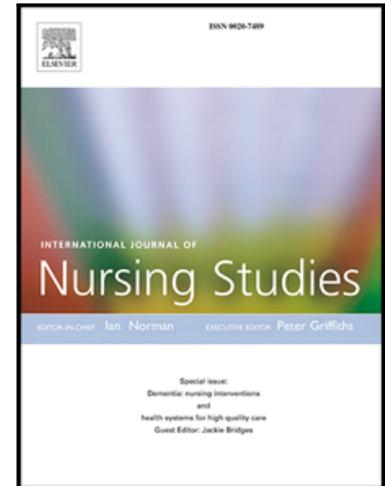


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Accuracy of the corrected nose-earlobe-xiphoid distance formula for determining nasogastric feeding tube insertion length in intensive care unit patients: A prospective observational study



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Accuracy of the corrected nose-earlobe-xiphoid distance formula for determining nasogastric feeding tube insertion length in intensive care unit patients: A prospective observational study

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ABSTRACT

Background: As nasogastric feeding tube insertion is a frequently applied, non-risk-free nursing technique, a high level of evidence-based nursing care is required. Little evidence is available regarding the accurate determination of the insertion length of nasogastric feeding tubes. The method of using the nose-earlobe-xiphoid distance as measurement is inadequate and not supported by evidence. Findings from a recent randomized trial led to an alternative calculation: the corrected nose-earlobe-xiphoid distance formula: (nose-earlobe-xiphoid distance × 0.38696) + 30.37 + 6 cm.

Objectives: To test the accuracy of the corrected nose-earlobe-xiphoid distance formula for determining the required nasogastric feeding tube insertion length in adults admitted on an intensive care unit and to investigate the probability to successfully obtain gastric aspirate for pH measurement.

Design: Prospective, single-centre observational study.

Participants and methods: Adult intensive care unit patients in a general hospital (N=218) needing a small-bore nasogastric feeding tube were included between March and September 2018. Correct tip positioning was defined as a tube tip located > 3 cm under the lower esophageal sphincter. Tip positioning was verified using X-ray.

Results: All nasogastric feeding tube tips were correctly positioned > 3 cm under the lower esophageal sphincter. The chance of successfully obtaining gastric aspirate within 2 hours after placement of the tube was 77.9%.

Conclusions: With all tips positioned > 3 cm in the stomach and zero tubes migrating back into the oesophagus, the corrected nose-earlobe-xiphoid distance formula can be considered a more accurate method to determine nasogastric feeding tube insertion length.

What is already known about the topic?

- Evidence does not support using the nose-earlobe-xiphoid distance to correctly determine the insertion length of nasogastric feeding tubes.
- Correct gastric tube tip positioning leads to a higher chance of successfully obtaining gastric aspirate for pH measurement.
- The corrected nose-earlobe-xiphoid distance formula is an alternative method for determining the nasogastric feeding tube insertion length.

What this paper adds?

- Nasogastric feeding tubes whose insertion length was determined with the corrected nose-earlobe-xiphoid distance formula were positioned correctly in the vast majority of cases.
- Use of the corrected nose-earlobe-xiphoid distance formula led to successfully obtaining gastric aspirate in 77.9% of placements.

Keywords: Adult; Enteral Nutrition; Evidence-Based Nursing; Gastrointestinal Intubation; Patient Safety; X-rays

Introduction

The medical decision to commit patients to tube feeding always relies on a multidisciplinary team approach in which nurses, doctors and dietitians are responsible for the safe administration of nutrients. Tube feeding via an incorrectly placed nasogastric feeding tube compromises safe administration of nutrients and increases the risk of food aspiration into the lungs (Chen, et al., 2014). Subsequently, this can lead to infection and tissue damage leading to serious conditions (e.g. aspiration pneumonia). To avoid these complications it is quintessential to aim for a correct gastric tube tip positioning, i.e. neither in the respiratory tract nor incorrectly positioned in the gastrointestinal tract. In contrast to readily available information on how to distinguish between gastric and pulmonary placement, limited research is available concerning the determination of the insertion length of the tube and subsequent correct positioning of the tube tip before inserting it blindly. This emphasizes the need for clinical research to develop an evidence-based method – based on external body markers – to determine the required insertion length of a nasogastric feeding tube.

Background

As enteral feeding is a common intervention in intensive care units, insertion of nasogastric feeding tubes is frequently applied by nursing staff on these units. Nasogastric feeding tubes are normally 5–12 French with large bore tubes (> 14 French) mainly used for gastric suctioning and decompression. Due to an increasing number of hospitalized patients, approximately 10 million nasogastric feeding tubes are used annually in Europe, of which 1 million in the United Kingdom. Data from the United States suggest the insertion of 1.2 million nasogastric feeding tubes per year (Energias Market Research, 2018). This high rate of tube use requires advanced nursing skills to perform safe insertion and positioning. Nursing staff does not only administer medication, nutrients and fluids, they also monitor the patient's condition.

