



A review of guidelines to distinguish between gastric and pulmonary placement of nasogastric tubes

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ABSTRACT

The purpose of this review was to (1) identify areas of agreement and disagreement in guidelines/recommendations to distinguish between gastric and pulmonary placement of nasogastric tube and (2) summarize factors that affect choices made by clinicians regarding which method(s) to use in specific situations. Systematic searches were conducted in the PubMed, Scopus, and CINAHL Plus databases using a combination of keywords and data-specific subject headings. Searches were limited to guidelines/recommendations from national level specialty groups and governmental sources published in the English language between January 1, 2015 and September 20, 2018. Fourteen guidelines that described methods to distinguish between gastric and pulmonary placement of nasogastric tubes were identified from a variety of geographic locations. Tube placement testing methods included in the review were: radiography, respiratory distress, aspirate appearance, aspirate pH, auscultation, carbon dioxide detection and enteral access devices. All fourteen guidelines agreed that radiography is the most accurate testing method. Of the nonradiographic methods, pH testing was most favored; least favored was auscultation.

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Introduction

Nasogastric (NG) tubes are commonly used in acute and chronic care settings for the delivery of feedings and/or medications to patients of all ages. Most often, these tubes are placed blindly by nurses at the bedside; although often perceived as a relatively innocuous procedure, it is not. The NG tube can easily enter the trachea instead of the esophagus during the insertion procedure, often resulting in catastrophic outcomes if the improperly positioned tube is not detected before feedings or medications are administered. It is difficult to pinpoint how often this type of error occurs because there is no central repository for reporting these events; however, two large studies of patients with NG tubes (9931 and 740 respectively) found that approximately 2% of small-bore NG tubes were inadvertently inserted into the respiratory tract.^{1,2} Although small-bore tubes are most often associated with complications, large-bore tubes are not without risk.³

Introducing fluids or medications into the respiratory tract or pleural space via a misplaced NG or orogastric tube is a Never Event in England. “Never Events are considered wholly preventable where

guidance or safety recommendations that provide strong systemic protective barrier are available at a national level, and should have been implemented by all healthcare providers.”⁴ Between September 2011 and March 2016, 95 incidents were reported to the National Reporting and Learning System and/or the Strategic Executive Information System where substances were administered through NG or orogastric (OG) tubes inadvertently introduced into the respiratory tract; 32 of the patients died.⁵ However, it was not possible to determine if death was directly related to the incidents because many of the patients were critically ill.⁵ In 2017, the Pennsylvania Patient Safety Authority in the U.S.A. issued an advisory titled “Data Snapshot: Complications Linked to Iatrogenic Enteral Feeding Tube Misplacements.” The report indicated that over a six-year period (January 2011–December 2016) there were 137 reported misplacements in the lung; in 81 cases the misplacements were detected before the tubes were used, but in 56 cases the misplacements went undetected and enteral feeds were introduced into the pleural space or respiratory tract.⁶ Clearly, failing to detect a NG tube inadvertently positioned in the lung is a serious event.

There are multiple guidelines/recommendations for determining NG tube placement. Most include two or more of the following methods: (1) radiography, (2) signs of respiratory distress, (3)

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Table 1
Keywords and database-specific headings.

Search term 1:	Search term 2:
Keywords: Enteral nutrition Nasogastric tube(s) Enteral feeding tube(s) Nasoenteral tube(s)	Keywords: guideline(s) recommendation(s) practice(s)
PubMed and CINAHL Headings: Enteral nutrition Feeding tubes Nasoenteral tubes Intubation, Gastrointestinal Tube placement determination	PubMed and CINAHL Headings: Practice guidelines Practice guideline [Publication type] Guideline [Publication type]

aspirate appearance, (4) aspirate pH, (5) carbon dioxide detection, (6) auscultation, and (7) enteral access devices. Unfortunately, despite a similar evidentiary basis, there are often key differences in the guidelines/recommendations to distinguish between gastric and pulmonary placement. These differences are a source of confusion to clinicians.

Purpose

This review is intended to (1) identify areas of agreement and disagreement in world-wide guidelines/recommendations to distinguish between gastric and pulmonary placement of NG tubes and (2) summarize factors that affect choices made by clinicians regarding which method(s) to use in specific situations.

Methods

To identify the guidelines/recommendations, systematic searches were conducted in the PubMed, Scopus, and CINAHL Plus with Full Text bibliographic databases in September 2018 using a combination of keywords and database-specific subject headings (see Table 1). The searches were limited to English language and to publication dates between January 1, 2015 and September 20, 2018. The search was limited to guidelines/recommendations from national level specialty groups and governmental sources since they were likely to have been developed by group consensus of individuals with expertise in determining correct NG tube placement.

Searches were also performed on the websites of 177 U. S. specialty nursing organizations and 6 national and international health-care guideline repositories: Agency for Healthcare Research and Quality (AHRQ) Evidence-Based Practice Centers Reports, National Institute for Health and Care Excellence (NICE) Evidence Search, Australian Government National Health and Medical Research Council (NHMRC) Guidelines, Scottish Intercollegiate Guidelines Network (SIGN), Guidelines International Network (GIN), and Canadian Medical Association Clinical Practice Guideline Infobase. Finally, the reference lists of articles and guidelines that addressed gastric and pulmonary placement of NG tubes were carefully reviewed for additional sources (see Fig. 1).

Inclusion criteria

- Guidelines/recommendations from a national-level nursing, medical or joint-practice specialty organization regarding methods to verify placement of NG tubes.
- Guidelines/recommendations from a government-level organization regarding methods to verify placement of NG tubes.
- Publication dates between January 1, 2015 and September 20, 2018
- English language.

Exclusion criterion

- Lack of specific information in guidelines/recommendations regarding methods to distinguish between gastric and pulmonary placement of newly inserted NG tubes.

Results

Fourteen guidelines/recommendations regarding methods to distinguish between gastric and pulmonary placement of NG tubes met the inclusion criteria (see Table 2). To increase readability of the remainder of the paper, the word 'guidelines' will be used as a proxy for 'guidelines/recommendations.' Information presented in the review is largely limited to what is provided in the guidelines about new tube insertions, emphasizing the importance of assuring correct tube location prior to the initial introduction of feedings or medications via the tube. Geographical locations from which the guidelines were obtained include Europe ($n=6$), the United States ($n=6$) and one each from New South Wales in Australia, and China. Of the 14 guidelines, four are limited to children, four to adults, and one includes both children and adults; the remaining five guidelines do not stipulate age groups. Excerpts from the guidelines that pertain to the topic areas are included in Table 3 through Table 9. Levels of Evidence are provided in some of the guidelines; these are included in the respective tables when available.

Eleven of the 14 guidelines refer to radiology as a method to distinguish between gastric and pulmonary placement of a NG tube. In contrast, non-radiological testing methods are addressed less frequently (range 4–9 guidelines).

