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Narrative Review

Technology advances in the placement of naso-enteral tubes and in the management of enteral feeding in critically ill patients: A narrative study

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SUMMARY

Enteral feeding needs secure access to the upper gastrointestinal tract, an evaluation of the gastric function to detect gastrointestinal intolerance, and a nutritional target to reach the patient's needs. Only in the last decades has progress been accomplished in techniques allowing an appropriate placement of the nasogastric tube, mainly reducing pulmonary complications. These techniques include point-of-care ultrasound (POCUS), electromagnetic sensors, real-time video-assisted placement, impedance sensors, and virtual reality. Again, POCUS is the most accessible tool available to evaluate gastric emptying, with antrum echo density measurement. Automatic measurements of gastric antrum content supported by deep learning algorithms and electric impedance provide gastric volume. Intragastric balloons can evaluate motility. Finally, advanced technologies have been tested to improve nutritional intake: Stimulation of the esophagus mucosa inducing contraction mimicking a contraction wave that may improve enteral nutrition efficacy, impedance sensors to detect gastric reflux and modulate the rate of feeding accordingly have been clinically evaluated. Use of electronic health records integrating nutritional needs, target, and administration is recommended.

1. Introduction

Nasogastric tubes (NGT) have been used for dozens of years for decompression of the stomach and administration of drugs and enteral feeding [1]. Many NGTs (USA: ~1 million; Europe: ~10 million) are introduced yearly [2,3]. Despite wide use, nurses' knowledge about insertion and tube location is insufficient [4,5]. The NGT insertion is blind, and the tip position is not always confirmed. The placement of an NGT without vision is contraindicated where congenital, surgical or traumatic anatomical defects present a high risk of perforation. This includes trauma to the face or the base of the skull in case of danger of introducing the tube to the brain, trauma to the esophagus, and ingestion of toxic substances into the esophagus [1]. The procedure may be associated with complications such as bleeding from the nose, the oropharynx, the esophagus, or misplacement of the NGT. Misplacement is the most challenging complication. Obstacles inhibiting NGT progression can occur at the following anatomical sites: nose, nasopharynx-esophagus, and stomach-upper and lower. Taylor et al. [6] evaluated the anatomical sites that could impair the progression of the NGT: from 913 tube placements, placement at the level of the nose or mouth was smooth, however, 30 (3.3 %) presented difficulty with advancement at this site. In only a small number of cases, a nasal airway was needed for the advancement of the NGT. Progressing from the pharynx to the esophagus was difficult in 24.5 % of the cases, and 10.6 % of the tubes were found to be in the airways. They were removed. According to Taylor, the following techniques could allow a better passage through the pharynx toward the stomach: tilting the head, thrusting the jaw, performing a laryngoscopy; insufflating air in

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the stomach (upper or lower), performing a flexible tube tip ± reverse Seldinger maneuver; using a flexible tip and wire stiffener; or administrating prokinetic drugs.

2. Current technologies

The current accepted clinical approach to introducing nasogastric tubes is to proceed through the nose and reach Xyphoid-ear-nose (XEN)+10 cm so that the tube's tip will be placed at least 3–7 cm below the esophagogastric junction [7]. However, blind insertion may be associated with misplacement: if too short, it could be associated with risks of aspiration, and if too deep, it could be associated with a kink of the tube in the stomach, an upward curl into the esophagus, or entrance into the duodenum [8]. Complications such as malposition occur in 0.5–16 % of cases, as well as misplacement in the pharynx, the mediastinum, the trachea, or the pleural spaces, and even in the skull. Respiratory misplacement occurs in 1.83 % of placements with 0.52 % developing pneumothorax. pneumonia, empyema, or even lung abscess [9–11]. 97 % of lung complications occur in-procedure [11]. Many confirm the placement by pH testing. The NHS has recommended colorimetric pH sticks or probes or meters testing to detect NG position [12,13]. Fluid may be of gastric origin if pH is below 5.5. Two studies have proposed this method as safe and reliable [14,15]. The method could fail when the patient suffers from hypochloridria, receives proton pump inhibitors, or if the fluid collected has been moved from the stomach to the lung. In addition, overall, 50 % of end-of-procedure pH fails because the pH is above the accepted threshold [16,17].

It may be useful to use a CO2 detector to recognize the location of the tube in the airways [18]. Colorimetric capnography has also been evaluated with satisfactory results [19]. CO2 level detection has been assessed recently and seems to have the potential to be of high sensitivity and specificity for the detection of inadvertent airway nasogastric tube placements in critically ill adults [20]. Detection may decrease the pneumothorax occurrence to 0.02 % [11]. However, because the colorimetric capnograph is not manufactured to fit an NG tube and, therefore, must be connected by an adaptor system, there is room for concern when broadly using this technique.

In more than 20 % of patients, an X-ray was required to confirm the NGT position, even when pH testing was used. This misposition contributed to missed medication and delayed enteral feeding [13]. Some consider that radiological confirmation of blind tube placement may be a gold standard [8]. Limitations of X-ray use are delay in the answer, no radiology facilities [19], X-ray exposure, cost, and possible misinterpretation as well as X-ray confirmation challenged by feeding tube migration. In case of a change in the position of the already inserted tube feeding, some institutions require an X-ray confirmation. Others like Ceruti et al. [18], compared capnography and pH testing. The ETCO2 (end-tidal CO2) ROC (receiver operating characteristic) analysis for predicting NGT tracheal misplacement found a 25.5. mmHg end-tidal CO2 cutoff value with very high sensitivity and specificity ($p < 0.001$). When pH measurement was used, the prediction of NGT correct gastric placement was optimal using a pH cutoff value of 4.25 [18]. In the UK, misplacement of NGT was associated with 21 cases of death and 79 cases of harm between 2005 and 2010 [21]. pdf. The interpretation of X-rays may be a cause of these complications [12]. Others have reported mortality rates of 0.27 % [21,22].

This following review will evaluate the new technologies (Table 1) that can improve safety and even give additional diagnostic and therapeutic benefits to this common daily practice. An update on the different recent tools evaluating gastric emptying and the improvement of nutritional efficacy will also be provided. This review will be based on the last 10 years' publications related to the topic as well as on our experience and practice.