Ellett et al. (2005) consider a nasogastric feeding tube to be correctly positioned when the tip is located between 3 and 10 cm under the lower esophageal sphincter. This enables feeding being delivered in the gastric corpus or

fundus (Ellett et al., 2005). Based on the combined median distance from the anterior nasal spine to the tracheoesophageal junction and the oesophagus, Pillai et al. (2005) even recommend a gastric tip positioning of 10 cm below the gastroesophageal junction (Pillai et al., 2005). This is congruent with the recommendation of Santos et al. (2016), emphasizing the importance that all lateral holes from the distal tip of the nasogastric tube are located in the stomach (Santos et al., 2016).

Inaccurate determination of nasogastric feeding tube insertion length can lead to complications due to gastrointestinal misplacement (i.e. tip positioning in the oesophagus or small bowel). Overestimation of the insertion length can cause coiling of the tube inside the stomach or even migration of the tube tip upwards back into the oesophagus or downwards into the duodenum. The latter can lead to dumping syndrome when using intermittent or bolus feeding (Lord, 2018). Underestimation of the insertion length can lead to tube feeding remaining in the oesophagus, increasing aspiration risk of tube feeding formula (Chen et al., 2014). Achieving a correct gastric tip positioning is essential to prevent these complications and requires a correct nasogastric feeding tube length measurement.

The nose-earlobe-xiphoid method, measuring the distance from the tip of the nose to the earlobe to the xiphoid, is still the most taught method to determine the insertion length of a nasogastric tube (Ellett et al., 2005; Taylor et al., 2014), but it may not be the safest approach. Despite being commonly used, no evidence is available to support the accuracy of this method (Santos et al., 2016). In a recent randomized controlled trial, use of the nose-earlobe-xiphoid distance to determine the insertion length resulted in incorrect positioning of over 20% of nasogastric feeding tubes (i.e. at least 1 lateral opening of the nasogastric feeding tube is located either in the oesophagus or aligned with the lower esophageal sphincter) (Torsy et al., 2018). Torsy et al. (2018) also compared this method with Hanson's formula: $(\text{nose-earlobe-xiphoid distance} \times 0.38696) + 30.37$ (Hanson, 1979). Both methods result in a high number of incorrectly positioned tube tips. Not only was the insertion length underestimated in > 20% of cases; in a significant number the length was overestimated: 17,2% for the nose-earlobe-xiphoid distance versus 4,8% for Hanson's formula. Ellett and colleagues proposed a 3-variable model (based on gender, weight and the distance between nose and umbilicus in supine position with the head flat) (Ellett et al., 2005). This model resulted in 85.3% of correct placements (vs. 72% for the nose-earlobe-xiphoid distance and 84.2% for Hanson). Still, 5 out of 11 incorrectly placed tubes were in the esophageal danger zone, i.e. less than 3 cm under the lower esophageal sphincter. To avoid underestimation of the required insertion length,

Taylor et al. (2014) suggested adding 10 cm to the nose-earlobe-xiphoid distance to ensure that the gastric body was reached (Taylor et al., 2014). However, accurate measurement of nasogastric feeding tube-length does not reduce the risk of pulmonary intubation.

Findings from Torsy et al. (2018), demonstrating an underestimation of the required nasogastric feeding tube insertion length in 22.6% and an overestimation in 4.8% of all patients in the intervention group (Hanson's formula), led to an alternative defined as the 'the corrected nose-earlobe-xiphoid distance' formula. This method (calculated in cm) is based on the nose-earlobe-xiphoid measurement and a modification of Hanson's formula: $(\text{nose-earlobe-xiphoid distance} \times 0.38696) + 30.37 + 6.0$ cm. The underestimation distances of the required insertion lengths were reported for all tubes with a tube tip positioned < 3 cm or not under the lower esophageal sphincter after which the average (4.8 cm) was calculated. Including a safety margin of 25.0% (1.2 cm), an addition of 6.0 cm to Hanson's formula was made. This corrected nose-earlobe-xiphoid distance formula intends to reduce the number of inadequately placed tubes: both those whose tips are placed near the gastroesophageal junction (i.e. tube too short) as those that are too long increasing the risk of coiling or protruding in the duodenum. However, the use of this formula does not reduce the risk of lung intubation, which is known to lead to medical complications in all cases when administering medication, nutrients or fluids. Further research was needed to confirm the applicability of the adjusted formula.

