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Crit Care Nurse 2014, 34:67-78. doi: 10.4037/ccn2014606
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Published online <http://www.cconline.org>
originally published online April 15, 2014

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Nasogastric Tube Placement and Verification in Children: Review of the Current Literature

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Placement of a nasogastric enteral access device (NG-EAD), often referred to as a nasogastric tube, is common practice and largely in the domain of nursing care. Most often an NG-EAD is placed at the bedside without radiographic assistance. Correct initial placement and ongoing location verification are the primary challenges surrounding NG-EAD use and have implications for patient safety. Although considered an innocuous procedure, placement of an NG-EAD carries risk of serious and potentially lethal complications. Despite acknowledgment that an abdominal radiograph is the gold standard, other methods of verifying placement location are widely used and have success rates from 80% to 85%. The long-standing challenges surrounding bedside placement of NG-EADs and a practice alert issued by the Child Health Patient Safety Organization on this issue were the stimuli for the conception of The New Opportunities for Verification of Enteral Tube Location Project sponsored by the American Society for Parenteral and Enteral Nutrition. Its mission is to identify and promote best practices with the potential of technology development that will enable accurate determination of NG-EAD placement for both the inpatient and outpatient pediatric populations. This article presents the challenges of bedside NG-EAD placement and ongoing location verification in children through an overview of the current state of the science. It is important for all health care professionals to be knowledgeable about the current literature, to be vigilant for possible complications, and to avoid complacency with NG-EAD placement and ongoing verification of tube location. (*Critical Care Nurse*. 2014;34[3]:67-78)

In 2012, a safety alert was distributed by the Child Health Patient Safety Organization to recommend immediate discontinuation of the auscultation method for the assessment and verification of nasogastric tube placement.¹ A study cited in the alert reported that 1.3% to 2.4% of nasogastric tubes in more than 2000 insertions were located outside the gastrointestinal tract. Moreover, more than 20% of the misplaced nasogastric tubes led to pulmonary complications.^{1,2} This alert acknowledges an abdominal radiograph as the current gold standard when other nonradiographic methods for validation of tube location are not confirmatory. In lieu of or when abdominal radiography is not readily available, accurate measurement of enteral tube insertion length, gastric pH testing, and visual observation of gastric aspirate are acceptable nonradiologic methods for assessing tube placement listed in the

alert.¹ In addition, the alert specifies children who are considered at high risk for misplaced or dislodged gastric enteral tubes: neonates, children with neurological impairment, children in an obtunded neurological state, and children who are encephalopathic, have a decreased gag reflex, or are sedated or critically ill. For these children, the alert included a recommendation for abdominal radiography as the best practice for verifying location of a gastric enteral tube.¹

Although placement of a nasogastric tube is a common procedure, it is not without risk of significant harm or death. In addition to this alert, the

Critical Care Nurse and *Nutrition in Clinical Practice* have arranged to publish this article simultaneously in their publications. Minor differences in style may appear in each publication but the article is substantially the same in each journal.

©2014 American Society for Parenteral and Enteral Nutrition and American Association of Critical-Care Nurses doi: <http://dx.doi.org/10.4037/ccn2014606>

American Association of Critical-Care Nurses issued a practice alert³ and the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) implemented practice recommendations⁴ to address the risks and potential complications associated with misplaced nasogastric tubes. Placement of a gastric EAD potentially poses risks to patient safety, and device dislodgement poses similar risks. These phenomena are not predictable. Because of the threat to patient safety, placement of a nasogastric tube should be treated with the same respect as placement and management of a central venous access device or an indwelling urinary catheter. All health care professionals should avoid complacency with nasogastric tube placement and ongoing location verification and be vigilant for possible complications.