Table 3 includes information from the eleven guidelines that refer to radiography as a method to distinguish between gastric and pulmonary placement of NG tubes. As can be seen, these recommendations range from 'always required' to 'use only when other methods fail'. Geographical location has an influence of whether or not radiography is recommended as the first-line method to distinguish between gastric and pulmonary placement. For example, most guidelines from the U.S. (I, V, X and XI) favor radiographic confirmation of tube location as the first-line method; in contrast, guidelines from Europe and Australia (II, VI and VII) typically favor radiographic testing only when the pH-method has failed or patients are 'at risk'. As shown in Table 3, none of the pediatric guidelines specify radiography as the first-line method to distinguish between gastric and pulmonary placement unless the child is at high risk for misplacement. For example, guideline XIV refers to "a known history of facial fractures, neurologic injury/insult/baseline abnormality, respiratory concerns, decreased or absent gag reflex, and those who are critically ill."

In Table 4, four guidelines refer to the efficacy of 'signs of respiratory distress' (such as coughing, choking and dyspnea) in distinguishing between gastric and pulmonary placement of a NG tube. Guideline V recommends use of the method, with a caveat that signs of respiratory distress may be absent when a tube is in the airway (especially in unconscious patients). Guidelines VI and VII discourage use of the method altogether since signs of respiratory distress may be absent in some patients even when the NG tube is inadvertently placed in the respiratory tract. Nonetheless, the presence of respiratory distress during tube insertion increases concern for inadvertent placement of a NG tube in the respiratory tract (XIII).

Three of the six guidelines (VI, VII, XIV) in Table 5 caution against use of aspirate appearance as a method to distinguish between gastric and pulmonary placement of a NG tube. Two others (V and XI) state that aspirate appearance may be helpful but cannot serve as an independent predictor. Only one of the guidelines (XI) includes information about the appearance of aspirates: "Fluid withdrawn from a tube that has perforated into the pleural space typically has a pale-yellow

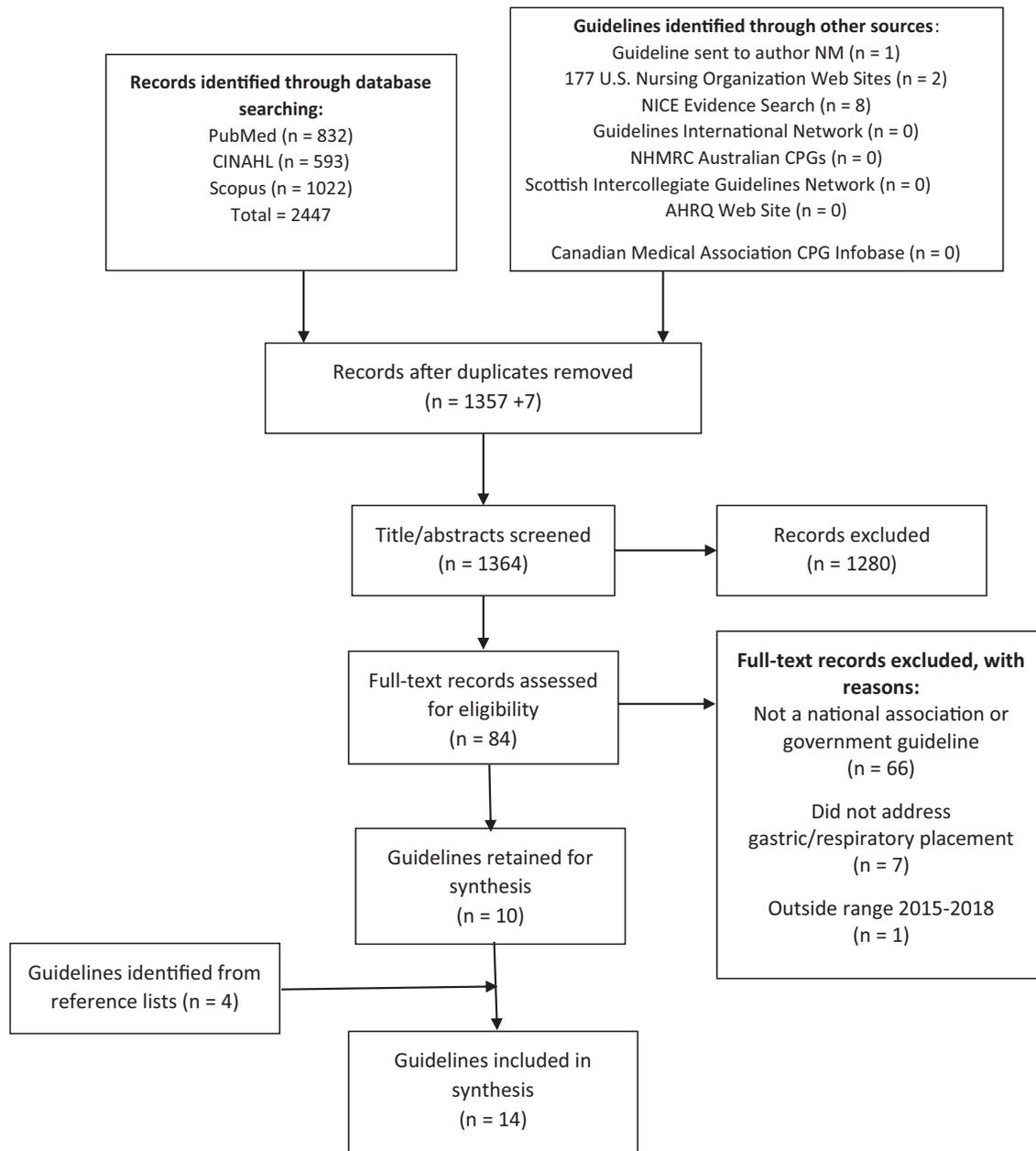


Fig. 1. PRISMA diagram of search.

serous appearance and a pH of 7 or higher, whereas fasting gastric fluid is typically clear and colorless or grassy green or brown with a pH of 5 or less." A single guideline (XII) considers aspiration of 'gastric content' equivalent to the accuracy of radiography in determining gastric placement; however, missing from the guideline is a description of 'gastric content.'

As shown in Table 6, there is considerable variation in the nine guidelines regarding the use of aspirate pH as a predictor of non-pulmonary placement of a NG tube. Guidelines II, VI, IX, and XIV indicate that a pH ranging from 1 to 5.5 indicates gastric placement and can serve as a substitute for radiographic confirmation of a newly inserted NG tube. A lower pH value (≤ 4.0) is advocated by guideline VII to increase the probability of gastric origin of the NG tube aspirate. Guidelines V and XI refer to using an aspirate pH of ≤ 5.0 as an indicator of gastric placement; however, neither views this method as a sufficient substitute for radiographic confirmation.

Although guidelines I and XII refer to pH testing as a method to determine tube placement, they do not refer to specific values.

Table 7 includes information from six guidelines; five of these (I, V, VIII, XI and XIV) specifically refer to the efficacy of carbon dioxide detection devices in distinguishing between gastric and pulmonary placement of a NG tube. All five agree that the method is helpful but insufficient as a sole method to distinguish between gastric and pulmonary tube placement. The NHS guideline (VI) indicates that there is no evidence that alternative devices or techniques equal or exceed the accuracy of pH or x-ray for confirming initial placement of a NG tube; it is assumed that the guideline includes carbon dioxide detectors in this statement.