3. Methods

In the last decade, new technologies have been developed to improve the safety and success of introducing a nasogastric tube. In addition, the evaluation of the gastric content has become a topic of discussion, but its accurate measurement has benefited from new techniques. Consequently, the delivery of enteral feeding may benefit from this improvement. This narrative review aims to provide an overall summary of the advanced techniques used to introduce a nasogastric tube and to evaluate the gastric content, extending the search to technologies that may improve nutritional enteral intake. The search was conducted using PubMed, PMC, Google Scholar, and NHS resources in the last 10 years. Key keywords were nasogastric tube insertion, position, malposition, complications, and technologies. Articles were selected to provide the best and most recent description of the techniques with interpretation and critique. A wide variety of studies could be obtained to cover this topic. NGT technology, NGT malposition and ultrasound, NGT position, NGT and feeding, and NGT feeding technology were analyzed for the literature search. Naso-duodenal and naso-jejunal tube insertion techniques were excluded. “Evaluation of gastric volume” was also analyzed by the literature search. Our narrative review included all the articles and reviews relevant to the topic according to the authors' perspectives and interpretations to better understand and deepen the topic of the use of NGT.

4. New technologies

To improve the safety of NGT placement, several new technologies have been developed. During COVID-19, point-of-care ultrasound (**POCUS**) was used extensively [23]. Placement confirmation of the NGT was performed in less than 4 min with very high sensitivity. In addition, in ARDS patients that required position changing (mainly prone position) many times during a day, POCUS was much more practical and was preferred to X-ray. In a prospective randomized study using POCUS to confirm NGT placement, the confirmation and securement of NGT was obtained with a high first attempt success rate, in intubated and non-intubated patients. POCUS-guided NGT insertion could replace X-ray confirmation [24]. However, a Cochrane analysis showed very low certainty of evidence for specificity, mainly because of the low rate of malposition [25]. Fluoroscopy is performed in the radiology suite and allows for continuous visualization of the tube progressing from the pharynx to the oesophagus to the stomach. It needs transport to the radiology department and therefore, is not frequently requested.

Cortrak (CORPAK, AVANOS Medical Inc, USA) is an Electro-Magnetic Sensor Guided Enteral Access EMS-EAS (Cortrak) composed of a stylet that emits an electromagnetic signal transmitted to a receiver that converts the signal into a position of the tube in the esophagus or the abdomen on a screen. In more than 21,000 cases, it has been compared to the blind introduction of NGT. It significantly reduced the risk of the introduction of NGT in the airways, decreasing the risks of pneumothorax and improving the ability to start feeding [26]. Low-use centers have a higher rate of respiratory placement (1.8 %) in comparison to high-use centers (1.4 %, $p = 0.03$), while Cortrak reduces overall pneumothorax risk (0.1 % vs 0.52 % blind), undetected lung misplacement and pneumothorax in low-use Cortrak centres (0.1 %) is higher than with blind placement (0.013 %) [17]. The larger experience and expertise of high-use centers were improved by a validated guide to teach

Table 1
Summary of all the recent technologies aiming to improve the placement of the NGT or the evaluation of the gastric content.

Type of technology	Purpose	Name	Advantage	Positive clinical trial
Ultrasound	Placement of the NGT	Any US	Instead of X ray	+ (11–12)
Electro magnetic sensor guided enteral access	Placement of the naso gastric or duodenal tube	Cortrak, avanos	No need for gastroscopy or fluoroscopy	++ (13–14)
Real-time video-assisted placement	Placement of the naso gastric or duodenal tube	Iris, Cardinal	No need of gastroscopy or fluoroscopy	++ (15–16)
Impedance sensors	Confirmation of the position and maintenance of the naso gastric tube	smART + ART MEDICAL	No need for Xray and stop feeding if out of position	+ (17)
Virtual reality	Predict the success of blind NGT introduction	Angle stomach-pylorus-line c	Higher success in introduction of NG-D tubes	± (18–19)
Ultrasound measuring antrum echodensity	Predict the occurrence of feeding intolerance	Any US	Improve enteral feeding progresses	+ (25–26)
POCUS antrum	GRV calculation by determining the antral cross-sectional area	Any US	Determine gastric content	+ (27–28–29)
Automatic measurements of gastric antrum content	Continuous measurement of gastric content		Prevent aspiration	+ (2–29)
Low-volume intragastric balloon	Gastric balloon motility index	VIPUN gastric monitoring system	Gastric contractions detection	± (30–31–32)
Impedance sensors disposed on the naso gastric tube above the lower esophageal junction	When fluids are reaching the lower sensors Z 1 to Z4, the system stops feeding	smART+ ART MEDICAL	Detects reflux and modules enteral feeding accordingly	+ (17, 37)
Esophageal stimulation	To produce a contraction wave in the esophagus resembling normal swallowing	E-motion medical	Achieve a better feeding efficiency	- (36)
Electric impedance	Measure of gastric content by impedance	Computer-based instrument	Continuous evaluation of gastric volume	
Computerized information systems	Provides comprehensive information regarding the nutritional targets, the prescribed medical nutritional therapy and the received nutrition intake in addition to non-nutritional calories	Metavision	Prevents from under and overnutrition and calculates energy balance	+ (34)

the user to interpret the electromagnetic traces. This method has a success rate of 82.6–85 % [26]. In patients with thrombopenia and/or anticoagulation, Cortrak was a safe, rapid, and efficient technique not associated with severe bleeding [27]. A feeding tube placement team improves the rate of introduction success [28–31]. It is highly user-dependent [28].