Verification of the actual position of the tip is a prerequisite before administering nutrients, medication and/or fluids. pH measurement of the gastric aspirate is a safe first-line bedside method to confirm a correct gastric tip positioning: the pH of the aspirate should be ≤ 5 (Boeykens et al., 2014; Ellett et al., 2011; Ni et al., 2017; Metheny et al., 2019). The success rate of obtaining gastric aspirate within 2 hours after insertion of a nasogastric feeding tube was 55.6% in the nose-earlobe-xiphoid distance formula and 56.0% in the Hanson's formula (Torsy et al., 2018). While X-ray is the gold standard second-line method for detecting the position of the tip of the nasogastric feeding tube (Nyqvist et al., 2005), UK guidelines strongly advise against the routine use of X-ray as a first-line confirmation method due to the risk of radiation exposure, costs, delay in case of tube feeding and its inapplicability in nursing homes and home care (National Patient Safety Agency, 2005 & 2011).

A rigorous evaluation of the accuracy of a new formula to determine the insertion length of a nasogastric feeding tube to ensure safe administration of nutrients is needed. The success rate of obtaining gastric aspirate should be

at least equal to that of other methods. Skilled insertion of nasogastric feeding tube is required to avoid misplacement in the pulmonary system.

Methods

Aims

The primary aim of this study was to test the accuracy of the corrected nose-earlobe-xiphoid distance formula for determining the length of the nasogastric feeding tube, aiming for a correct positioning in adults. A validated method already exists in neonates and children (Beckstrand et al., 2007; Ellett et al., 2011). The secondary aim was to investigate the possibility to obtain gastric aspirate allowing pH measurement.

Design

The study is a prospective, single-center observational study. Data were collected between March and September 2018 at an intensive care unit in a Belgian general hospital. The 'Strengthening the Reporting of Observational Studies in Epidemiology' (STROBE) guidelines have been applied for reporting this study.

Participants

Eligible patients were critically ill adults (≥ 18 years) at an intensive care unit, in need of feeding through a nasogastric feeding tube. Patients were excluded if the xiphoid was not palpable making an accurate determination of the nose-earlobe-xiphoid distance impossible. Written informed consent was obtained from all patients or their legal representatives in case of compromised cognitive awareness or coma. Consecutive sampling was used to include patients. Characteristics of participants are shown in Table 1.

Data collection

The nasogastric feeding tube was a small-bore polyurethane radiopaque tube (Nutricia Flocare NG-ENFit; 10 Fr, total length 110 cm), manufactured by Danone Trading B.V., Schiphol, The Netherlands, with following characteristics: An internal guidewire, a distal opening in the tip, and lateral openings up to 2 cm from the distal tip. The guidewire ends 5 cm before the distal tip opening.

A certified clinical nutrition nurse specialist measured the nose-earlobe-xiphoid distance for each participant following this procedure: Patient seated in Semi Fowler's position with chest at an angle of 30° and facing

forward. The xiphoid was marked. A newly developed 'corrected nose-earlobe-xiphoid distance formula' measuring tape was directed in a straight line from the tip of the nose to the ear lobule to the marked xiphoid. The front of the 80 cm measuring tape is marked with 0.5 cm intervals. The back of the tape shows the conversion of the measured metric distance into the adjusted corrected nose-earlobe-xiphoid distance: (nose-earlobe-xiphoid distance $\times 0.38696$) + 30.37 + 6.0 cm. If a normal metric measuring tape is used, a conversion table can be applied.

After obtaining the correct measurement, the nasogastric feeding tube was marked accordingly and then placed following standard protocol. The nasogastric feeding tube was placed correctly when the tip was positioned > 3 cm under the lower esophageal sphincter in the stomach and therefore not in the oesophagus, small bowel or a bronchial tree. After insertion, the tube was secured to the nose with a fixation tape for nasal tubes manufactured by ConvaTec, Deeside, UK (ConvaTec Naso-Fix).

Immediately after insertion, a first attempt was made to obtain an aspirate for pH measurement. This is an adequate bedside method to confirm correct gastric tip positioning and can be used in addition to or in place of X-ray to assess the tip position (Ellett et al., 2011; Ni et al., 2017; Metheny et al., 2019). A large syringe (60 ml) with an ENFit (Danone Trading B.V., Schiphol, The Netherlands) connection was used for aspiration. If no aspirate could be obtained, a second attempt was made within 2 hours after insertion. Aspirate was tested using pH colour-indicator strips (pH 2.0 – 9.0) with a 0.5 pH interval (Merck KGaA, Darmstadt, Germany). If an aspirate could be obtained, a pH value ≤ 5 was taken to indicate gastric aspirate (Ni et al., 2017). 'Obtainment of aspirate' was considered negative after 2 failed attempts.