This practice alert along with long-standing challenges surrounding bedside placement (also called blind placement) of nasogastric tubes was the stimulus for the conception

of The New Opportunities for Verification of Enteral Tube Location (NOVEL) Project sponsored by A.S.P.E.N. NOVEL is an interorganizational, multiprofessional undertaking with representatives from the American Association of Critical-Care Nurses; the Society of Pediatric Nurses; the North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition; the Child Health Patient Safety Organization; and the American Association for Medical Instrumentation. This issue of nasogastric tube placement and ongoing location verification crosses the continuum of care. Recognizing this, the goal of the NOVEL project is to work toward effective, practical solutions to the challenge of safe initial placement of nasogastric tubes and ongoing verification of correct placement. Its mission is “to identify and promote best practices for [nasogastric tube] placement and to explore the potential of technology development that will allow for accurate determination of [nasogastric] tube

placement for both the inpatient and outpatient pediatric populations.”

In an effort to present the scope of the challenge for bedside placement of a nasogastric tube accurately, the authors felt it important to present an overview of the current literature addressing this issue. Therefore, the purpose of this article is to review the current state of the science for verification of bedside placement of nasogastric tubes and ongoing assessment of tube location in children. Although the term nasogastric tube is well-recognized and often used, the more comprehensive and inclusive term is nasogastric enteral access device (NG-EAD), the preferred terminology of A.S.P.E.N.⁴ This term will be used throughout the remainder of this article.

Background

In many hospitalized children and pediatric patients receiving home care, NG-EADs are used to facilitate nutrient intake and medication administration.⁵⁻⁸ Halloran et al⁹ estimated that more than 1 million NG-EADs are placed annually in adults. However, the number of NG-EADs placed and used in children and the frequency of placement errors is not known. The initial placement and ongoing verification of an NG-EAD is common practice for pediatric nurses and other care providers.^{6,10} These devices are most often placed at the bedside without radiographic assistance, and such placement has the potential for serious complications.

Studies^{2,10-12} have demonstrated that errors in NG-EAD placement are not uncommon. Sorokin and Gottlieb² reported a 1.3% to 2.4%

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incidence of misplacement of an EAD in 2000 NG-EAD insertions into adults. Of the misplaced devices, 28% resulted in pulmonary complications, with 2 of these misplacements culminating in death.² In a retrospective study with children, Ellett et al¹³ demonstrated by radiographic documentation a prevalence of 21% for misplaced or dislodged nasogastric, orogastric, and transpyloric EADs. In a follow-up prospective study, Ellett and Beckstrand¹⁴ used abdominal radiography to evaluate device placement and reported a prevalence between 22% and 44% in NG-EAD placement error in children in their institution, beyond the range found in adult studies.

Although alternative methods exist, abdominal radiographic imaging is the “gold standard” for verifying NG-EAD placement.^{4,6,7,10,15} However, even with radiographs, there may be variation in the interpretation of device location. This variation is due to a lack of consensus on identification of specific anatomic landmarks used to verify the NG-EAD position within the gastric cavity.¹⁵ In addition, the lack of a relevant clinical history explaining the need for a radiograph along with omission of a specific request for device and device tip location in the radiology requisition can influence the radiology report.^{15,16} Despite this, radiographic determination is the standard by which all other methods of verifying NG-EAD location are measured. An abdominal or chest radiograph that includes an abdominal view is considered the most reliable method to document the course of the EAD and its tip location at the time the radiograph is obtained.¹⁰

Although the radiation exposure associated with a single abdominal

radiograph may be low, repeated exposures for multiple placement verifications may, over time, result in high cumulative radiation doses. Both cohort and case-control studies have associated increased radiation doses with various types of cancer including childhood leukemia.^{17,18} Moreover, obtaining abdominal radiographs for home care patients and those in ambulatory and long-term care centers is not practical.¹⁰

The desire to provide enteral nutrition and deliver medications by the most physiological route with minimal risk to the patient prompts the bedside placement and use of an EAD. Placement of such a device is appropriate for those patients with a functional and intact gastrointestinal tract with adequate length and absorptive ability^{3,4} whom the clinical team has determined cannot or should not feed by mouth, and in whom the use of the EAD is temporary.^{19,20} Techniques for inserting a gastric EAD and equipment vary across institutions. The task of verifying tube position and ensuring ongoing correct location lies largely with the nurse but is the responsibility of the entire team caring for the patient.