Using a **real-time video-assisted placement** (Iris, Cardinal Health, Mansfield, MA, USA), gastric placement is very successful with a rate of 98 % [32]. The technique uses a mini video camera at the tube tip and confirms/re-confirms position using direct vision. The feeding tube placement is guided under direct visualization. Tracheal misplacement was recognized immediately and removed without complications. It occurred in 12 of 40, making the procedure safe regarding the risk of pulmonary malposition [33]. However, the post pyloric placement success rate was reported to be lower than expected (53 %) [32]. Another series of 20 patients with increased gastric residual volume was analyzed for insertion of the post-pyloric tube using IRIS by an experienced health professional. The success rate was 75 % [34]. Direct visualization of the stomach was obtained in almost all cases in another study, suggesting that this technique could replace the X-ray confirmation [35]. A local data analysis showed that Respiratory tube misplacement was detected in the order: X-ray for blind placement < Cortrak traces < IRIS direct vision (1.7 % vs 11.1 %, $p < 0.0001$ vs 18.5 %, $p = 0.003$) [33]. This guidance allowed a fast initiation of enteral feeding [24]. There is an internally and externally validated training guide for IRIS tube placement; this is lacking for Cortrak. However, in comparison to the Cortrak technique, there is no evidence-based, internally and externally validated operator training guide. Taylor et al. [33] recommended that training material should include a video of external placement alongside internal images and a photographic bank to extend operators' training experience.

A smART + device has been evaluated [36]. It includes an NGT equipped with impedance sensors that assist tube localization next to the lower esophageal sphincter and detect subsequent tube movement. The platform informs the user when the NGT is in place and then allows the start of enteral nutrition (EN). When the tube is out of position, an alarm is activated, and the feeding is automatically stopped. The device is not adapted for duodenal feeding. There was a 100 % match in the position determination between the X-Ray and the smART + device in a prospective randomized study [36].

Machine learning has been used as a training tool for NGT insertion [37]. Machine learning uses algorithms trained on data sets to create models that will be able to predict the success of blind NGT introduction. Radiological data from hundreds of patients were analyzed, as well as images of the electronic medical record system, encompassing 3 parameters [38]. These three parameters were angles defined as Angle cardia-pylorus-line a (Angle CPA): the line connecting the cardia to the upper edge of the pylorus and line a, Angle stomach-pylorus-line c (Angle SPC) c defined as the angle formed by the line connecting the lowest point of the lower edge of the stomach with the upper edge of the pylorus and line, and finally Distance line c-pylorus (Distance CP) as defined as the distance from the superior margin of the pylorus to line c (see Fig. 1). The study found that the success rate of blinded placement of NGT for the first time was associated with

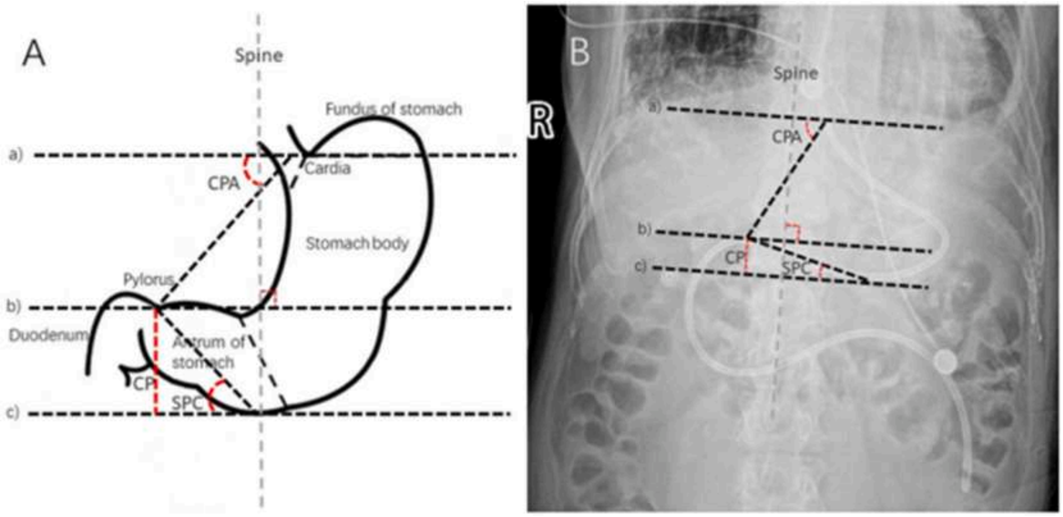

Fig. 1. Based on radiological analysis, Angle cardia-pylorus-line a (Angle CPA) was defined as the angle formed by the line connecting the cardia to the upper edge of the pylorus and line a. The Angle stomach-pylorus-line c (Angle SPC) was defined as the angle formed by the line connecting the lowest point of the lower edge of the stomach with the upper edge of the pylorus and line c. Distance line c-pylorus (Distance CP) as defined as the distance from the superior margin of the pylorus to line c. From [19].

the size of Angle SPC, Distance CP, and pyloric types. Task value, satisfaction, and extrinsic goals were achieved with a higher score in the virtual reality group.

5. Evaluation of gastric emptying

Enteral feeding is recommended as the preferred route for medical nutritional therapy in critically ill patients [39]. Gastric emptying involves coordination of different regions (fundus, antrum, pylorus relaxation and contractions). If impaired it could be associated with increased gastric residual volume. Feeding intolerance (FI) has often been described. It is difficult to define only one symptom [40]. It can manifest as large gastric residual volume (GRV), nausea and vomiting, or inability to reach 70 % of the nutritional target at day 3 [41]. GRV threshold varies from 75 to more than 500 mL according to the authors. It is remarkable to note that GRV was a very poor symptom in definition, and the reported rate of feeding intolerance [42]. The authors concluded that FI should not be determined only on the GRV routine measurement. Analyzing all the GI symptoms and in a secondary analysis of the iSOFA (Sequential Organ Failure Assessment) study, a large variability of GRV measurement techniques was found, but this had no impact on the amount of GRV. High GRV was not associated with mortality or ventilator-free days but may serve as a marker of GI dysfunction and disease severity. Reignier et al. [43] compared patients with GRV measured or not and found that not measuring GRV was associated with improved feeding delivery and no increase in ventilator-associated pneumonia in a medical ICU population fed with full enteral nutrition. However, a large GRV may be associated with poor outcomes [44]. Using the gold standard technique to measure gastric emptying (GE), the GE was delayed in all (23/23) patients with feed intolerance (GRV >250 mL) on scintigraphy [45]. Heyland demonstrated that enteral feeding intolerance (GRV> 250 mL) was associated with increased morbidity and mortality [46]. GRV may not be used as a monitoring tool, as demonstrated by the Reignier study [43]. However, GRV remains valuable with many other parameters to evaluate GI function, diagnose gastrointestinal dysfunction, and define patient prognosis.