In Table 8, seven guidelines refer to the efficacy of 'auscultation' in distinguishing between gastric and pulmonary positioning of a NG tube. Four of the sources (V, VI, VII and XIV) state that this method should not be used at all, while two others (I and XI) state that it is

Table 2
Guidelines/recommendations included in review.

I.	Emergency Nurses Association (ENA): Clinical Practice Guideline: 'Gastric Tube Placement Verification'. 2015. ¹¹
II.	Guidelines and Audit Implementation Network (GAIN): 'Guidelines for caring for an infant, child or young person who requires enteral feeding. (NICE National Institute for Health and Care Excellence) (excludes neonates)' February 2015. ¹²
III.	Nutritional Therapy in Paediatric ICUs: A consensus statement of the Section of Paediatric Anaesthesia and Intensive Therapy of the Polish Society of Anaesthesiology and Intensive Therapy, Polish Society of Neonatology and Polish Society for Clinical Nutrition of Children. <i>Anaesthesiology Intensive Therapy</i> . (47(4)267–283, 2015. ¹³
IV.	Guidelines for parenteral and enteral nutrition support in geriatric patients in China. <i>Asia Pac J Clin Nutr</i> 24(2)336–246, 2015. ¹⁴
V.	American Association of Critical Care Nurses (AACN) Practice Alert: 'Initial and Ongoing Verification of Feeding Tube Placement in Adults'. <i>Critical Care Nurse</i> . April 2016. ³
VI.	National Health Service (NHS) Improvement. 'Resource Set: Initial Placement Checks for Nasogastric and Orogastric Tubes.' July 2016. ⁵
VII.	New South Wales (NSW) Government Health: 'Infants and Children Insertion and Confirmation of Placement of Nasogastric and Orogastric Tubes. Agency for Clinical Innovation.' Document type: Guideline; Document number: GL2016_006, February 4, 2016. ¹⁵
VIII.	Intensive Care Society. Additional Uses for Capnography. Capnography after Placement of Nasogastric Tubes. 2016. ¹⁶
IX.	National Nurses Nutrition Group (NNG) 'Good Practice Guideline – Safe Insertion and Ongoing Care of Nasogastric (NG) Feeding Tubes in Adults (2nd ed).' (sub-group of the British Association of Parenteral & Enteral Nutrition [BAPEN]) April 2016. ¹⁷
X.	American College of Gastroenterology (ACG) Clinical Guideline: "Nutrition Therapy in the Adult Hospitalized Patient." <i>American Journal of Gastroenterology</i> 111,315–334, 2016. ¹⁸
XI.	American Society for Parenteral and Enteral Nutrition (ASPEN): 'Safe Practices for Enteral Nutrition Therapy'. January 2017. ¹⁹
XII.	European Society for Clinical Nutrition and Metabolism (ESPEN) Guideline Clinical Nutrition in Neurology. <i>Clinical Nutrition</i> 37:354–396, 2018. ²⁰
XIII.	U.S. Food and Drug Administration (FDA): 'Letter to Health Care Providers: Reports of Pneumothorax Events.' Posted 01/12/2018. ²¹
XIV.	Pediatric Nasogastric Tube Placement and Verification: Best Practice Recommendations from the NOVEL Project. (sub-group of American Society of Parenteral and Enteral Nutrition) <i>Nutrition in Clinical Practice</i> . Volume 00, Number 0, 1–7, 2018. ²²

Table 3
Excerpts from 2015–August 2018 guidelines/recommendations for using radiography to distinguish between gastric and pulmonary placement of nasogastric tubes.

Guideline Number	
I	Emergency Nurses Association: Clinical Practice Guideline: 'Gastric Tube Placement Verification'. 2015. <ul style="list-style-type: none"> • "Radiographic examination (x-ray or CT scan) remains the gold standard for verifying gastric tube placement prior to instillation of any substance." (Level A: High)
II	Guidelines and Audit Implementation Network (GAIN): 'Guidelines for caring for an infant, child or young person who requires enteral feeding. (NICE National Institute for Health and Care Excellence) (excludes neonates)' February 2015. <ul style="list-style-type: none"> • Appendix 4: "If unable to obtain aspirate or if pH of aspirate is not between 1 and 5.5, proceed to x-ray, ensure reason for x-ray documented on request form."
III	Nutritional Therapy in Paediatric ICUs: A Consensus statement of the Section of Paediatric Anesthesia in an Intensive Therapy of the Polish Society of Neonatology and Polish Society for Clinical Nutrition of Children. 2015 <ul style="list-style-type: none"> • Referring to gastric and post-pyloric tubes: "In both cases, the tube location should be radiologically confirmed, although auscultation is also acceptable when the tubes are inserted into the stomach."
IV	Guidelines for Parenteral and Enteral Nutrition Support in Geriatric Patients in China. 2015 <ul style="list-style-type: none"> • "Before enteral nutrition feeding, location of the nasogastric tube should be determined. If displacement is suspected, radiologic examination should be referred to." (Oxford Evidence-based Medicine principle of Grading of Recommendations Assessment, Develop and Evaluation: B)
V	American Association of Critical Care Nurses Practice Alert: 'Initial and Ongoing Verification of Feeding Tube Placement in Adults'. April 2016. <ul style="list-style-type: none"> • "Recommend radiographic confirmation of correct placement of a blindly inserted small-bore or large-bore tube before its initial use for feedings or medical administration; this recommendation also applies to a tube inserted with assistance from an electromagnetic tube placement device and gastric decompression tubes that are later used for other purposes." • "The radiograph should visualize the entire course of the feeding- tube in the gastrointestinal tract and should be interpreted by a radiologist to avoid errors." (AACN Levels of Evidence: A)
VI	National Health Service Improvement. Resource set: Initial placement checks for nasogastric and orogastric tubes. July 2016 <ul style="list-style-type: none"> • "Radiology (x-ray) can be used to confirm placement but should not be used routinely for all patients." • "If fluid in the 'safe range' of pH cannot be obtained, an x-ray would be required to confirm nasogastric tube placement and may be routinely used for some patients in specialist settings." • "Interpretation of the x-ray would typically be done by medical staff or by radiologists."
VII	New South Wales Health: Guideline: Infants and Children Insertion and Confirmation of Placement of Nasogastric and Orogastric Tubes. Feb 4, 2016 <ul style="list-style-type: none"> • "Consider an x-ray prior to commencement of feeds on all new insertions in 'at risk' infant or child. pH testing may give false negatives for initial confirmation of placement in the presence of acid suppression therapy. 'At risk' infants and children include those on gastric acid pump inhibitors, with diminished or absent gag reflex (e.g. children with developmental delay, neuromuscular disorders, bulimia) and those with an altered level of consciousness."
X	American College of Gastroenterology Clinical Guideline: "Nutrition Therapy in the Adult Hospitalized Patient." <i>American Journal of Gastroenterology</i> 111,315–334, 2016. <ul style="list-style-type: none"> • "Radiologic confirmation of placement in the stomach should be carried out prior to feeding (except with the use of electromagnetic transmitter-guided feeding tubes)." (Conditional recommendation, very low Level of Evidence)
XI	American Society of Parenteral & Enteral Nutrition: 'Safe Practices for Enteral Therapy'. January 2017. <ul style="list-style-type: none"> • "For adult patients, obtain radiographic confirmation for any blindly placed short-term enteral access device to demonstrate that it is properly positioned in the GI tract prior to its initial use for administering feedings and medications in adult patients." • "For pediatric/neonatal patients, obtain an abdominal al radiograph when non-radiographic methods (measurement of enteral tube insertion length, gastric pH testing, and visual observation of gastric aspirate) for validation of tube location are not confirmatory."
XII	ESPEN Guideline Clinical Nutrition in Neurology. 2018. <ul style="list-style-type: none"> • "The placement of a nasogastric tube should be done by trained and technically experienced medical staff. Due to the risk of misplacement, the correct position should be controlled before the application of tube feed. This can be done via x-ray or by the aspiration of gastric content."
XIV	Pediatric Nasogastric Tube Placement and Verification: Best Practice Recommendations from the NOVEL Project. August, 2018 <ul style="list-style-type: none"> • "Consider a radiograph for any patient in whom there is any concern for correct NGT placement, such as: difficulty placing the NGT, NGT placement in any patient at high risk of misplacement (includes those with known history of facial fractures, neurologic injury/insult/baseline abnormality, respiratory concerns, decreased or absent gag reflex, and those who are critically ill), and in any patient whose condition deteriorates shortly after NGT placement." • "The radiograph requisition should contain a statement of the tube path, the location of the tube tip, and confirmation that the tube is positioned in the desired location and is appropriate for use."