A chest X-ray – as prescribed in patient's standard care according to the local hospital's policy – was taken in situ. The patient was positioned in supine position as described above. Preferably, the guidewire was left inside the tube to increase visibility of the tube on X-ray. The chest X-ray images covered the area from the apex to the base of the lungs, the diaphragm and the stomach. All images were retrieved from the hospital picture archiving and communication system, processed and anonymized using DicomCleaner (PixelMed Publishing, Bangor, PA), and evaluated on medical imaging monitors. Because the lower esophageal sphincter itself is not very clear visible on an X-ray, researchers and participating radiologists used the top of the vault of the diaphragm as the reference point for the location of the lower esophageal sphincter in the assessment of the images because the crural part

of the diaphragm is aligned with the lower esophageal sphincter (Mittal, 2011). Final determination of tube tip positioning was made by the participating radiologists.

Ethical considerations

The study protocol was approved by the central Review Committee for Medical Ethics from UZ/KU Leuven (Leuven, Belgium) (S61220) and the local Review Committee for Medical Ethics from AZ Nikolaas (Sint-Niklaas, Belgium) (EC15053). Written informed consent was collected from all patients (or their legal representative in case of diminished awareness or coma) by a clinical nutrition nurse specialist. Patients or their representatives who were unable or unwilling to sign the written informed consent were excluded from the study.

Data analysis

Statistical analyses were conducted using SPSS 25.0 (IBM Corporation, Armonk, NY). Categorical variables (e.g. gender, use of proton pump inhibitors, tip positioning interval, gastric aspirate, looping of the tube upwards inside stomach) were presented using frequencies and percentages. Mean and standard deviations (SD) were used to present normally distributed continuous variables (e.g. age). Categorical data were compared using χ^2 test. A significance level of $\alpha = 0.05$ was adopted. An association between possible predictive factors and binary outcome variables was demonstrated by performing both a univariate and a multivariate binary regression analysis.

X-ray images were separately and independently evaluated by 2 radiologists using a custom-made reporting sheet. They scored the tip position as (1) tip < 3cm under lower esophageal sphincter, (2) tip between 3 and 5 cm under lower esophageal sphincter; (3) tip between 5 and 10 cm under lower esophageal sphincter; (4) tip > 10 cm under lower esophageal sphincter; (5) tip positioning unable to confirm. Inter-observer agreement between the 2 independent radiologists was assessed using κ statistics. Agreement was defined as 2 concurring interpretations of the X-ray according to the above criteria. In case of disagreement, the final decision was made by a third radiologist.

Results

Patient Characteristics

A total of 218 intensive care unit patients were enrolled in the study. Data of 199 patients were used for further analysis. Of 17 patients X-ray quality was insufficient to allow conclusive determination of the position of the tube tip. Whereas the X-ray showed a clear image of the proximal segment of the oesophagus, it lacked sufficient contrast to evaluate the tip position in the distal segment of the oesophagus or the stomach, often due to pulmonary pathology. Two other patients were excluded from the data-analysis because of a tube completely coiled in a hiatal hernia. Characteristics of the participants are shown in Table 1.

Table 1: Characteristics of participants (n=199)^a

Characteristics	Participants (n = 199)
Demographic variables	
Age, mean (SD), years	69.5 (12.9)
Gender	
Male, no. (%)	125 (62.8)
Female, no. (%)	74 (37.2)
Clinical variables	
PPI > 24 prior to tube insertion	
Yes, no. (%)	157 (78.9)
Gastric aspirate obtained	
Within 2h after insertion, no. (%)	155 (77.9)

no., number; PPI, proton pump inhibitors; SD, standard deviation

^a Data collected by clinical nutrition nurse specialist

Nasogastric feeding tube insertion length & tip positioning

Figure 1 shows the distribution of the tube insertion lengths using the corrected nose-earlobe-xiphoid distance formula. The mean insertion length was 56.72 cm (SD 1.44) and the interquartile range (IQR) was 2.0 with a minimum insertion length of 53.0 cm and a maximum insertion length of 61.0 cm.

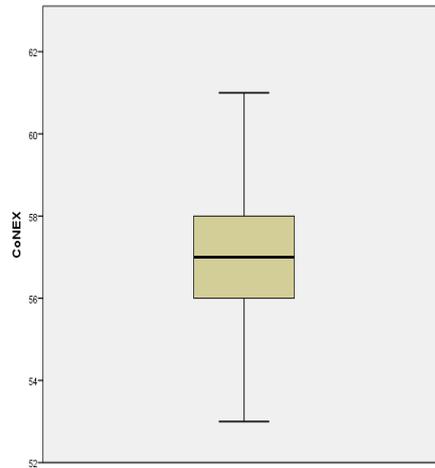


Figure 1: Boxplot describing the distribution of insertion lengths

The tip of the nasogastric feeding tube was positioned 3-10 cm or >10 cm below the lower esophageal sphincter in 37.7% (n = 75) and 62.3% (n = 124), respectively with no misplacement into either the lungs or small bowel. Absolute values and column percentages are shown in Table 2.