Other technologies have been proposed to evaluate gastric volume by **measuring antrum echodensity** using ultrasound. Echodensity expresses the quality of the gastrointestinal tract. It refers to the ability to transmit ultrasound waves in the context of surrounding tissues [47]. Using the POCUS B mode images at the time of the terminal contraction of the antrum, echo density was measured. To calculate the area of the gastric antrum, its anteroposterior and craniocaudal diameters were measured between contractions, and the area of the gastric antrum was calculated as follows: cross-sectional area $=\pi \times$ anteroposterior diameter $\times$ craniocaudal diameter $\div$ 4. There was a strong correlation between this finding and the severity of Acute Gastrointestinal injury (AGI) [48]. Measurement of gastric antrum echo density was feasible with acceptable reproducibility and repeatability. The authors concluded that patients who developed FI also had significantly higher gastric antrum echo density on the first day of enteral feeding. Gastric antrum echo density might be able to predict the occurrence of FI at EN initiation and guide the management of FI in critically ill patients [47]. It can predict the success of prokinetic therapy or choice for duodenal tube insertion [49].

POCUS is simple to use, does not endanger the patient, and if used in a dynamic time monitoring way, can allow GRV calculation by determining the antral cross-sectional area (CSA). The liquid or solid contents of the stomach can be determined by calculating antral CSA. This is achieved by measuring the 2 perpendicular diameters of the antrum and GRV estimation [50]. Evaluation of GRV may guide health professionals before emergency intubation to prevent aspiration before intubation. A calculated ultrasound gastric CSA cut-off $\geq$9.27 cm^2 (sensitivity 100 %, specificity 87 %) and a USG gastric volume $\geq$111.594 mL (sensitivity 100 %, a specificity 92 %) predicts aspiration [51].

This technology has even been improved using artificial intelligence [52], obtaining automatic **measurements of gastric antrum volume** using algorithms. The estimation of gastric volume is important to define to assess the risks of aspiration. Therefore, the antral cross-sectional area (antral CSA) is measured to evaluate the gastric volume quantitatively. Since the volume of the gastric content varies over time, the CSA area is presented as a line (see Fig. 2). This line indicates the level of gastric volume content over time. This measurement of gastric cross-sectional area (GCSA) by ultrasound would allow the prediction of gastric intolerance in critically ill patients [53]. By using this tool after enteral nutrition initiation, the evaluation of GRV at the end of the 4th hour was an excellent predictor of feeding intolerance [54].

The assessment of gastric motility by measuring the pressure in a low volume **intragastric balloon** mounted on a gastric feeding tube was studied by Goelen [55]. A Gastric Balloon Motility Index (GBMI) was calculated. It was based on the gastric contraction's detection, quoted from no contraction (quote 0) to continuous contractions (quote 1) [56]. This methodology was validated versus manometry with a strong correlation [57] and confirmed when patients were receiving erythromycin infusion and presenting strong contractions. However, Deane and Chapman [58] pointed out that isolated pyloric pressure waves or disorganized waves were not identified by the GBMI algorithm. The balloon may also detect motility from both the fundus and the antrum. Antral activity may be a greater determinant of the gastric emptying rate than fundal activity during critical illness. Therefore, it is still unclear whether this technology will improve enteral feeding administration.

The electric impedance method has been explored to evaluate gastric content [59]. Electric impedance measures the obstruction to electrical current. Ionic fluids composed of bulky organic cations or anions lead to less obstruction, and therefore, after feeding, there will be a decrease in impedance followed by a gradual increase during gastric emptying, in relation to the volume remaining in the stomach. Placing 4 electrodes around the position of the stomach allowed evaluation of gastric content quite accurately. Impedance of the epigastric area is increased by a low-conductivity liquid meal. This impedance value will decrease exponentially with the gastric emptying. In a pilot study [60], impedance was measured using 4 electrodes positioned on the line of the lower stomach with the central pair of electrodes approximately positioned at the two margins of the stomach. If ZE is the impedance at an empty stomach and ZF is the impedance just after feeding a volume V F of liquid food, the variations between these 2 parameters will allow continuous evaluation of gastric volume content.

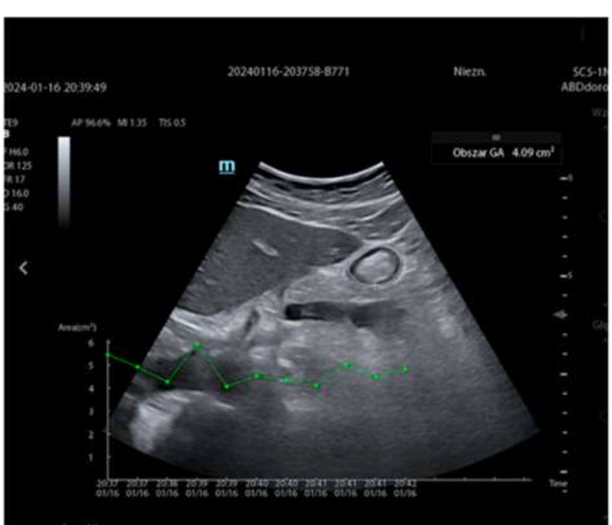

Fig. 2. Using ultrasound, gastric residual volume is calculated by determining the antral cross-sectional area (CSA). Using serial measurements, a trend of this volume can be obtained (green line). From [29].

6. Improvement of nutrition intake

Reflux occurs during mechanical ventilation and when comparing post pyloric to nasogastric enteral tube, reflux of gastric content was significantly higher with gastric nutrition (OR = 8.23; 95 % CI: 2.43–27.89) [61]. Heyland et al. [62] used **esophageal stimulation** to overcome gastrointestinal intolerance and achieve better feeding efficiency. E-Motion Medical (EPG-1000 E-Motion Medical, Tel Aviv, Israel) developed an oral/nasogastric tube producing a contraction wave in the esophagus. This wave resembles swallowing. The device incorporates eight pairs of electrodes at 3 cm intervals and a stimulator that serially activates the electrodes. A phase II trial included long-term ICU stayers receiving opiates. The group was compared to a control group. The nutrition protocol was similar in the 2 groups. The study could not find a significant advantage in the study group, with the same level of nutritional efficiency reaching around 62 % of the target in both groups. However, there were significantly more patients actively treated for cardiac arrhythmias with either medication or cardioversion in the intervention group (26 % vs 12 %; p = 0.03) [62]. Because nutritional input was not improved, the risk of cardiac arrhythmias precludes clinical use.

