 90% [15-17].

According to these aforementioned studies, the success rate of electromagnetic-guided catheterization in severely ill patients is significantly lower than that in other patients receiving post-pyloric feeding, which may be related to the fact that severely ill patients often have gastrointestinal dysfunction. Endoscopic catheterization is the gold standard for nasoenteral tube catheterization [18,19]. Moreover, there are few control studies on electromagnetic-guided and endoscopic catheterization [13,20-22]. The Dutch scholar Gerritsen used electromagnetic-guided and endoscopic catheterization for patients with postoperative gastrointestinal surgery. When the catheterization depth was defined as the duodenojejunal curvature, 82% (74/90) and 88% (140/159) of patients in the electromagnetic-guided group and endoscopy group, respectively, had successful initial catheterization (P = 0.20) [23].

It is worth noting that anatomical changes in the digestive tract are traditionally regarded as relative contraindications for nasal tube catheterization. Some researchers have attempted using electromagnetic-guided for catheterization in patients after pancreaticoduodenectomy, with a success rate of only 58%, but this is still 5% higher than the success rate of endoscopic tube placement [24]. Although there are some differences in the results of diverse studies, the success rate of electromagnetic -guided catheterization is not lower than that of endoscopic catheterization, proving that electromagnetic-guided is as effective as endoscopic catheterization and is expected to be widely performed in clinical practice. Nevertheless, whether electromagnetic-guided can replace endoscopy as the preferred technology for nasal catheterization requires more supportive evidence [25].

Accuracy of Electromagnetic-Guided and Positioning

Radiography is the gold standard for locating the tip position of the nasal canal. Hemington-Gorse et al. revealed that the accuracy of the nasal gut tube in patients with severe burns was 84%, with the results being consistent with the X-ray findings, indicating that electromagnetic-guided and positioning have high accuracy. Jacobson et al. reported that 96.5% of cases were confirmed by X-ray, and the tube end position was reconfirmed at 12–49 h after insertion, with 89.5% of cases matching the X-ray results. Powers et al. [26,27,18].

Showed that electromagnetic-guided and abdominal X-ray alignment were up to 99.5%. A study abroad and the research results of Zhang Xuan et al. and Shen Ruting et al. in China both achieved 100%.Rivera et al. compared electromagnetic-guided and X-ray utilization and pointed out that X-ray confirmation was required only if the catheter tip was suspected to be in the proximal duodenum [17,28-30]. In summary, electromagnetic-guided can accurately locate the nasal tube tip without the need to locate the X-line again, thereby avoiding radiation and reducing the cost of catheterization.

Clinical Safety of the Electromagnetic-Guided and Positioning System

Complications linked to nasoenteral tube placement include ectopic catheters, nausea, nasal mucosal bleeding, and

gastrointestinal bleeding. Catheter displacement is the most common and serious complication of blind insertion [31]. In a study on airway insertion and pneumothorax, Koopmann et al. showed that electromagnetic -guided insertion did not have any of these complications, resulting in increased airway placement (3/143, P = 0.001) and pneumothorax (2/143, P = 0.001). Arjaans et al. conducted a literature search and identified 32 studies documenting electromagnetic-guided lung placement and/or catheter-related complications in 202 electromagnetic-guided catheterization procedures [32,33].

During 199 operations, the operator tracked the catheter into the airway through electromagnetic-guided and immediately removed it, suggesting that electromagnetic-guided enables early identification of nasoenteral tube misplacement, which leads to timely catheter removal and reduction in the risk of pulmonary complications. A previous study confirmed that the endoscopic catheterization time was shorter than the electromagnetic-guided; however, the total catheterization time was longer than the electromagnetic-guided [24]. Endoscopic catheterization is an invasive procedure that can easily damage the digestive tract mucosa; in another study, it was found that there was no difference in the incidence of epistaxis when comparing electromagnetic -guided and endoscopy. Gerritsen et al. [21,34].

Reported that the incidence of nosebleeds was significantly lower with electromagnetic-guided than with endoscopy (0.4% vs. 4%) and that there were no catheterization-related complications even in the upper gastrointestinal tract during catheterization [24]. In the study by Gao et al., two patients developed hypoxia under endoscopic catheterization and had prolonged hospitalization for 3 days [22]. Owing to the large friction between the endoscope and catheter, the mirror can sometimes bring the nasal gut tube out of the duodenum. A previous study showed that the incidence of complications (mainly catheter displacement and/or obstruction) after catheterization was the lowest in the electromagnetic-guided group, followed by the fluoroscopy and endoscopy groups [34]. In a single-center study, 14 (39%) of 36 patients had tube displacement and/or blockage, whereas 8 (47%) of 17 patients in the endoscopy group had tube displacement and/or blockage (P = 0.57) [18].