Constructed of polyurethane or silicone, the diameter of NG-EADs runs from 3.5F to 16F and the length runs from 15 to 170 cm.²¹ These tubes may be designed with a removable stylet, weighted tip, magnet, or radiopaque indicators to assist with placement.²² The number of institutions that routinely provide gastric EADs with a stylet for insertion has not been reported; however, anecdotal information is that most tubes used in children require a stylet because of the small size and pliability of the tube. Although less frequently used

outside the inpatient acute care setting, orogastric EADs can also be used for the same purpose as NG-EADs; they may, however, have an increased risk of displacement because of the greater oral stimulation.¹⁴ In this article, we specifically refer to NG-EAD placement for simplicity, with the inherent understanding that orogastric EADs carry similar risks to patient safety.⁹

The placement and use of an NG-EAD presents 2 issues of concern that have important implications for patient safety: (1) the achievement of correct initial NG-EAD placement and (2) ongoing verification for correct NG-EAD location. Despite the routine nature of their use, errors in NG-EAD placement and difficulties with ongoing location verification continue to exist and are reported with varying frequency, making it difficult to quantify the incidence of placement errors and failures in ongoing maintenance of correct location.^{2,22} Variability in defining misplacement (device placement anywhere other than its intended location) and inconsistency in reporting device dislodgement (movement from original intended location) following initial insertion add to the complexity of this issue.^{9,10}

Methods

Systematic searches of PubMed, Scopus, and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) databases were conducted to identify peer-reviewed, English language, human subject research studies published from January 2004 to May 2013, examining the measurement, placement, and verification of NG-EADs in the

pediatric population. Search phrases used were *gastric tube*, *nasogastric tube*, *feeding tube*, and *nasogastric intubation*. The term *enteral access device* was not used in the search because that term produced articles related to percutaneous and endoscopic devices, which were not the topic of interest. These terms were then meshed with terms that included complications, placement, misplacement, or displacement and filtered to the specifications described. Although NG-EADs have been used for decades, the authors chose the defined interval years, January 2004 to May 2013, to identify the most current published literature related to NG-EAD placement and ongoing verification of tube location. Duplicate articles were removed.

Eight studies conducted solely within pediatrics during the specified time interval were found (see Table). Of the 8 studies found, 7 were conducted in hospitalized children and 1 in a pediatric emergency department. Only 1 of these studies was a randomized controlled trial; the others were observational studies. One adult study reported data from a pediatric subset. The remaining articles referenced are studies carried out in adults, review articles, case reports, editorials, or commentaries that added to the definition and clarity of the topic of interest. Primary adult-based studies were referenced if they were frequently cited and where we deemed necessary to support the overall purpose of this review. Finally, articles that included neonates were included, with the exception of studies that were specific to premature infants, owing to known differences in anatomy and physiology in premature infants that may influence NG-EAD placement and mode(s) of verification.

Overview of the Literature Misplacement and Dislodgement

A misplaced or dislodged NG-EAD puts the patient at risk for a variety of complications. In a retrospective investigation, Quandt and colleagues⁸ reported that NG-EAD misplacement occurred in 59% of the 381 radiographs reviewed from 173 neonates. Although single-center reporting is useful, the overall number of NG-EADs placed and used in US facilities specifically in children and the overall incidence of misplacement or dislodgement are unknown.

A tube misplaced into the esophagus increases the risk of aspiration owing to the proximity of the trachea. Misplacement or dislodgement of the NG-EAD into the trachea or lungs risks tracheal or pulmonary perforation and pneumothorax. Instilling enteral formula and/or medications into the pulmonary bed results in aspiration with potential for chemical pneumonitis and pneumonia.^{10,23} An EAD misplaced into the trachea or lungs is a potentially devastating and life-threatening complication.