Table 2: Localization of nasogastric feeding tube tip positionings and obtainment of gastric aspirate

	CoNEX distance formula (n = 199)	Obtaining gastric aspirate ^a (n = 199)	Tubes looping upwards ^b (n = 199)
Tip positioning			
< 3 cm under LES, no. (%)	0 (0.0)		
3 – 5 cm under LES, no. (%)	12 (6.0)	10 (83.3)	1 (8.3)
6 – 10 cm under LES, no. (%)	63 (31.7)	46 (73.0)	2 (3.2)
> 10 cm under LES, no. (%)	124 (62.3)	99 (79.8)	14 (11.3)
No aspirate / aspirate, no. (%)		44 (22.1) / 155 (77.9)	
Not looping upwards, no. (%)			182 (91.5)

CoNEX, corrected nose-earlobe-xiphoid; LES, lower esophageal sphincter; no., number

^aWithin 2h after placement/reposition

^bLooping upwards inside the stomach

In a binary logistic regression analysis there was no statistically significant association between tube tip depth below the lower esophageal sphincter (< 3 cm, 3-5 cm, > 10 cm below lower esophageal sphincter) and the tube looping upwards inside the stomach towards the oesophagus ($p = 0.21$). Although no aspiration was obtained within 2 hours of placement in 4 of the 17 upwards looping tubes, these factors were not statistically significant associated. ($p = 0.88$; odds ratio [OR], 1.09; 95% confidence interval [CI], 0.34-3.54).

Interobserver agreement between the 2 participating radiologists indicated a substantial level of agreement regarding the tip positioning confirmation ($\kappa = 0.69$; 95% confidence interval [CI], 0.60-0.75). A decisive determination from the third radiologist was needed in 13 cases.

Obtainment of aspirate

The overall chance of successfully obtaining gastric aspirate within 2 hours after placement/repositioning of the tube was 77.9% with a 21.6% chance of a pH value > 5 versus a 56.3% chance of a pH value ≤ 5 . In 22.1% of all cases no gastric aspirate could be obtained. χ^2 test demonstrated no significant difference ($p > 0.05$) in successfully obtaining gastric aspirate and the different gastric tube tip positionings. The probability of successfully obtaining gastric aspirate when the tube tip is 3-5 cm, 6-10 cm and > 10 cm below the lower esophageal sphincter was 83.3%, 73.0% and 79.8%, respectively (Table 2).

Three factors which may affect the successful obtainment of gastric aspirate were analyzed in a multivariate binary logistic regression analysis: age, gender and use of proton pump inhibitors (Table 3). The binary outcome variable was 'gastric aspirate within 2h after placement of the tube' (yes/no). Other variables were not included in the model due to the limited data set. The model did not result in any significant association between one of these three variables and the outcome.

Table 3: Multivariate binary logistic regression between possible influencing factors in obtainment of gastric aspirate

	β coefficient	Standard error	Wald statistic	df	OR (95 % CI)	p value
Age	0.008	0.013	0.410	1	1.008 (0.983 – 1.034)	0.522
Gender	0.201	0.361	0.308	1	1.222 (0.602 – 2.481)	0.579
Male ^a						
Female						
PPI	-0.655	0.480	1.861	1	0.520 (0.203 – 1.331)	0.173
Yes ^a						
No						
Constant	1.149	1.011	1.291	1	3.155	0.256

CI, confidence interval; df, degrees of freedom; OR, odds ratio; PPI, proton pump inhibitors

^a Reference category

Discussion

This observational prospective study testing the corrected nose-earlobe-xiphoid distance formula for determining the required insertion length of nasogastric feeding tubes in adults admitted to the intensive care unit provided valuable evidence supporting this method. With all tips positioned > 3 cm in the stomach and zero tubes migrating back into the oesophagus, the corrected nose-earlobe-xiphoid distance formula can be considered as a safer alternative to the nose-earlobe-xiphoid distance measurement which has been a topic for discussion (Santos et al., 2016; Torsy et al., 2018; Beckstrand et al., 2007; Ellett et al., 2011). However, tubes migrating back to the oesophagus are a patient safety risk. In this study, no such events were documented. In a blinded randomized trial by Torsy et al. (2018), both the nose-earlobe-xiphoid distance and Hanson's formula were found to be inaccurate as $> 20\%$ of the nasogastric feeding tubes were located in the esophageal danger zone (Metheny & Titler, 2001). Also, there was an overestimation (17.2%) of the required insertion length by using the nose-earlobe-xiphoid distance measurement compared to Hanson's formula (4.8%). This also explained why the nose-earlobe-xiphoid distance measurement resulted in a wider range of tip positions compared to Hanson's formula in the study conducted by Torsy et al (2018). In their 2018 study, Torsy and colleagues also showed that various factors (e.g. age, gender, cognitive awareness level) have no influence on the outcome of nasogastric feeding tubes placement. They were therefore not taken into account in the present study.