Longer catheterization times increase patient discomfort and the risk of adverse consequences. Therefore, minimizing the duration of catheterization is preferable. In the study conducted by Kappelle et al., the time taken for the middle tube was 30 min, which increased up to 13 min after skilled operation [13]. In terms of the patient's feelings and overall recommendations, the discomfort was higher in the electromagnetic-guided guidance group than in the endoscopic group; a possible reason for this was that the electromagnetic-guided group consisted of all awake patients [20]. However, 82% of patients in the endoscopic group used sedatives, and the overall recommended score was higher. Therefore, electromagnetic-guided has a shorter duration, fewer complications, and requires fewer patients.

Economic benefits of the Electromagnetic-Guided

Blind insertion requires only nasal tube material, and the catheterization cost is the lowest among all methods. Equipment cost is incurred for electromagnetic-guided, endoscopy, ultrasound, and fluoroscopic catheterization. The existing literature only reports on the cost-effectiveness of electromagnetic navigation and endoscopic catheterization, and few studies have been conducted. Gerritsen et al. and Kappelle et al. reported similar catheterization costs ($585.2 ± 47.6 and $543.3 ± 335.8, respectively), which were lower than those of endoscopic catheterization. In contrast, Gao et al. showed that the cost of electromagnetic-guided management ($301) was lower than that reported by the two previous studies, which may be related to the instrument, production technology, and import tariffs [22].

It is worth noting that the study also took into account the catheterization-related complications and post-intervention costs, with a total cost saving of approximately $100 compared to that for endoscopic catheterization. Although the initial investment in electromagnetic-guided is relatively high, it lowers the overall medical costs by reducing unnecessary consumption of medical resources. In the long run, electromagnetic-guided is a more economically efficient choice [35]. There is no need to use analgesics or sedatives in the process of electromagnetic-guided and catheterization, which undoubtedly reduces the treatment cost compared to endoscopy. Therefore, considering the patients' economic condition, blind insertion is the best choice for patients with poor economic conditions; however, if electromagnetic-guided and endoscopy are chosen, electromagnetic-guided may be more economical.

Research status of Electromagnetic-Guided in China

Success rate and Positioning Accuracy of Electromagnetic-Guided and Catheterization

Few studies in China have investigated electromagnetic-guided, which is mainly compared with the blind insertion method. Nevertheless, the research subjects are not limited to gastrointestinal surgery and severely ill patients, but also include patients with end-stage tumors or high paraplegia, older patients, and other patients with reduced gastrointestinal function. Xuan et al.[35] reported an electromagnetic -guided success rate of 92.5% for catheterization in cancer patients. Xiuhua selected 73 cases of terminal cancer patients, of whom 70 (95.89%) successfully underwent electromagnetic-guided in one attempt. Jinmin et al. performed nasojejunal tube placement with electromagnetic-guided on 32 patients with cervical fractures and high-level paraplegia, with successful placement in one attempt in 30 patients. Xiao et al. reported a nasoenteral catheterization success rate of 95.7% for nasoenteral catheterization with electromagnetic-guided in older bedridden patients. Ruting et al. [28,29,36-38].

performed a study on general surgery patients and reported a catheterization success rate of 97.6%; 38 patients were mechanically ventilated, and the accuracy rate was up to 100% by X-ray. Additionally, Xuejin et al. reported that the success rate of bedside EMV placement in patients undergoing gastrointestinal surgery was 93.2%. Zhao Xin in a randomized control study showed that of 190 patients admitted to the neurosurgery intensive care unit, the success rate of nasal tube and electromagnetic -guided and the success rate of catheterization was 97.9%, proving that electromagnetic-guided is suitable for any patient with pyloric feeding indications, and the success rate of catheterization was significantly higher than that in foreign studies, which may be related to the severity of

disease in patients, and more importantly, the routine use of gastrointestinal motility drugs before catheterization [29,39,40].