There are situations in which feeding into the proximal portion of the patient's intestine (the duodenum or jejunum) is intended, in which case an EAD is placed specifically for that purpose. However, a misplaced tube distal to the gastric cavity may increase the risk for dumping syndrome if enteral feeding intended to be gastric is delivered in bolus amounts into the duodenum or jejunum. Dumping syndrome can be described as the accelerated transport of a large amount of hyperosmolar fluid (enteral formula) into the duodenum or proximal intestine, overwhelming its absorptive

capacity.²⁴⁻²⁶ It is associated with abdominal pain and distension, hypoglycemia, and diarrhea. The accelerated bypass of the stomach along with the increased osmotic load into the proximal small intestine results in fluid shifts out of the intravascular space into the intestinal lumen. This causes distension of the small intestine, leading to hypoglycemia and hypovolemia.^{24,27} Dumping syndrome is a complex, multiphasic condition, a full description and explanation of which is beyond the scope of this article. It is, however, an important potential complication of a distally misplaced NG-EAD.

Initial NG-EAD misplacement can occur because of a patient's size and may be related to the requirement for a smaller tube, proximity of the trachea to the esophagus, depressed or dysfunctional cough reflex, and the experience of the nurse, other health care provider, or caregiver placing the tube.^{7,10,26} Children, as compared with adults, are at increased risk for NG-EAD displacement because of their age (younger children are at higher risk), increased activity, and nonpurposeful movements of limbs or the head and neck.^{10,14} In addition, a change in or an altered level of consciousness, vomiting, dysfunctional swallowing, and the type and size of the NG-EAD used put the patient at risk for device misplacement or dislodgement.^{10,26,28} Malpositioning of the tube can precipitate an adverse event and result in untoward outcomes for patients. Such an event can cause significant psychological distress for the family, the health care provider who placed the tube, and those persons caring for the patient after the event.^{29,30}

Verification Methods

Although methods for assessing correct NG-EAD location at the bedside are available, each has its limitations. Current nonradiologic methods used to verify NG-EAD location include air auscultation; visual inspection of aspirated gastric secretions; gastric secretion pH, bilirubin, and/or enzyme testing; tube-end water submersion; capnography; electromagnetic tracer; age-related, height-based measurements; and ultrasound. Discussion of each of these methods follows.

Auscultation Insufflated air auscultation over the epigastrium or the left upper quadrant of the abdomen to assess NG-EAD placement has been common practice to verify correct placement. However, air insufflation with auscultation is problematic in that sounds emitted from the introduction of air through the NG-EAD can be transmitted to the epigastrium regardless of placement of the device in the lung, esophagus, or stomach.^{4,6,10,11,25,31-34} Because of the potential for duplicity of sounds from surrounding orifices, auscultation as a means of verifying NG-EAD placement is discouraged in the literature and is no longer supported by clinical practice organizations.^{3,4,6,22,33}

Aspiration of Gastric Secretions

Aspiration of gastric secretions is used for visualization and inspection, pH testing, and/or testing for bilirubin content or gastric enzyme concentration. Each of these methods can be challenging because of the continuum of pH between gastric and intestinal sites and the difficulty in obtaining aspirate from some small-bore tubes.^{10,11,34,35} The widespread use

of histamine₂ receptor antagonists and proton pump inhibitor medications confounds the usefulness of assessing pH to verify NG-EAD placement.^{10,28,33-35} In addition, continuous infusion of enteral formula, which many children require, further complicates pH testing. The range of pH for gastric secretions is 1 to 4, in contrast to the pH of many commercially prepared formulas, which is 6.6. This produces an alkalizing effect, confounding the accuracy of gastric pH measurement as a method to verify NG-EAD placement. In addition, sterile water, which has a pH of 5.5 to 7, may produce spurious results if used to flush an NG-EAD before use. Last, small-bore feeding tubes often collapse when negative pressure is applied to aspirate gastric contents, making it difficult, if not impossible, to obtain aspirate for visualization and inspection or pH, bilirubin, or enzyme testing.⁷

In a 2005 prospective study (n=72) by Ellett et al.,³² a pH upper limit of 5 was used to correctly predict proper placement in 62% of NG-EADs shown by radiography to be properly placed in the stomach. Using the same pH upper limit of 5, 54% of the NG-EADs were improperly placed outside of the stomach. These researchers reported a sensitivity of 54% and specificity of 69% for NG-EAD placement when the pH limit was expanded to 5.15 for their study sample.³² The study sample was further stratified, comparing participants who received histamine₂ receptor antagonists against participants not receiving these medications. They reported 60% sensitivity and 88% specificity using an upper limit pH of 5.9. It was concluded from these data that the use of acid-inhibiting medication

did not significantly affect testing of gastric pH as a determinant of NG-EAD placement.³² Overall, this study demonstrated a rate of 21% for misplaced NG-EADs in their study population.