The smART + design enables the detection of both minor and massive presence of fluids in the esophagus, using **impedance sensors** disposed on the nasogastric tube above the lower esophageal junction (36, 63, see Fig. 3). When fluids reach the lower sensors Z1 to Z4, the system stops feeding. When fluids reach the upper sensors Z5 and Z6, or when fluids stay in contact with the sensors for more than 15 s, the system not only pauses feeding but also opens the nasogastric tube to allow residual fluid to be drained. This continuous monitoring allows the feeding to be adapted to the stomach's compliance and its ability to cope with the feeding load. Moreover, if an interruption occurs due to a diagnostic or a therapeutic procedure, this time will be automatically compensated to reach the nutritional target at the end of the

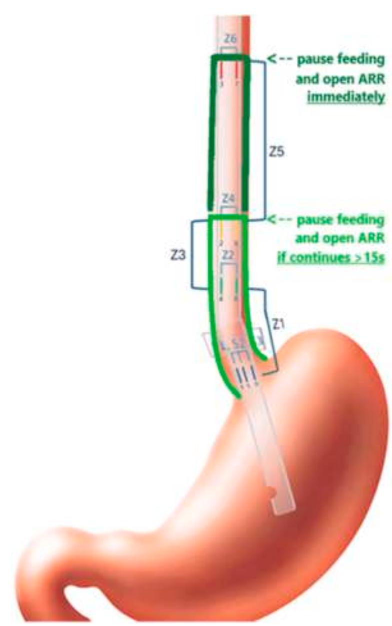

Fig. 3. The nasogastric tube (14 French) from the smART + platform is equipped of 2 impedance sensors Z1 and Z2 that confirm the position of the tube in place when these sensors are close to the lower esophageal sphincter. The impedance sensors Z2 to Z4 deliver a message to stop the enteral feeding when reflux is in contact with them. When this contact is longer than 15 s or is the reflux reaches Z5 and Z6, activate the gastric residual release. From [48].

24 h. GRV is usually measured electively once a shift or ad hoc. In the smART platform, elective GRV is replaced by an active residual release (ARR). In case of the presence of massive residual fluid, the system stops the feeding, and the NGT is opened for the release and collection of gastric fluid that may induce regurgitation and aspiration. In the Kagan et al. study, the mean maximal and daily active residual release (ARR) was low in comparison to the gastric residual volume measured using the standard method [36]. These findings suggest that continuous monitoring of the gastric function using gastroesophageal reflux detection may be an alternative to the evaluation of gastric function using GRV. These findings also suggest that GRV measurement is of less importance. Interestingly, it was observed that during the High Flow Nasal Cannula Oxygen Therapy, which is used quite frequently in the ICU, the ARR was increased in comparison to the ARR obtained during mechanical ventilation in the same patients [63]. This new technology creates new opportunities to explore the enteral feeding limitations and efficacy in various clinical settings.

7. Chyme reinfusion

In patients with intestinal failure with proximal high output stoma or fistula and existing distal stoma, reinstallation of intestinal chyme is feasible using new technology [64]. Described firstly by Etienne Levy in 1983, many chyme reinfusion methods have been described. A review of hundreds of cases shows significant clinical improvement in terms of the ability to stop parenteral nutrition, improve weight, and decrease liver function test disturbances. This technique was used in the past, but the technology has been improved significantly (The Insides System™, Australia). Effective use of the device was easily learned by the patients with minimal demands on nursing assistance [65,66].

Computerized information systems have been progressively implemented and can provide comprehensive information regarding the nutritional targets, the prescribed medical nutritional therapy, and the received nutrition intake in addition to non-nutritional calories such as propofol or citrate. This information allows health professionals to determine energy and protein intake, alert for under or overnutrition, lipid overdose from propofol, and prevent refeeding syndrome. An additional value of these information systems is the ability to create specific windows grouping all the nutrition variables enabling the practitioner to analyze all the parameters immediately. Trends of medical nutritional therapy, calculated energy and protein balances, and integration of days and weeks of hospitalization are better understood while using these electronic medical records [67–72].

8. Conclusions

Improving technology can assist health professionals in the determination of the positioning of NGTs and the evaluation of the gastric content, even in a continuous way. Ultrasound is a widely available tool and increases the ability to assess the stomach [43]. POCUS use could help to confirm NGT position and gastric content. Collecting increasing amounts of data from radiological confirmation of nasogastric tubes allows predicting the success of blind insertion of an NGT using artificial intelligence interpretation of X ray. Magnets or small video cameras included in the NGT facilitate a better positioning without the need for radiological confirmation. However, these techniques need experienced users. A gastric balloon but also the echodensity of the antrum can more accurately evaluate gastric emptying. Abdominal electric impedance may measure gastric volume. Impedance sensors placed on the NGT can confirm the appropriate position of the NGT and the occurrence of gastric reflux. If this reflux is massive, feeding will be interrupted, and residual release will be activated to decrease the risk of aspiration. These techniques should be confirmed by more studies. Finally, computerized information systems that closely monitor feeding administration can prevent under or overfeeding. Implementation of many of these technologies is already successful.

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Declaration of competing interest

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ES has no conflict of interest to declare.