Previously, studies focused on alternatives to replace the nose-earlobe-xiphoid distance measurement. The 3-variable model from Ellett et al. (2005) resulted in 85.3% correct tip positionings (vs 72% for the nose-earlobe-xiphoid distance measurement and 84.2% for Hanson's formula). However, 5 out of 11 incorrectly positioned tubes were in the danger zone (Ellett et al., 2005). The 2005 Ellett model shows an increased risk of nutrients entering the oesophagus due to incorrect tube tip positioning. This method is also less attractive in the clinical setting because of the difficulty of accurately weighing bedridden patients; the discomfort it causes patients to maintain the required position; and a higher likelihood to make mistakes when having to obtain various parameters and applying them in a formula. Taylor et al. (2014) suggested the use of the nose-earlobe-xiphoid distance + 10 cm as an alternative to the nose-earlobe-xiphoid distance measurement. This would lead to a decrease from 16% to 7% of tubes located with the tip into the oesophagus. Besides the fact that 7% of all nasogastric feeding tubes were still misplaced (i.e. too high), there was also a high risk of overestimation of the

required insertion length when using the formula suggested by Taylor (Taylor et al., 2014). This is presented in Figure 2 where nasogastric feeding tube insertion lengths are shown according to both the nose-earlobe-xiphoid distance, nose-earlobe-xiphoid + 10 cm and the corrected nose-earlobe-xiphoid distance formula proposed. The current study – using the corrected nose-earlobe-xiphoid distance formula as an estimator for nasogastric feeding tube insertion length – demonstrated no significant association between 'nasogastric feeding tube tip positioning' and 'tube looping upwards inside the stomach towards the oesophagus'. This cannot be claimed when using the nose-earlobe-xiphoid distance + 10 cm. Adding 10 cm to the nose-earlobe-xiphoid distance, as suggested by Taylor and colleagues, leads to a larger variability of the actual nasogastric feeding tube insertion lengths compared to the corrected nose-earlobe-xiphoid distance formula, making the actual length too long, especially in the case of a large nose-earlobe-xiphoid distance. This might increase the risk of coiling of the tube inside the stomach, migration of the tube back into the oesophagus or extension beyond the pylorus into the duodenum.

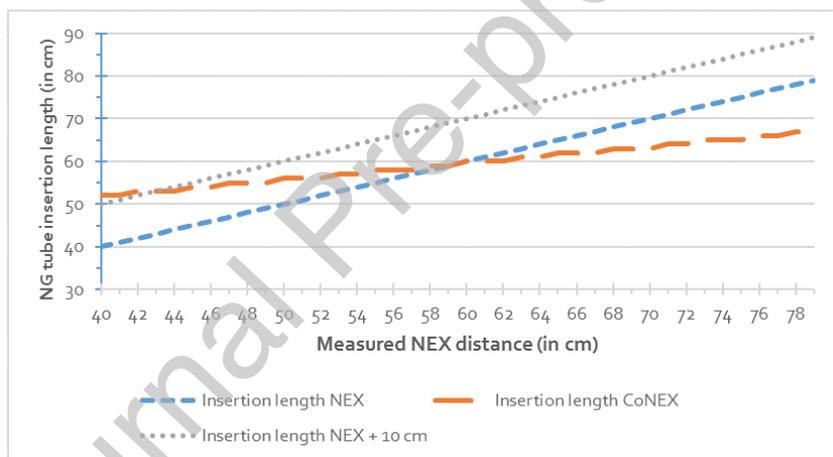


Figure 2: Nasogastric feeding tube insertion lengths (in cm) calculated according to the corrected nose-earlobe-xiphoid distance formula, nose-earlobe-xiphoid distance measurement and nose-earlobe-xiphoid + 10 cm

Correct tip positioning leads to a higher chance of successfully obtaining gastric aspirate and therefore a higher chance of performing pH measurement. As recommended by Metheny and colleagues, pH measurement is the preferred non-radiographic method to confirm correct nasogastric feeding tube positioning. It is evidence-based, has a favorable cost-benefit ratio, is applicable in most settings and results are readily available (Metheny et al., 2019). Despite this evidence-based recommendation, it appears that verification by X-ray is still standard practice with adult patients. This in-hospital clinical practice has to be reassessed given that a 2011 Patient Safety Alert reported that between 2005 and 2010 in the UK, 45% of all cases of harm caused by a misplaced NGT reported by the National Patient Safety Agency were due to misinterpreted X-rays (National Patient Safety Agency, 2011).