Table 4
Excerpts from 2015–2018 guidelines/recommendations for signs of respiratory distress as a method to distinguish between gastric and pulmonary placement of nasogastric tubes.

Guideline number	
V	<p>American Association of Critical Care Nurses Practice Alert: 'Initial and Ongoing Verification of Feeding Tube Placement in Adults (applies to blind insertions and placements with an electromagnetic device).' <i>Critical Care Nurse</i>. Vol 36, No 2, April 2016.</p> <ul style="list-style-type: none"> • "Observe for signs of respiratory distress." (AACN Levels of Evidence: B) • "Important to recognize that signs of respiratory distress are sometimes absent when feeding tubes inadvertently position in the airway, especially in patients with an impaired level of consciousness."
VI	<p>National Health Service Improvement. Resource set: Initial placement checks for nasogastric and orogastric tubes. July 2016</p> <ul style="list-style-type: none"> • "DO NOT interpret absence of respiratory distress as an indicator of correct positioning" • "Observing for respiratory distress is ineffective in detecting misplaced nasogastric tubes as nasogastric tubes can enter the respiratory tract without causing any symptoms."
VII	<p>NSW New South Wales (NSW) Government Health: 'Infants and Children Insertion and Confirmation of Placement of Nasogastric and Orogastric Tubes. February 4, 2016</p> <ul style="list-style-type: none"> • "Absence of respiratory distress must not be used to determine NG tube placement"
XIII	<p>U.S. Food and Drug Administration (FDA): 'Letter to Health Care Providers: Reports of Pneumothorax Events.' Posted 01/12/2018.</p> <p>For enteral access systems, the FDA recommends:</p> <p>"Confirmation of the final tube position should be done per institution protocol, in particular if:</p> <ul style="list-style-type: none"> <input type="radio"/> any difficulty occurred during insertion <input checked="" type="radio"/> the patient displayed any signs of respiratory distress during the procedure <input type="radio"/> the tube's path during placement appeared to deviate from expected <input type="radio"/> the final location is uncertain <input type="radio"/> the patient has a variation in normal gastrointestinal anatomy <input type="radio"/> or the patient is intubated or has an altered level of consciousness."

Table 5
Excerpts from 2015–2018 guidelines/recommendations for visual characteristics of aspirate as a method to distinguish between gastric and pulmonary placement of nasogastric tubes.

Guideline Number	
V	<p>American Association of Critical Care Nurses Practice Alert: 'Initial and Ongoing Verification of Feeding Tube Placement in Adults (applies to blind insertions and placements with an electromagnetic device).' <i>Critical Care Nurse</i>. Vol 36, No 2, April 2016.</p> <ul style="list-style-type: none"> • Observe visual characteristics of aspirate from the tube. (AACN Levels of Evidence: B) <input type="radio"/> "Aspirate appearance is not sufficient to eliminate the need for a confirming radiograph before first-time use of a feeding tube."
VI	<p>National Health Service Improvement. Resource set: Initial placement checks for nasogastric and orogastric tubes. July 2016</p> <ul style="list-style-type: none"> • "DO NOT interpret appearance of aspirate as an indicator of correct positioning" • "There is no absolute distinction that can be made in the appearance of gastric, respiratory and pleural secretions that can easily be described and applied to normal variation in healthy people and to patients with a wide range of gastric and respiratory conditions."
VII	<p>New South Wales Health: Guideline: Infants and Children Insertion and Confirmation of Placement of Nasogastric and Orogastric Tubes. Feb 4, 2016</p> <ul style="list-style-type: none"> • "Secretion color must not be used for confirming tube placement."
XI	<p>American Society for Parenteral & Enteral Nutrition: 'Safe Practices for Enteral Therapy.' <i>Journal of Parenteral & Enteral Nutrition</i>. Vol 41, No 1, January 2017.</p> <ul style="list-style-type: none"> • Refers to Adults: "When attempting to insert a short-term feeding tube, obtain a tube aspirate for appearance and pH measurement. The appearance and pH are likely dependent on location." <input type="radio"/> "Fluid withdrawn from a tube that has perforated into the pleural space typically has a pale-yellow serous appearance and a pH of 7 whereas fasting gastric fluid is typically clear and colorless or grassy green or brown with a pH of 5 or less." <input type="radio"/> "The appearance of aspirates from a feeding tube may provide a clue to an enteral access device location but has not been shown to be reliable as a single marker for tube tip location." • Refers to Pediatric/Neonatal patients: <ul style="list-style-type: none"> <input type="radio"/> "Use accurate measurement of enteral tube insertion length, gastric pH testing, and visual observation of gastric aspirate as acceptable nonradiological methods for assessing tube placement when radiographic verification is not available."
XII	<p>ESPEN Guideline Clinical Nutrition in Neurology. 2018.</p> <ul style="list-style-type: none"> • "The placement of a nasogastric tube should be done by trained and technically experienced medical staff. Due to the risk of misplacement, the correct position should be controlled before the application of tube feed. This can be done via x-ray or by the aspiration of gastric content."
XIV	<p>Pediatric Nasogastric Tube Placement and Verification: Best Practice Recommendations from the NOVEL Project.' August, 2018</p> <ul style="list-style-type: none"> • "Safety and practice alerts warn against the use of visual inspection of gastric aspirate to determine placement of NG tubes..."

unreliable as a solitary indicator of tube location. Only one of the guidelines (III) referred to auscultation as being sufficient to confirm gastric placement.