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References

[1] Vadivelu N, Kodumudi G, Leffert LR, Pierson DC, Rein LK, Silverman MS, et al. Evolving therapeutic roles of nasogastric tubes: current concepts in clinical practice. Adv Ther 2023 Mar;40(3):828–43.
[2] Blumenstein I, Shastri YM, Stein J. Gastroenteric tube feeding: techniques, problems and solutions. World J Gastroenterol 2014;20(26):8505–24.
[3] Sumant O. Nasogastric tubes market: global opportunity analysis and industry forecast, 2022–2029 [internet]. London, United Kingdom: Allied Market Research; 2022. Available from:https://www.alliedmark etresearch.com/nasogastric-tubes-market-A10901.
[4] Turan Mensure PhD, RN, Cengiz Zeliha PhD, RN, Olmaz, Dilek PhD RN. Evidence-based investigation of nurses' nutrition interventions in intensive care patients regarding enteral nutrition. Dimens Crit Care Nurs 2024;43:123–9.
[5] Sancar, Behire; Surmeli, Yagmur; Dogan, Ayse Buket; Ozcanarslan, Fugen. Nurses' knowledge and practice of nasogastric tube placement: a descriptive research study. Gastroenterol Nurs 46(1):p 47-53.
[6] Taylor SJ, Sayer K, White P. Nasointestinal tube placement: techniques that increase success. J Intensive Care Soc 2023;24(1):62–70.
[7] Cirgin Ellett ML, Beckstrand J, Flueckiger J, Perkins SM, Johnson CS. Predicting the insertion distance for placing gastric tubes. Clin Nurs Res 2005;14(1):11–27.
[8] Boeykens K, Holvoet T, Duysburgh I. Nasogastric tube insertion length measurement and tip verification in adults: a narrative review. Crit Care 2023 Aug 18;27(1):317.
[9] Halloran O, Grecu B, Sinha A. Methods and complications of nasoenteral intubation. JPEN - J Parenter Enter Nutr 2011;35(1):61.
[10] Taylor SJ. Guided feeding tube placement. Bristol UK: Silhouette Publications; 2022.
[11] Taylor SJ. Feeding tube safety: national guidance ignores the 'elephant in the room'. Int J Risk Saf Med 2024 Nov 5. 9246479241295560.
[12] NHS Improvement. Resource set initial placement checks for nasogastric and orogastric tubes. NHS Improvement 2016. https://improvement.nhs.uk/documents/193/Resource_set_-_Initial_placement_checks_for_NG_tubes_1.pdf.
[13] Glen K, Weekes CE, Banks M, Arbi I, Hannan-Jones M. A prospective observational study of pH testing to confirm ongoing nasogastric tube position. J Clin Nurs 2024;33:3624–33. https://doi.org/10.1111/jocn.17188.
[14] Gilbertson HR, Rogers EJ, Ukoumunne OC. Determination of a practical pH cutoff level for reliable confirmation of nasogastric tube placement. JPEN J Parenter Enteral Nutr 2011;35:540–4.
[15] Nil MZ, Huddy JR, Priest OH, Olsen S, Philipps LD, Bossyt PMM, et al. Selecting pH cut offs for the safe verification of nasogastric feeding tube placement, a decision analytical modelling approach. BMJ Open 2017;7:e018128.
[16] Earley T, Young A, Pringle S, Clarkson Y, Williams A, Howell R, et al. Fibre-optic, electronic pH test device compared with current NHS guidance to confirm nasogastric tube placement. BMJ Nutr Prev Health 2022;5(2):306–12.
[17] Taylor SJ, Karpasiti T, Milne D. Safety of blind versus guided feeding tube placement: misplacement and pneumothorax risk. Intensive Crit Care Nurs 2023;76:103387.
[18] Ceruti S, Dell'Era S, Ruggiero F, Bona G, Glotta A, Biggiogero M, et al. Nasogastric tube in mechanical ventilated patients: ETCO2 and pH measuring to