In another pediatric study (n=56), Westhus³⁴ investigated the pH, aspirate color, and pepsin and trypsin concentrations in gastric and small-bowel aspirates. This researcher concluded that a pH of 6 or less and clear, tan, or green coloration of the aspirate was indicative of gastric placement. These data are based on results of aspirate testing with 87% gastric placement and 13% duodenal placement.³⁴ In this study,³⁴ a pH of 6 or less was obtained from the gastric aspirate in 23 of 49 participants (47%) who were receiving acid-blocking medications.

Another prospective pediatric study investigating the usefulness of pH as a method to verify NG-EAD location was conducted by Gilbertson and colleagues,³⁵ who confirmed gastric placement with a pH of 5.5 or less in 93% of the 4330 specimens from 645 patients tested. However, the investigators also reported a coiled tube in the esophagus that produced a pH of 5.5; thus, it was determined that a pH of 5.5 or less was not acceptable as definitive of gastric placement.³⁵ Instead, these data suggest that a cutoff pH of 5 or less, which produced 90% confirmation of gastric placement, is recommended.³⁵

In a study conducted in an urban emergency department with pediatric patients, Stock and colleagues³⁶ reported that gastric pH testing was reliable in a group of predominately healthy children. The gastric pH was 4 or less in 86.8% of the 393

Table Summary of articles related to methods of verifying feeding tube placement in pediatric and neonatal patients

Reference, year	Study design	Population, setting, N	Study objective
Westhus, ³⁴ 2004	Prospective cohort	Children (birth-168 months), NICU or PICU, N = 56	Identify pH, aspirate color, pepsin and trypsin concentrations as determinates for differentiating gastric versus intestinal tube placement
Ellett et al, ³² 2005	Prospective cohort	Children (3 days-88 months) with gastric tube placed, hospitalized, N = 72	Test the effectiveness of carbon dioxide, pH, and bilirubin levels to determine the internal position of the nasogastric tube
Beckstrand et al, ⁴¹ 2007	Prospective cohort	Children (2 weeks-231 months), suite for diagnostic endoscopy and manometry, N = 498	Assess effectiveness of nasogastric tube insertion methods (height-specific equations, NEX, NAR, NU, NMU, NEM)
Stock et al, ³⁶ 2008	Prospective cohort	Children (<18 years), emergency department	Determine if gastric aspirates can be obtained after nasogastric tube placement to determine pH; determine pH of children with and without gastroenteritis and if gastric pH is affected
Quandt et al, ⁸ 2009	Retrospective cohort	Neonates (25-42 weeks gestational age), NICU, N = 173 (381 radiographs)	Radiologic feeding tube evaluation
Gilbertson et al, ³⁵ 2011	Prospective cohort	Children (4-62 months), hospitalized patients, inclusive of ICU and cardiac patients, N = 645 (4330 gastric aspirate samples)	Determine pH cutoff for confirming nasogastric tube placement; compare range of pH values between gastric and endotracheal aspirate; obtain evidence for National Patient Safety Agency consensus statement
Powers et al, ⁴⁰ 2011	Prospective cohort ^a	Children (12 days-204 months), multicenter, hospitalized children, total of 206 patients (194 for analysis), 18 children	Assess accuracy of electromagnetic placement device for gastric placement of a small-bore feeding tube by comparing with an abdominal radiograph
Ellett et al, ²⁰ 2012	Randomized control trial	Children (1 month-204 months), hospital, N = 103	To compare error rates of 3 methods (ARHB, NEX, and NEMU) used to predict correct nasogastric tube insertion

Abbreviations: ARHB, age-related, height based; NAR, nose around ear-10th rib; NEM, nose-ear-mid-xiphoid; NEMU, nose-ear-mid-xiphoid-umbilicus; NEX, nose-ear-xiphoid; NICU, neonatal intensive care unit; NMU, nose-mid-xiphoid-umbilicus; NU, nose-umbilicus; PICU, pediatric intensive care unit; PPV, positive predictive value.