Table 9 includes information from seven guidelines regarding the efficacy of enteral access devices in distinguishing between gastric and pulmonary placement of a NG tube. A single medical specialty group (X) in the U.S. states that an enteral access device can be used as the sole source of verifying correct tube placement. Two nursing specialty groups (V and IX) disagree. The NHS guideline (VI) indicates that there is no evidence that alternative devices or techniques equal or exceed the accuracy of pH or x-ray for confirming initial placement of a NG tube; it is assumed that the guideline includes enteral access devices in this statement. The U.S. Food and Drug Administration (XIII) has outlined specific conditions under which

an enteral access device might require additional testing (according to institution protocol) to assure that a NG tube is not placed in the respiratory tract. According to guideline XIV, use of enteral access devices in pediatric settings to confirm NG tube placement is controversial. Still another guideline (I) indicates that there is insufficient evidence to recommend the method.

Discussion

Radiography

There is general consensus among the guidelines that a properly obtained and interpreted x-ray is the most accurate method to distinguish between gastric and pulmonary placement of NG tubes. Thus,

Table 6
Excerpts from 2015–2018 guidelines/recommendations for testing the pH of aspirate as a method to distinguish between gastric and pulmonary placement of nasogastric tubes.

Guideline number	
I	Emergency Nurses Association: Clinical Practice Guideline: Gastric Tube Placement Verification. 2015. <ul style="list-style-type: none"> • “Use of pH testing of gastric tube aspiration as a component of a multiple method bedside verification method for gastric tube placement is supported by the literature.” (Level B: Moderate)
II	Guidelines and Audit Implementation Network: Guidelines for caring for an infant, child or young person who requires enteral feeding. (NICE National Institute for Health and Care Excellence) February 2015 (excludes neonates) <ul style="list-style-type: none"> • “Test aspirate on CE marked pH indicator paper for use on human gastric aspirate.” • “Correct gastric tube position is confirmed with a gastric aspirate pH value between 1 and 5.5.” • “Do not use the device if pH value is above 5.5.” • “Children taking antacids, H2 antagonists or proton pump inhibitors are likely to have a stomach pH greater than 5.5 in which case it may be difficult to confirm tube placement with the necessary accuracy. The need to continue this medicine should be reviewed by the prescriber against the need to feed via gastric tube.”
V	American Association of Critical Care Nurses Practice Alert: Initial and Ongoing Verification of Feeding Tube Placement in Adults (applies to blind insertions and placements with an electromagnetic device). Critical Care Nurse. Vol 36, No 2, April 2016. <ul style="list-style-type: none"> • “Measure pH of aspirate from tube if pH strips are available.” (AACN Levels of Evidence: B) • “Fasting gastric pH is usually 5 or less, even in patients receiving gastric-acid inhibitors. Respiratory secretions typically have a pH of 6 or greater. “Because gastric fluid occasionally has a high pH, the pH method is not sufficiently reliable to rule out the need for radiography to distinguish between gastric and respiratory tube placement.”
VI	National Health Service Improvement. Resource set: Initial placement checks for nasogastric and orogastric tubes. July 2016 <ul style="list-style-type: none"> • “pH in the ‘safe range’ of 1–5.5 can be used as the first line test to exclude placement in the respiratory tract.” • “The normal human stomach has a pH of approximately 1–3 in an empty stomach and approximately 4–5 after food has been eaten. Patients on acid-reducing medication may have a stomach pH level of 6 or above. The pH in healthy lungs is between 7.38 and 7.42.” • “No local or national clinical guidance should widen the safe range.” • “All pH strips should be CE marked and intended by the manufacturer to test human gastric aspirate”
VII	New South Wales Health: Guideline: Infants and Children Insertion and Confirmation of Placement of Nasogastric and Orogastric Tubes. Feb 4, 2016 <ul style="list-style-type: none"> • “Threshold for ‘positive placement confirmation’ pH reduced to 4.0 or less.” • “Use narrow range pH paper [around 2.0–9.0] in minimum 0.5 increments”.
IX	National Nurses Nutrition Group: Good Practice Guideline – Safe Insertion of Nasogastric (NG) Feeding Tubes in Adults and Ongoing care. April 2016 <ul style="list-style-type: none"> • “Test the aspirate obtained with pH indicator paper/strips that are CE marked for human gastric aspirate. Ensure aspirate is measured and strips read as per manufacturers’ instructions” ○ “The pH reading must be 5.5 or below before feed, fluid or medication can be administered via the nasogastric tube.” ○ “The pH ‘cut-off’ reading may differ according to local policy and pH indicator strips used but should never exceed 5.5.”
XI	American Society for Parenteral & Enteral Nutrition: “Safe Practices for Enteral Therapy. Journal of Parenteral & Enteral Nutrition. Vol 41, No 1, January 2017. <ul style="list-style-type: none"> • “When attempting to insert a short-term feeding tube, obtain a tube aspirate for pH measurement. ○ “Fluid withdrawn from a tube that has perforated into the pleural space typically has a pale-yellow serous appearance and a pH of 7 whereas fasting gastric fluid is typically clear and colorless or grassy green or brown with a pH of 5 or less.” ○ “The pH of aspirates from a feeding tube may provide a clue to an enteral access device location but has not been shown to be reliable as a single marker for tube tip location.”
XII	ESPEN Guideline Clinical Nutrition in Neurology. 2018. <ul style="list-style-type: none"> • “The placement of a nasogastric tube should be done by trained and technically experienced medical staff. Due to the risk of misplacement, the correct position should be controlled before the application of tube feed. This can be done via x-ray or by the aspiration of gastric content. A further possibility to control tube position is the measurement of gastric pH.”
XIV	Pediatric Nasogastric Tube Placement and Verification: Best Practice Recommendations from the NOVEL Project. August 2018 <ul style="list-style-type: none"> • “Use gastric pH testing as the first-line method for NGT location verification” • “A gastric pH value of 1–5.5 without a change in the patient’s clinical status is indicative of gastric placement.”

Table 7
Excerpts from 2015–2018 guidelines/recommendations for carbon dioxide detection as a method to distinguish between gastric and pulmonary placement of nasogastric tubes.