confirm correct placement. A pilot study. PLoS One 2022 Jun 2;17(6): e0269024.
[19] Bennetzen LV, Håkonsen SJ, Svenningsen H, Larsen P. Diagnostic accuracy of methods used to verify nasogastric tube position in mechanically ventilated adult patients: a systematic review. JBI Database Syst Rev Implement Rep 2015 Jan;13(1):188–223.
[20] Chau JPC, Liu X, Choi KC, Lo SHS, Lam SKY, Chan KM, et al. Diagnostic accuracy of end-tidal carbon dioxide detection in determining correct placement of nasogastric tube: an updated systematic review with meta-analysis. Int J Nurs Stud 2021;123:104071.
[21] British Association for Parenteral and Enteral Nutrition (BAPEN). A position paper on nasogastric tube safety. 2020. Available from: https://www.bapen.org.uk/pdfs/ngsig/a-position-paper-on-nasogastric-tube-safetyv2.
[22] Patient safety alert NPSA/2011/PSA002: reducing the harm caused by misplaced nasogastric feeding tubes in adults, children and infants. United Kingdom: National Patient Safety Agency; 2011. http://www.gbukenteral.com/pdf/NPSA-Alert-2011.pdf. [Accessed 14 November 2020].
[23] Tsolaki V, Zakynthinos GE, Zygoulis P, Bardaka F, Malita A, Aslanidis V, et al. Ultrasonographic confirmation of nasogastric tube placement in the COVID-19 era. J Pers Med 2022;12(3):337.
[24] Yaseen M, Kumar A, Bhoi S, Sinha TP, Jamshed N, Aggarwal P, et al. Point-of-care ultrasonography assisted nasogastric tube placement in the emergency department: a randomized controlled trial. Eur J Emerg Med 2022;29:431–6.
[25] Tsujimoto Y, Kataoka Y, Banno M, Anan K, Shiroshita A, Jujo S. Ultrasonography for confirmation of gastric tube placement. Cochrane Database Syst Rev 2024 Jul 25;7(7).
[26] Powers J, Luebbehusen M, Spitzer T, Coddington A, Beeson T, Brown J, et al. Verification of an electromagnetic placement device compared with abdominal radiograph to predict accuracy of feeding tube placement. J Parenter Enteral Nutr 2011;35:535–9. https://doi.org/10.1177/0148607110387436.
[27] Stecher SS, Barnikel M, Drolle H, Pawlikowski A, Tischer J, Weiglein T, et al. The feasibility of electromagnetic sensing aided post pyloric feeding tube placement (CORTRAK) in patients with thrombocytopenia with or without anticoagulation on the intensive care unit. JPEN J Parenter Enteral Nutr 2022 Jul;46(5):1183–90.
[28] Taylor S, Allan K, McWilliam H, Manara A, Brown J, Toher D, et al. Confirming nasogastric tube position with electromagnetic tracking versus pH or X-ray and tube radio-opacity. Br J Nurs 2014 Apr 10-23;23(7):354e8. 352.
[29] McCutcheon KP, Whittet WL, Kirsten JL, Fuchs JL. Feeding tube insertion and placement confirmation using electromagnetic guidance: a team review. JPEN - J Parenter Enter Nutr 2018 Jan;42(1):247–54.
[30] Smithard D, Barrett NA, Hargroves D, Elliot S. Electromagnetic sensor-guided enteral access systems: a literature review. Dysphagia 2015 Jun;30(3): 275–85. https://doi.org/10.1007/s00455-015-9607-4. Epub 2015 May 6. PMID: 25943295; PMCID: PMC4469250.
[31] Bourgault AM, Gonzalez L, Aguirre L, Ibrahim JA. CORTRAK superuser competency assessment and training recommendations. Am J Crit Care 2019 Jan;28(1):30–40. https://doi.org/10.4037/ajcc2019170. PMID: 30600224).
[32] Slingerland-Boot R, Bouw-Ruiter M, van Manen C, Arbous S, van Zanten A. Video-assisted placement of enteral feeding tubes using the integrated Real-time imaging system (IRIS)-Technology in critically ill patients. Clin Nutr 2021 Aug;40(8):5000–7. https://doi.org/10.1016/j.clnu.2021.07.026. Epub 2021 Jul 30. PMID: 34364239.
[33] Taylor S, Sayer K, Milne D, Brown J, Zeino Z. Integrated real-time imaging system, 'IRIS', Kangaroo feeding tube: a guide to placement and image interpretation. BMJ Open Gastroenterol 2021 Oct;8(1):e000768.
[34] Karpasiti T, Shepherd SJ. Bedside post-pyloric tube placement using direct visualisation in mechanically ventilated patients: a single centre case series. Intensive Crit Care Nurs 2022 Jun;70:103222. https://doi.org/10.1016/j.iccn.2022.103222. Epub 2022 Feb 24. PMID: 35221142.
[35] Wischmeyer PE, McMoon MM, Waldron NH, Dye EJ. Successful identification of anatomical markers and placement of feeding tubes in critically ill patients via camera-assisted technology with real-time video guidance. JPEN - J Parenter Enter Nutr 2019 Jan;43(1):118–25.
[36] Kagan I, Hellerman-Itzhaki M, Bendavid I, Statlender L, Fishman G, Wischmeyer PE, et al. Controlled enteral nutrition in critical care patients - a randomized clinical trial of a novel management system. Clin Nutr 2023 Sep;42(9):1602–9.
[37] Lo YT, Yang CC, Yeh TF, Tu HY, Chang YC. Effectiveness of immersive virtual reality training in nasogastric tube feeding education: a randomized controlled trial. Nurse Educ Today 2022 Dec;119:105601. https://doi.org/10.1016/j.nedt.2022.105601. Epub 2022 Oct 12. PMID: 36244254.
[38] Zheng Z, Wang J, Shao Z, Cai H, Lu L, Tang S, et al. Multivariate analysis of factors associated with the successful prediction of initial blind placement of a nasointestinal tube in the stomach based on X-ray imaging: a retrospective, single-center study. BMC Gastroenterol 2024 Aug 23;24(1):284. https://doi.org/10.1186/s12876-024-03363-z. PMID: 39179985; PMCID: PMC11342475.
[39] Singer P, Blaser AR, Berger MM, Calder PC, Casaer M, Hiesmayr M, et al. ESPEN practical and partially revised guideline: clinical nutrition in the intensive care unit. Clin Nutr 2023 Sep;42(9):1671–89.
[40] Bachmann KF, Jenkins B, Asrani V, Bear DE, Bolondi G, Boraso S, et al. Core outcome set of daily monitoring of gastrointestinal function in adult critically ill patients: a modified Delphi consensus process (COSMOGI). Crit Care 2024 Dec 18;28(1):420.
[41] Jenkins B, Calder PC, Marino LV. A systematic review of the definitions and prevalence of feeding intolerance in critically ill adults. Clin Nutr ESPEN 2022 Jun;49:92–102.
[42] Lindner M, Padar M, Mändul M, Christopher KB, Reintam Blaser A, Gratz HC, et al. Current practice of gastric residual volume measurements and related outcomes of critically ill patients: a secondary analysis of the intestinal-specific organ function assessment study. J Parenter Enteral Nutr 2023;47: 614–23.
[43] Reignier J, Mercier E, Le Gouge A, Boulain T, Desachy A, Bellec F, et al. Effect of not monitoring residual gastric volume on risk of ventilator-associated pneumonia in adults receiving mechanical ventilation and early enteral feeding: a randomized controlled trial. JAMA 2013;309:249–56.
[44] Blaser AR, Starkopf J, Kirsimägi Ü, Deane AM. Definition, prevalence, and outcome of feeding intolerance in intensive care: a systematic review and meta-analysis. Acta Anaesthesiol Scand 2014 Sep;58(8):914–22. https://doi.org/10.1111/aas.12302. Epub 2014 Mar 11. PMID: 24611520.
[45] Nguyen NQ, Bryant LK, Burgstad CM, Chapman M, Deane A, Bellon M, et al. Gastric emptying measurement of liquid nutrients using the (13)C-octanoate breath test in critically ill patients: a comparison with scintigraphy. Intensive Care Med 2013 Jul;39(7):1238–46.
[46] Heyland DK, Ortiz A, Stoppe C, Patel JJ, Yeh DD, Dukes G, et al. Incidence, risk factors, and clinical consequence of enteral feeding intolerance in the mechanically ventilated critically ill: an analysis of a multicenter, multiyear database. Crit Care Med 2021 Jan 1;49(1):49–59.
[47] Wang L, Yang H, Lv G, Fu X, Cheng Y, Zhong X, et al. Association of gastric antrum echodensity and acute gastrointestinal injury in critically ill patients. Nutrients 2022 Jan 27;14(3):566. https://doi.org/10.3390/nu14030566. PMID: 35276925; PMCID: PMC8838069.
[48] Hu B, Sun R, Wu A, Ni Y, Liu J, Guo F, et al. Severity of acute gastrointestinal injury grade is a predictor of all-cause mortality in critically ill patients: a multicenter, prospective, observational study. Crit Care 2017 Jul 14;21(1): 188.
[49] Lv G, Zhang T, Wang L, Fu X, Wang Y, Yao H, et al. Prediction of prokinetic agents in critically ill patients with feeding intolerance: a prospective observational clinical study. Front Nutr 2023 Oct 27;10:1244517.
[50] Bouvet L, Mazoit JX, Chassard D, Allaouchiche B, Boselli E, Benhamou D. Clinical assessment of the ultrasonographic measurement of antral area for estimating preoperative gastric content and volume. Anesthesiology 2011;114:1086–92.
[51] Asokan R, Bhardwaj BB, Agrawal N, Chauhan U, Pillai A, Shankar T, et al. Point of care gastric ultrasound to predict aspiration in patients undergoing urgent endotracheal intubation in the emergency medicine department. BMC Emerg Med 2023 Sep 21;23(1):111.
[52] Schroeder J, Sitze Ka Mika S, Gola W, Gil-Mika M, Wilk M, Misiołek H. Ultrasonographic applications of novel technologies and artificial intelligence in critically ill patients. J Pers Med 2024 Mar 7;14(3):286.
[53] El Khoury D, Pardo E, Cambriel A, Bonnet F, Pham T, Cholley B, et al. Gastric cross-sectional area to predict gastric intolerance in critically ill patients: the Sono-ICU prospective observational bicenter study. Crit Care Explor 2023 Mar 20;5(3):e0882.
[54] Ankalagi B, Singh PM, Rewari V, Ramachandran R, Aggarwal R, Soni KD, et al. Serial ultrasonographic-measurement of gastric residual volume in critically ill patients for prediction of gastric tube feed intolerance. Indian J Crit Care Med 2022;26(9):987–92.
[55] Goelen N, Tack J, Janssen P. Erythromycin stimulates phasic gastric contractility as assessed with an isovolumetric intragastric balloon pressure measurement. Neuro Gastroenterol Motil 2021;33:e13991.
[56] Goelen N, de Hoon J, Morales JF, Varon C, Van Huffel S, Augustijns P, et al. Codeine delays gastric emptying through inhibition of gastric motility as assessed with a novel diagnostic intragastric balloon catheter. Neuro Gastroenterol Motil 2020;32:e13733.
[57] Raymenants K, Huang IH, Goelen N, Janssen P, Van Tichelen N, Burton D, et al. Clinical validation of the VIPUN gastric monitoring system versus manometry for the evaluation of gastric motility. Neuro Gastroenterol Motil 2024: e14783.
[58] Deane AM, Chapman MJ. Technology to inform the delivery of enteral nutrition in the intensive care unit. JPEN J Parenter Enteral Nutr 2022;46: 754–6.
[59] McClelland GR, Sutton JA. Epigastric impedance: a non-invasive method for the assessment of gastric emptying and motility. Gut 1985 Jun;26(6):607–14.
[60] Basher A, Moniruzzaman M, Islam MM, Rashid MM, Chowdhury IH, Akm A, et al. Evaluation of gastric emptying in critically ill patients using electrical impedance method: a pilot study. J Med Eng Technol 2022 Jul;46(5):363–9.
[61] Yong A, Li X, Peng L, Cheng S, Qiu W. Efficacy and safety of enteral nutrition in prone position among critically ill ventilated patients: a meta-analysis. Wideochir Inne Tech Maloinwazyjne 2024 Jun;19(2):168–77.
[62] Heyland DK, Marquis F, Lamontagne F, Albert M, Turgeon AF, Khwaja KA, et al. Promotion of regular oesophageal motility to prevent regurgitation and enhance nutrition intake in long-stay ICU patients. A multicenter, phase II, sham-controlled, randomized trial: the PROPEL study. Crit Care Med 2020 Mar;48(3):e219–26.