Therefore, pH measurement can be considered as an alternative to X-ray in confirming correct tube tip positioning, also in home care patients and patients in nursing homes receiving enteral nutrition. However, it is still recommended to obtain a chest X-ray prior to the administration of tube feeding via a nasogastric tube when pH measurement is impossible due to e.g. pulmonary intubation or placement of the tube tip in the oesophagus, inadequate patient position, blockage at the end of the tube or when the tube tip is positioned against the lining of the stomach. When aspirate can be obtained, but fails to confirm a $\text{pH} \leq 5$, this can be due to gastric acid deficiency, caused by the use of proton pump inhibitors by the patient (Ni et al., 2017), reducing gastric secretion volume by about 50% (Steingoetter et al., 2015). Also in these situations it is recommended to obtain a chest X-ray to check the nasogastric feeding tube position. Torsy et al. (2018) obtained gastric aspirate in 55.6% of cases using the nose-earlobe-xiphoid distance measurement and 56.0% when using the Hanson's formula. Using the corrected nose-earlobe-xiphoid distance formula resulted in 77.9% of successfully obtained aspirate. However, none of these above reasons are directly related to the determination of the nasogastric feeding tube insertion length.

Limitations

There are some limitations in this prospective observational study. Firstly, to avoid dropout (8.7%) due to insufficient contrast in the thoracic X-ray images, it is recommended to use supplementary abdominal X-ray images to be able to evaluate the tip positionings of the tubes. Secondly, the participating clinical nutrition nurse specialist reported some cases in which it was, for organizational reasons, not possible to access the patient for a second attempt to obtain gastric aspirate after a first unsuccessful attempt. This has led to a potential underestimation of the outcome 'obtaining gastric aspirate'. A second attempt might have increased the chance of obtaining gastric aspirate. Finally, the clinical significance of the κ value depends on its context. In the context of medical imaging and with regard to categorical data, a κ value of 0.69 suggests a substantial level of observer agreement (Landis & Koch, 1977; Kundel & Polansky, 2003).

Conclusion

Use of the corrected nose-earlobe-xiphoid distance formula as an alternative method to determine the insertion length of a nasogastric feeding tube leads to a correct positioning of the tip in the stomach (> 3 cm under lower

esophageal sphincter). The success rate of obtaining gastric aspirate is at least equal to that of other methods. Using the formula proposed in this study reduces and even avoids complications such as regurgitation and aspiration (tube tip positioned too high) and dumping syndrome (tube tip positioned too low). However, the use of the corrected nose-earlobe-xiphoid distance formula does not reduce the risk of pulmonary intubation. The development of a custom-made tape measure makes the application of the improved formula easy. We also suggest that the exact length of the nasogastric feeding tube is entered in the patient's clinical record, in order to facilitate future application of a nasogastric feeding tube in the patient without causing more discomfort.

Relevance to clinical practice

Applying the findings of this study in clinical practice increases the number of correctly placed nasogastric feeding tubes in adults. Healthcare practitioners can easily apply the corrected nose-earlobe-xiphoid distance formula through the use of a conversion table or a specific measuring tape. Nevertheless, a correct technique for measuring the nose-earlobe-xiphoid distance remains a prerequisite when determining nasogastric feeding tube insertion length before using the corrected nose-earlobe-xiphoid distance formula. Based on 100% correct nasogastric feeding tube tip positioning in this study, we recommend further validation and comparison studies.