Guideline number	
I	Emergency Nurses Association: Clinical Practice Guideline: Gastric Tube Placement Verification. 2015. <ul style="list-style-type: none"> • “There is some evidence to support the use of carbon dioxide detection for bedside verification of gastric tube placement.” (Level C: Weak)
V	American Association of Critical Care Nurses Practice Alert: Initial and Ongoing Verification of Feeding Tube Placement in Adults (applies to blind insertions and placements with an electromagnetic device). Critical Care Nurse. Vol 36, No 2, April 2016. <ul style="list-style-type: none"> • “Use capnography if available.” (AACN Levels of Evidence: B) • “A carbon dioxide detector is helpful in detecting when a feeding tube is in the tracheobronchial tree; however, capnography is not sufficiently sensitive and specific to preclude the need for a confirming radiograph before initial use of a feeding tube.”
VI	National Health Service Improvement. Resource set: Initial placement checks for nasogastric and orogastric tubes. July 2016 <ul style="list-style-type: none"> • “To date there is no evidence that alternative devices or techniques equal or exceed the accuracy of pH or x-ray for confirming initial placement of a nasogastric tube.”
VIII	Intensive Care Society: Standards for Capnography. Capnography after placement of nasogastric tubes. 2016 <ul style="list-style-type: none"> • “Capnography trace can be obtained from a nasogastric (NG) tube placed inadvertently in the bronchial tree. This confirmation may be useful in the following circumstances: (a) If a NG tube is thought to have been misplaced in the bronchial tree, then obtaining a respiratory waveform would allow the NG tube to be removed without having to use a chest x-ray to confirm this incorrect placement. (b) If a capnography trace is obtained when the NG tube has been advanced to about 25 cm in an adult, then intra-bronchial placement can be confirmed before the possibility of pneumothorax could arise.”
XI	American Society for Parenteral & Enteral Nutrition: ‘Safe Practices for Enteral Therapy.’ Journal of Parenteral & Enteral Nutrition. Vol 41, No 1, January 2017. <ul style="list-style-type: none"> • “Even though capnography may indicate absence of non-bronchial and non-tracheal placement of a newly inserted tube, a radiograph is still required to ensure proper placement in the stomach.”
XIV	Pediatric Nasogastric Tube Placement and Verification: Best Practice Recommendations from the NOVEL Project. Nutrition in Clinical Practice. August, 2018 <ul style="list-style-type: none"> • “Capnography is not currently recommended to be used as an independent method to verify NGT placement.”

Table 8
Excerpts from 2015–2018 guidelines/recommendations for auscultation as a method to distinguish between gastric and pulmonary placement of nasogastric tubes.

Guideline Number	
I	Emergency Nurses Association: Clinical Practice Guideline: Gastric Tube Placement Verification. 2015. • “Use of auscultation as a single verification method is unreliable in determining gastric tube location.” (Not recommended).
III	Nutritional therapy in paediatric intensive care units: A consensus statement of the Section of Paediatric Anaesthesia and Intensive Therapy of the Polish Society of Anaesthesiology and Intensive Therapy, Polish Society of Neonatology and Polish Society for Clinical Nutrition of Children, 2015. • Referring to gastric and post-pyloric tube: “In both cases, the tube location should be radiographically confirmed, although auscultation is also acceptable when the tubes are inserted into the stomach.”
V	American Association of Critical Care Nurses Practice Alert: Initial and Ongoing Verification of Feeding Tube Placement in Adults (applies to blind insertions and placements with an electromagnetic device). (Critical Care Nurse. Vol 36, No 2, April 2016. • “Do not use the auscultatory (air bolus) method to determine tube location.” (AACN Level of Evidence: B)
VI	National Health Service Improvement. Resource set: Initial placement checks for nasogastric and orogastric tubes. July 2016 • “Do not use the ‘whoosh test’ ○ “Clinicians’ hearing cannot precisely locate the origin of a sound in the patient’s physiology; the lungs and stomach are in very close proximity.” ○ “No local or national clinical guidance should amend this requirement.”
VII	New South Wales Health: Guideline: Infants and Children Insertion and Confirmation of Placement of Nasogastric and Orogastric Tubes. Feb 4, 2016 • “Gas insufflation/auscultation must not be used for confirming tube placement.”
XI	American Society for Parenteral & Enteral Nutrition: Safe Practices for Enteral Therapy. Journal of Parenteral & Enteral Nutrition. Vol 41, No 1, January 2017. • “Do not rely on the auscultatory method alone to differentiate between gastric and respiratory placement.”
XIV	Pediatric Nasogastric Tube Placement and Verification: Best Practice Recommendations from the NOVEL Project. (sub-group of American Society of Parenteral and Enteral Nutrition) Nutrition in Clinical Practice. 2018 • “Safety and practice alerts warn against the use of auscultation. . . .”

Table 9
Excerpts from 2015–2018 guidelines/recommendations for an enteral access system to distinguish between gastric and pulmonary placement of nasogastric tubes.

Method	
I	Emergency Nurses Association: “Clinical Practice Guideline: Gastric Tube Placement Verification.” 2015. • “Use of translumination and magnetic detection requires equipment that may be difficult to obtain and its use as a single bedside verification method for gastric tube placement requires further study.” (Level E: Insufficient evidence)
V	American Association of Critical Care Nurses Practice Alert: Initial and Ongoing Verification of Feeding Tube Placement in Adults (applies to blind insertions and placements with an electromagnetic device). Critical Care Nurse. Vol 36, No 2, April 2016. • “Recommend radiographic confirmation of correct placement of a blindly small-bore or large-bore tube before its initial use for feedings or medication administration; this recommendation also applies to a tube inserted with assistance from an electromagnetic tube placement (ETP) device.” (AACN Levels of Evidence: A)
VI	National Health Service Improvement. Resource set: Initial placement checks for nasogastric and orogastric tubes. July 2016 • “To date there is no evidence that alternative devices or techniques equal or exceed the accuracy of pH or x-ray for confirming initial placement of a nasogastric tube.”
IX	National Nurses Nutrition Group: “Good Practice Guideline-Safe Insertion of Nasogastric Feeding Tubes in Adults and Ongoing Care.” April 2016 • “If an electromagnetic tracking device is used to monitor the progress of a nasogastric tube during placement, pH of aspirate or x-ray should always be used as a final means of confirming tube position.”
X	American College of Gastroenterology Clinical Guideline:” Nutrition Therapy in the Adult Hospitalized Patient. “American Journal of Gastroenterology 111,315–334, 2016. • “Radiologic confirmation of placement in the stomach should be carried out prior to feeding (except with the use of electromagnetic transmitter-guided feeding tubes).” (Conditional recommendation, very low Level of Evidence)
XIII	U.S. Food and Drug Administration: Letter to Health Care Providers: ‘Reports of Pneumothorax Events.’ Posted 01/12/2018. For enteral access systems, the FDA recommends: “Confirmation of the final tube position should be done per institution protocol, in particular if: ○ any difficulty occurred during insertion ○ the patient displayed any signs of respiratory distress during the procedure ○ the tube’s path during placement appeared to deviate from expected ○ the final location is uncertain ○ the patient has a variation in normal gastrointestinal anatomy ○ or the patient is intubated or has an altered level of consciousness.” • For the Cortrak device in particular, the FDA also recommends: “The user observes and assesses the real-time tracing to ensure the proper path of the tube. The final location, including which quadrant the tip is located in, and the centimeter marking, should not be solely relied upon for assessment of whether the device is correctly placed or not.”
XIV	Pediatric Nasogastric Tube Placement and Verification: Best Practice Recommendations from the NOVEL Project. (sub-group of American Society of Parenteral and Enteral Nutrition) Nutrition in Clinical Practice. Volume 00, Number 0, 1–7, 2018 • “The use of an electromagnetic sensor-guided device of NGT placement verification in pediatric patients is controversial”

the primary benefit of radiography is its high degree of accuracy. As indicated earlier, geographic location has a strong influence on when radiographic confirmation of tube location is recommended. For example, guidelines from the U.S. (I, V, X, and XI) favor radiographic confirmation of tube location as the first-line method in adults; in contrast, guidelines from Europe and Australia (II, VI and VII) favor radiographic testing only when the pH-method has failed or the patient is ‘at risk’.