[63] Hellerman Itzhaki M, Hoshen S, Singer P, Statlender L, Fishman G, Bendavid I, et al. The effect of mechanical ventilation compared to high-flow nasal cannula on gastric residual volume and reflux events using novel automated technology. Clin Nutr ESPEN 2024;63:68–73.
[64] Bhat S, Sharma P, Cameron NR, Bissett IP, O'Grady G. Chyme reinfusion for small bowel double enterostomies and enteroatmospheric fistulas in adult patients: a systematic review. Nutr Clin Pract 2020 Apr;35(2):254–64.
[65] Solis E, Wright DB, O'Grady G, Ctercteko G. Chyme reinfusion nutritional management for enterocutaneous fistula: first international application of a novel pump technique. Colorectal Dis 2021 Jul;23(7):1924–9.
[66] Liu C, Bhat S, Bissett I, O'Grady G. A review of chyme reinfusion: new tech solutions for age old problems. J R Soc N Z 2022 Sep 7;54(2):161–76.
[67] Berger MM, Que YA. Bioinformatics assistance of metabolic and nutrition management in the ICU. Curr Opin Clin Nutr Metab Care 2011 Mar;14(2): 202–8.
[68] Berger MM, Reintam-Blaser A, Calder PC, Casaer M, Hiesmayr MJ, Mayer K, et al. Monitoring nutrition in the ICU. Clin Nutr 2019 Apr;38(2):584–93.
[69] Berger MM, Revelly JP, Wasserfallen JB, Schmid A, Bouvry S, Cayeux MC, et al. Impact of a computerized information system on quality of nutritional support in the ICU. Nutrition 2006;22:221e9.
[70] Berger MM. How to prescribe nutritional support using computers. World Rev Nutr Diet 2013;105:32e42.
[71] Dvir D, Cohen J, Singer P. Computerized energy balance and complications in critically ill patients: an observational study. Clin Nutr 2006 Feb;25(1):37–44.
[72] Mihnovits V, Reintam Blaser A, Gualdi T, Forbes A, Piton G. Gastrointestinal ultrasound in the critically ill: a narrative review and a proposal for a protocol. J Parenter Enteral Nutr 2024:1–11. https://doi.org/10.1002/jpen.2687.