^a Researchers in this study broke out data for the pediatric subset population, these data are reported within this table.

Results

Comments

pH <6 in 78% of nasogastric tubes placed in stomach, resulting in a PPV of 94.4%
Participants taking acid inhibitors had significantly higher ($P = .006$) mean pH = 4.97 (SD, 0.48) than did those not taking acid inhibitors (mean pH, 3.27; SD, 0.36)
Gastric aspirate color was indicative of gastric contents in 84% (41/49) of aspirates obtained
Aspirate color was consistent with intestinal contents in 71% (5/7) of intestinal tubes
Trypsin and pepsin were significant discriminators ($P < .001$ and $P = .03$, respectively) between gastric and intestinal aspirates

The authors attempted to increase the specificity and sensitivity of the tests by combining the tests.
The combination of pH and color assessment resulted in a specificity of 100%, a sensitivity of 70%, and a PPV of 100%.
Author acknowledged that laboratory enzyme markers are not readily available for bedside use.

Correct placement in 79.2% (57/72) validated by radiograph
pH parameter set at <5 detected gastric placement in 61.8% (34/55); PPV, 85%
Patients taking acid inhibitor medications with a pH set at 5.9, PPV of 92% (60% sensitivity, 89% specificity for gastric placement)
Bilirubin testing set at >5 mg/dL failed to detect tubes placed in duodenum
No tubes placed into trachea
Carbon dioxide levels were 0-2 mm Hg, well below the adult established cutoff of <15 mm Hg

All patients were assessed with the gold standard (abdominal radiograph).
Two different measures (pH paper, pH meter) were used for pH measurements based on the amount of gastric aspirate obtained.

Regression modeling indicated that height-specific equations were superior to other methods of inserting nasogastric tubes
NEM was the only morphological distance method that approached the height-specific equations

Of the participants, 396 had oral manometry only, with the nasal-oral distance for the equations being based on the estimated age-stratified 95th percentile of a subset of the population ($n = 34$) in which oral and nasal manometry was used.

Aspirates with pH ≤ 4 were obtained in 86.8% (341/393) of participants
Median pH in all participants was 2
In 85.2% (335/393), pH was the only confirmatory method of tube location
Radiography for tube placement performed in 18 of 52 participants (34.6%), of these 3 tubes (1.7%) were misplaced into the distal esophagus

Radiograph to confirm tube placement was not used in all participants.
Tube location assumed because no respiratory symptoms were noted.
Author recommends radiograph if no aspirate is obtained and/or the gastric pH is >4.

Feeding tube correctly placed in 41% (124/303) of the population
Of the 179 incorrect placements, 61.4% (110/179) were along stomach greater curvature or in pyloric sphincter
The odds of a feeding tube being displaced into lower part of esophagus is 2.74 times higher in intubated neonates than in nonintubated neonates
No tubes were placed into trachea

NEX method used to measure tube insertion length.
Correct nasogastric tube placement was defined as the tube's tip or orifices being in body of stomach.
Per protocol results were reported as the researchers were not able to visualize the tip of the nasogastric tube and/or the stomach in 78 radiographs; therefore, these results were excluded from the analysis.

27% of participants were receiving antacid medication and had a higher pH (mean, 4.2 vs 3.4)
More participants <1 year old had increased mean pH than those >1 year old (4.0 vs 3.3)
Mean pH = 8.3 (95% CI, 6.0-9.5) in patients with endotracheal tubes
No difference in aspirate color between gastric aspirate and endotracheal aspirate
When gastric aspirate could not be obtained, radiograph was used, 8 misplaced tubes were identified
Recommend pH value <5 for 90% confirmation rate; 77% if antacid medications used

Inconsistent assessment of nasogastric tube placement based on consent obtained for study participation.
With consent, if pH >4, radiograph obtained for placement verification.
Without consent, if pH >4, nasogastric tube placement was then verified by evidence-based techniques (although most [73%] of these techniques were not recorded).