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Conflict of interests

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REFERENCES

- Beckstrand, J., Ellett, M. L., & McDaniel, A. (2007). Predicting internal distance to the stomach for positioning nasogastric and orogastric feeding tubes in children. *Journal of Advanced Nursing*, *59*(3), 274-289. doi:10.1111/j.1365-2648.2007.04296.x
- Boeykens, K., Steeman, E. & Duysburgh, I. (2014) Reliability of pH measurement and the auscultatory method to confirm the position of a nasogastric tube. *International Journal of Nursing Studies*, *51*(11), 1427-1433. doi:10.1016/j.ijnurstu.2014.03.004
- Chen, Y., Wang, L., Chang, Y., Yang, C., Wu, T., Lin, F., . . . Wei, T. (2014). Potential Risk of Malposition of Nasogastric Tube Using Nose-Ear-Xiphoid Measurement. *PLoS One*, *9*(2), e88046. doi:10.1371/journal.pone.0088046
- Ellett, M. L., Beckstrand, J., Flueckiger, J., Perkins, S. M., & Johnson, C. S. (2005). Predicting the Insertion Distance for Placing Gastric Tubes. *Clinical Nursing Research*, *14*(1), 11-27. doi:10.1177/1054773804270919
- Ellett, M. L., Cohen, M. D., Perkins, S. M., Smith, C. E., Lane, K. A., & Austin, J. K. (2011). Predicting the Insertion Length for Gastric Tube Placement in Neonates. *Journal of Obstetric Gynecologic & Neonatal Nursing*, *40*(4), 412-421. doi:10.1111/j.1552-6909.2011.01255.x
- Energias Market Research. (2018). *Global Nasogastric Tube (NGT) Market to Witness a CAGR of 6.4% during 2018-2024*. Buffalo, New York, USA. Retrieved from <https://www.energiasmarketresearch.com/global-nasogastric-tube-market-report/>
- Hanson, R. L. (1979). Predictive criteria for length of nasogastric tube insertion for tube feeding. *Journal of Parenteral and Enteral Nutrition*, *3*(3), 160-163. doi:10.1177/0148607179003003160
- Kundel, H. L., & Polansky, M. (2003). Measurement of observer agreement. *Radiology*, *228*(2), 303-308. doi:10.1148/radiol.2282011860
- Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159-174. doi:10.2307/2529310
- Lord, L. M. (2018). Enteral Access Devices: Types, Function, Care, and Challenges. *Nutrition in Clinical Practice*, *33*(1), 16-38. doi:10.1002/ncp.10019
- Metheny, N. A. (2006). Preventing respiratory complications of tube feedings: Evidence-based practice. *American Journal of Critical Care*, *15*(4), 360-369.
- Metheny, N. A., & Titler, M. G. (2001). Assessing placement of feeding tubes. *American Journal of Nursing*, *101*(5), 36-45. doi:10.1097/00000446-200105000-00017
- Metheny, N. A., Krieger, M. M., Healey, F., & Meert, K. L. (2019). A review of guidelines to distinguish between gastric and pulmonary placement of nasogastric tubes. *Heart & Lung*, *48*(3), 226-235. doi:10.1016/j.hrtlng.2019.01.003
- Mittal, R. (2011). *Motor Function of the Pharynx, Esophagus and its Sphincters*. San Rafael, CA, USA: Morgan & Claypool Life Sciences. doi:10.4199/C00027ED1V01Y201103ISP016
- National Patient Safety Agency. (2005). *Patient Safety Alert: Reducing the harm caused by misplaced nasogastric feeding tubes*. United Kingdom. Retrieved June 25, 2019, from <http://www.nrls.npsa.nhs.uk/resources/?EntryId45=59794>

- National Patient Safety Agency. (2011). *Reducing the harm caused by misplaced nasogastric feeding tubes in adults, children and infants*. NHS, United Kingdom. Retrieved June 25, 2019, from <http://www.procurement.wales.nhs.uk/23814.file.dld>
- Ni, M. Z., Huddy, J. R., Priest, O. H., Olsen, S., Phillips, L. D., Bossuyt, P. M., & Hanna, G. B. (2017). Selecting pH cut-offs for the safe verification of nasogastric feeding tube placement: a decision analytical modelling approach. *BMJ Open*, 7(11), e018128. doi:10.1136/bmjopen-2017-018128
- Nyqvist, K. H., Sorell, A., & Ewald, U. (2005). Litmus tests for verification of feeding tube location in infants: evaluation of their clinical use. *Journal of Clinical Nursing*, 14(4), 486-495. doi:10.1111/j.1365-2702.2004.01074.x
- Pillai, J. B., Vegas, A., & Brister. (2005). Thoracic complications of nasogastric tube: review of safe practice. *Interactive Cardiovascular and Thoracic Surgery*, 4(5), 429-433. doi:10.1510/icvts.2005.109488
- Santos, S. C., Woith, W., Freitas, M. I., & Zeferino, E. B. (2016, September). Methods to determine the internal length of nasogastric feeding tubes: An integrative review. *International Journal of Nursing Studies*, 61, 95-103. doi:10.1016/j.ijnurstu.2016.06.004
- Steingoetter, A., Sauter, M., Curcic, J., Liu, D., Menne, D., Fried, M., . . . Schwizer, W. (2015). Volume, distribution and acidity of gastric secretion on and off proton pump inhibitor treatment: A randomized double-blind controlled study in patients with gastro-esophageal reflux disease (GERD) and healthy subjects. *BMC Gastroenterology*, 15(1), 111. doi:10.1186/s12876-015-0343-x
- Taylor, S. J., Allan, K., McWilliam, H., & Toher, D. (2014). Nasogastric tube depth: the 'NEX' guideline is incorrect. *British Journal of Nursing*, 23(12), 641-644. doi:10.12968/bjon.2014.23.12.641
- Torsy, T., Saman, R., Boeykens, K., Duysburgh, I., Van Damme, N. & Beeckman D. (2018) Comparison of Two Methods for Estimating the Tip Position of a Nasogastric Feeding Tube: A Randomized Controlled Trial. *Nutrition in Clinical Practice*, 33(6), 843-850. doi: 10.1002/ncp.10112