Clinical safety of Electromagnetic-Guided

Xuejin et al. found no serious complications during catheterization in 117 patients (only one minor nasal mucosal bleeding in a patient with a history of long-term nasogastric tube placement). Xiao et al. reported an incidence of 6.5% for epistaxis and a positive rate of 2.2% for fecal occult blood test, which may be related to mucosal thinning in older patients and their vulnerability to injury during tube placement [39,38]. In addition, some studies showed that the positive rates of fecal occult blood, mean arterial pressure, and internal abdominal pressure were statistically significant ($P < 0.05$), indicating that nasoenteral tube placement under magnetic navigation guidance can effectively reduce the stimulation of the gastrointestinal tract and nerve function during the process of catheterization and prevent the occurrence of complications such as gastrointestinal flatulence and elevated blood pressure caused by frequent gas injections to confirm the tip position and change position during the operation [41].

Domestic and foreign countries are basically similar in terms of catheterization time, with an average time of approximately 15 min. Xuan et al. reported that the insertion time of electromagnetic navigation was 15.94 ± 1.71 min, and the recovery time of vital signs was 14.93 ± 1.65 min [38,29,42,28]. When compared with the study by Xiuhua and Jun the results were highly consistent, with an average catheterization time of 13 min and recovery of vital signs in 94.52% of patients at 15 min after catheterization [36]. Compared with the blind intubation method, the catheterization and recovery times of vital signs were significantly shortened. Wu Lei had a relatively long catheterization time of (18.55 ± 7.26) minutes, due to the significantly higher difficulty of catheterizing pancreatitis patients compared to other critically ill patients [41,43].

Advantages, Limitations, and Application Prospects of the Electromagnetic -Guided

Advantages

Electromagnetic-guided opens up a new technique for nasal tube catheterization, having the following advantages:

1. Electromagnetic-guided is easy to operate, can be operated by trained nurses, and catheterization success rate is 95%, saving the cost of endoscopic technicians.
2. The strength of the magnetic field is equal to the earth's magnetic field, and the entire operation is performed under a weak magnetic field. There is no need to confirm the position of the catheter tip via radiography, which reduces the exposure of doctors and patients to potentially harmful radiation.
3. The guidewire can predict the operative direction, avoid entering the airway, and reduce the risk of permanent pipeline dislocation into the lungs.
4. Real-time guidance and positioning beside the bedside minimizes waiting time. Compared with popular blind insertion and endoscopic catheterization, the catheterization time is shorter, which shortens the start time of enteral nutrition and is conducive to the improvement of patient prognosis.
5. in later stages, there is no need to remove the catheter, which reduces the risk of catheter replacement.
6. Patient satisfaction surveys, electromagnetic-guided, and positioning system-guided nasal tubes are more easily accepted by patients.

Limitations

Although the electromagnetic-guided has been widely praised, there are still some challenges in its application:

1. Electromagnetic-guided, like other electronic devices, may be disturbed by other medical devices, wireless communication equipment, and other external electromagnetic sources, affecting the accuracy of positioning.
2. At the same time, if the patient has metal implants (such as pacemakers, metal dentures, etc.), they may interfere with the distribution of electromagnetic fields and affect the accuracy of navigation.
3. Electromagnetic-guided require high-precision sensors and complex algorithms, which result in high equipment and maintenance costs.
4. Electromagnetic-guided is not visual and cannot directly examine the digestive tract.
5. The electromagnetic-guided is a single-lumen nasoenteral tube that cannot meet the requirements of simultaneous decompression and tube feeding in patients with severe gastric retention.
6. Electromagnetic-guided penetration is too strong to form a tissue contour, which needs to be improved in subsequent research and development.

Summary

Nasoenteral tube placement should consider the accessibility of medical resources, catheterization complications, the risk of transporting patients, and the impact of delayed enteral nutrition owing to catheter placement. Electromagnetic-guided is a new type of intestinal catheterization technology that can guide the intestinal tube in real-time, and the accurate positioning of the catheter tip position requires only one trained nurse beside the bed, reducing the risk of transshipment and the cost of technical support from other departments. Moreover, bedside waiting time and catheterization time are short, and the time from receiving the installation instruction to successful installation should not exceed 3 hours, greatly shortening the amount of enteral nutrition supply time, enabling patients to achieve the target feeding amount as soon as possible. With few complications related to electromagnetic-guided catheterization and high acceptance by patients and their families, it is expected to become the preferred method for nasoenteral catheterization in the future.

Author Contribution

Y.J consulted the literature and wrote the manuscript. L.H provided critical revision. All authors contributed to the article and approved the submitted version.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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