Precautions to assure accurate results

Certain precautions are needed to assure accurate results from radiography. For example, guidelines V and XIV stipulate that the radiograph should visualize the entire course of the NG tube in the gastrointestinal tract, and guideline VI requires staff interpreting radiographs to have undertaken specific training in this interpretation technique. Guideline V emphasizes the film should be interpreted by a radiologist and guideline II recommends that the x-ray request clearly state that the purpose of

the x-ray is to determine if the NG tube is properly positioned. These are sound recommendations since faulty x-ray procedures and interpretations are not uncommon. For example, 42.1% (40/95) of the incidents of undetected tubes in the lung reported in the U.K. between 9/12/11 and 3/11/16 were related to faulty interpretation of x-rays (VI), as were 28.6% (16/56) of the incidents described by the Pennsylvania Safety Authority.

In addition to accuracy, clinicians consider other factors when determining which patients require radiographic confirmation of tube location. Among these are: risk factors for undetected tube malposition, cost, age, risk for radiation injury, setting, and delayed initiation of use of the tube for feedings or medications.

Risk factors

Some patients are at much greater risk than others for inadvertent placement of a NG tube in the pulmonary tract. Among frequently cited risk factors are altered level of consciousness, diminished or absent gag reflex, heavy sedation, and critical illness. Thus, it is understandable why the Emergency Nurses Association (I) and the American Association of Critical Care Nurses (V) recommend radiological verification of a NG tube's position prior to its initial use for feedings and/or medications.

Cost

The cost of a single chest or abdominal x-ray typically ranges from \$100 to several hundred dollars.^{7,8} It is reasonable to speculate that cost of an x-ray to confirm NG tube placement prior to its initial use for feedings/medications is minimal when compared to the cost of care for a patient who has received feedings into the lung via a poorly positioned NG tube. However, another point of view is that non-radiographic methods may be acceptable within defined limits to minimize use of radiographic confirmation. For example, in the U.K., it has been concluded that an aspirate within a specified pH range is sufficient evidence of non-pulmonary placement of the tube (VI).

Age

A patient's age is a factor in recommendations for use of radiography to test tube placement. For example, guideline XI recommends radiographic verification of any blindly placed short-term enteral access device in adults prior to initial use for feedings and medications; however, the same organization recommends an x-ray in children only after non-radiographic methods ("measurement of enteral tube length, gastric pH testing, and visual observation of gastric aspirate") have failed. As shown in Table 3, none of the pediatric guidelines specify radiography as the first-line method; instead, recommendations for radiographic confirmation in children are prefaced with comments such as: "if unable to obtain aspirate or if pH of aspirate is not between 1 and 5.5" (II), "when non-radiographic methods are not confirmatory" (XI), "in 'at risk' infant or child" (VII), or if there is "any concern for correct placement" (XIV). The major concern with use of radiography use in children is risk for radiation injury.

Risk for radiation injury

Understandably, clinicians worry more about the possibility for radiation injury in children than in adults. This is because repeated x-rays may slightly increase a child's risk for cancer later in life. A single chest or abdominal x-ray provides very little radiation exposure and therefore little, if any, risk.⁹ "For example, a standard x-ray of the chest provides about the same amount of radiation that you would normally get from background environmental radiation in 2–3 days... less than you get on an airplane flight".⁹ However, for children who require repeated tube insertions over the course of prolonged NG feedings, the risk for radiation injury is increased. While clinicians strive to use x-rays as sparingly as possible in children, risk for radiation injury must be weighed against potential harm from other conditions (such as administering feedings via a NG tube inadvertently positioned in the lung).

Setting

Radiographic confirmation of tube position is not an option in the home setting. It also is not a readily available option in many long-term care settings. In these situations, a stronger emphasis is placed on non-radiographic testing methods.

Delay in use of tube

In busy clinical settings, it may take several hours to obtain results from an x-ray examination, thus delaying use of the tube for feedings or medications. In contrast, results from non-radiographic methods (such as pH-testing and aspirate appearance) may be obtained in a matter of minutes.

Observing for signs of respiratory distress

The important message from the guidelines in Table 4 is that the absence of respiratory distress does not confirm non-pulmonary placement of a tube. This is because some patients don't display signs of respiratory distress when a NG tube is inadvertently placed into the respiratory tract. Nonetheless, when signs of respiratory distress are present, the suspicion of inadvertent respiratory placement of the tube is heightened. As indicated in guideline XIII, the presence of respiratory distress during tube insertion with an enteral access device is an indication to consider additional testing methods (according to institutional policies) to confirm correct tube position.

Observing aspirate appearance

Overlap between the expected appearance of aspirates from gastric and respiratory sites likely contributes to lack of reliance on this method. Only one of the six guidelines included in Table 5 recommends use of this method as a single indicator of gastric placement; however, it refers to obtaining 'gastric content' without describing its characteristics.

Measuring aspirate pH

As shown in Table 6, geographical location has a strong influence on recommendations for use of the pH method. For example, guidelines from the U.K. (II, VI and IX) favor the pH method as first-line testing for NG tube placement. In contrast, guidelines from the U.S. (I, V and XI) favor pH testing only as a precursor to radiographic confirmation of correct tube location. Regardless of geographical location, pediatric guidelines are more likely to favor the pH method for first-line testing, presumably to avoid risk for radiation injury from x-rays.

Advantages of pH-testing

There are important advantages to use of the pH method:

- (1) *Theoretical basis.* A distinct difference is typically present between the pH of fasting gastric juice and pulmonary aspirates (tracheo-bronchial secretions and pleural fluid).
- (2) *Cost.* Compared to radiography, pH-testing is cost-effective. For example, a typical pH test strip costs less than 25 cents.¹⁰ In contrast, an x-ray may cost several hundred dollars.
- (3) *Time to results.* Once an aspirate has been obtained from the NG tube, it can be applied to a test strip or paper and results are available within one or two minutes.
- (4) *Setting.* The pH method can be used in home settings as well as in acute and long-term care facilities.

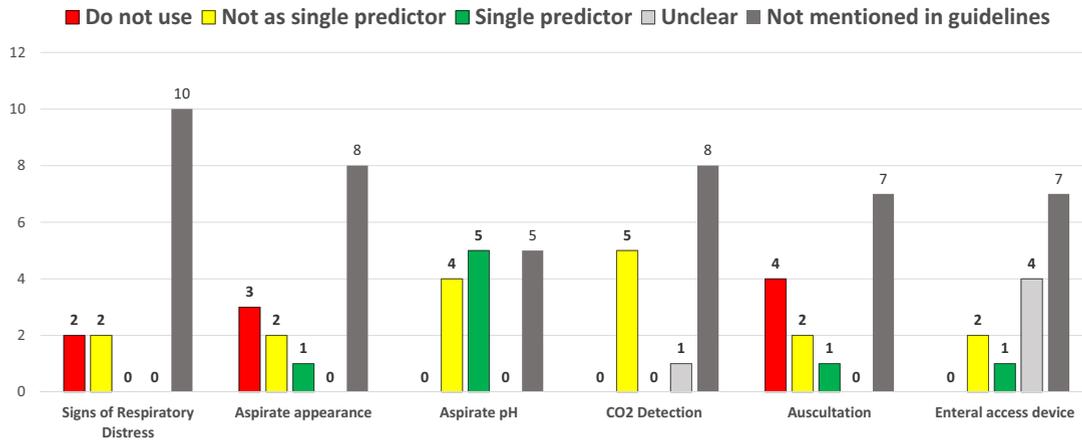


Fig. 2. Summary of recommendations for non-radiological testing methods to distinguish between gastric and respiratory placement of NG tubes ($n = 14$ guidelines).

Disadvantages of pH-testing

There are potential problems with the pH-method:

1. *Disagreement about best pH-cut-point.* There is considerable disagreement about the 'best' pH cut-point to distinguish between gastric and respiratory aspirates. Guidelines from the U.K. (II, VI and IX) state that a pH in the 'safe range' of 1–5.5 can be used as the first-line test to exclude placement in the respiratory tract." A lower value (5 or less) is cited by two sources from the U.S. (V and XI) while an even lower value of 4.0 or less is cited in pediatric guidelines from New South Wales (VII). Obviously, the lower the pH, the more convincing is the evidence that the aspirate is from the stomach instead of the respiratory tract. However, from a practical standpoint, it is reasonable to select the highest gastric pH value that is likely to differentiate between gastric and respiratory fluids (tracheobronchial secretions and pleural fluid). Unfortunately, there is considerable variation in the guidelines regarding the pH of fluids in the respiratory tract. According to the guideline from N.S.W. (VII), some fluids in the respiratory tract have a pH as low as 5.5. The AACN guideline (V) states that respiratory secretions usually have a pH of 6.0 or greater (with pleural fluid typically having a pH of 7 or higher). In contrast, the NHS guideline (VI) refers to 'pH in healthy lungs as ranging between 7.38 and 7.42.'
2. *Effect of gastric acid inhibitors.* Gastric acid inhibiting medications (such as proton pump inhibitors and H₂ receptor antagonists) elevate gastric pH and make it more difficult to distinguish between gastric and pulmonary placement on the basis of pH testing. For this reason, the GAIN pediatric guideline (II) states that the prescriber of acid-inhibitors may need to review their benefit in children fed via a NG tube. Although gastric acid inhibitors may limit the ability of aspirate pH to confirm gastric placement, they do not create a risk for pulmonary placements being incorrectly identified as gastric placements (thus, use of pH as a first-line test is not contraindicated).
3. *Potential for measurement error with colorimetric tests.* In typical clinical settings, aspirate pH is tested with a colorimetric paper or test strip. Since these tests require subjective interpretation, it may be difficult to make accurate readings, especially between pH values of 5.0–6.0. For this reason, the GAIN guideline (II) recommends that a second competent person check the reading when a pH value is between 5.0 and 6.0. Further, in situations in which a pH of ≤ 5.5 is deemed adequate, a pH indicator calibrated in units of 0.5 and approved for use with human secretions must be used (II, VI and IX). The NHS guideline requires competency-based training for those undertaking pH tests, which provides an opportunity to detect if staff members have poor color discrimination.

4. *Difficulty obtaining aspirate from NG tube.* According to the AACN guidelines (V) for adults, this problem can usually be solved by injecting air boluses into the tube with a large syringe and then applying slow negative pressure to the plunger to withdraw fluid. If not possible to aspirate fluid from a NG tube in an infant/child, the GAIN guideline (II) suggests turning "the child/infant onto the left side if possible, inject 1–5 ml of air into the tube using a syringe and wait for 15–30 min before aspirating again."

As described earlier, over a four-and-a-half-year period, 95 incidents were reported to the National Reporting and Learning System and/or the Strategic Executive Information System where patients were harmed as a result on incorrect predictions of tube location (VI), in a context of around 700,000 NG tube insertions annually in England. As described in Guideline VI, 23 of the 95 incidents were related to pH-testing. Seven of the 23 incidents occurred in circumstances in which safety-critical advice was not followed (including flushing tubes prior to pH testing). Ten of the 23 incidents described a pH within the 'safe range' of 1–5.5; however, details of the incident reports were not always adequate to exclude failure to test correctly (VI).

Carbon dioxide detection

There is consensus among the guidelines that specifically refer to carbon dioxide detectors that these devices may be helpful in distinguishing between gastric and pulmonary placement of a NG tube but are not sufficiently accurate to use as a single confirmatory method. Also, apparently the NHS guideline (VI) agrees. A problem identified in guideline V is that capnography equipment may not be readily available on patient care units.

Auscultation

There is consensus among six of the seven guidelines (I, V, VI, VII, XI and XIV) in Table 8 that the auscultatory method is not adequate to distinguish between gastric and pulmonary placement of a NG tube. In fact, four of the guidelines states that the method should not be used at all since air injected through the tube may be heard in a variety of body sites.

Enteral access devices

There is little support for use of an enteral access device as a solitary method to distinguish between gastric and pulmonary placement of a NG tube. Only one of the guidelines in Table 9 directly indicates that

the method is comparable to radiographic confirmation of tube location. Following multiple pneumothorax events associated with enteral access systems, the U.S. Food and Drug Administration (XIII) issued an alert in January, 2018 that recommended “confirmation of final tube position according to institution protocol, in particular if the patient has an altered level of consciousness, is intubated, or displays signs of respiratory distress during the insertion procedure.” While the FDA alert recognizes multiple situations in which use of an enteral access device failed to identify inadvertent pulmonary placements, it leaves the decision about how to confirm final tube position to individual institutions. See Table 9 for additional information.

Conclusions

The single area of agreement among the guidelines is that an x-ray, when properly performed and interpreted, is the most accurate method for distinguishing between gastric and pulmonary placement of a newly inserted NG tube. Although not recommended for first-line use in all situations, radiography is generally supported for high risk patients (such as those who are critically ill or have an altered level of consciousness or diminished or absent gag reflex). As shown in Fig. 2, there is less agreement among the guidelines concerning non-radiological methods to distinguish between gastric and pulmonary placement. Most favored among these methods is pH testing of NG aspirates, although there is lack of consensus on the best pH cut-point to make the distinction (values of ≤ 4.0 , ≤ 5.0 and ≤ 5.5 were cited in the guidelines). Least favored among the non-radiological methods are auscultation, aspirate appearance, and signs of respiratory distress. Lack of availability of special testing equipment, such as carbon dioxide detectors and enteral access devices, in routine clinical settings is a limiting factor for their use, and the evidence base for their accuracy has not been established. There is a general lack of support in the guidelines for either of these methods as a single predictor of tube location. Finally, variations in cost between radiography and non-radiological methods may be a factor in decisions about testing tube placement.

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