Median time for nasogastric tube placement was 20 minutes
In the tubes placed with placement device, correct placement confirmed 99.4% of the time by first radiograph
Inadvertent airway placement avoided in 4/18 (22%) participants

All children were enrolled from same site.
Small pediatric sample size
No inadvertent airway tube placement
No raw data presented related to radiographic confirmation of nasogastric tube placement following use of device (eg, what was the outcome of the remaining 13% at first abdominal radiograph?)
Device was used only by a trained experienced nurse, who was well versed in its use.

Method of tube placement: 36 tubes placed by ARHB, 35 by NEMU, and 32 by NEX
Accuracy of placement using each method: NEMU, 97.1%; ARHB, 88.9%; NEX, 59.4%
Accuracy of nasogastric tube placement differed ($P < .001$) among the 3 methods
NEMU and ARHB more accurate than NEX ($P < .001$).
No significant difference between ARHB and NEMU methods
Using NEX rather than ARHB or NEMU increased risk of tube misplacement x5
Acid-inhibiting medications did not substantially change results

Correct nasogastric tube placement was defined as tubes placed in the stomach, pylorus, or duodenum.
All patients received the gold standard (abdominal radiograph reviewed by a pediatric radiologist) following initial tube placement to verify placement.

participants in the study, which correlated with correct gastric NG-EAD placement.³⁶ For the 52 participants with pH greater than 4, only 18 had an abdominal radiograph obtained to confirm NG-EAD placement; the auscultation method was used in 7 participants, 11 participants had feedings aspirated, and no information on how NG-EAD location was verified was provided for the remaining 16 participants.³⁶ Results of that study suggested that pH testing of gastric aspirate is a reliable method of verifying NG-EAD location in children in an emergency department setting. However, the researchers recommended a radiograph to confirm location when no aspirate is obtained or the pH of the gastric aspirate is greater than 4.³⁶

Bilirubin testing is best used to determine placement of an EAD beyond the gastric cavity, as bilirubin is excreted through the common bile duct into the duodenum.^{7,34} It has been suggested that combining bilirubin testing with pH testing may provide a more accurate differentiation between respiratory, gastric, and postpyloric placement of an NG-EAD.⁷ Ellett et al³² found very little bilirubin in the gastric aspirate of children. In addition to bilirubin concentration, Westhus³⁴ also examined the presence and concentration of trypsin and pepsin as a method to determine NG-EAD placement. Although these enzymes were significant discriminators for gastric versus intestinal placement, Westhus³⁴ acknowledges that bedside enzyme testing of trypsin and pepsin may not be practical. Despite the accuracy of pH and enzyme testing, if NG-EAD placement or location is uncertain, an abdominal radiograph is warranted, as it is accepted as the

confirmatory method to verify NG-EAD placement.^{32,34,35}

Submergence Submerging the open end of the NG-EAD in water and observing for bubbles synchronous with expiratory respiration is a bedside verification technique sometimes used in adults.³⁷ The submergence method may be helpful to determine tracheal placement if rhythmic bubbling is observed; however, the absence of bubbling does not ensure gastric location. Therefore, submergence is not considered an efficient, reliable method of verifying NG-EAD location.^{37,38} In addition, the tube submersion method may increase the risk for aspiration with the patient's inspiration and is therefore not recommended.

Capnography The use of colorimetric capnography to detect expired carbon dioxide during placement of an EAD has shown promise in adults with a high sensitivity (88%-100%) and specificity (95%-100%) for lung misplacement.^{24,39} Ellett et al³² (N = 72) demonstrated 98.6% accuracy for NG-EAD placement using capnography with a value of 0 mm Hg at tube insertion. These researchers reported that all EADs were outside the respiratory tract, although not all were in the stomach. The tip of 13 of the EADs were in the esophagus and in 2 cases, the tip was beyond the pyloric sphincter.³² In a recent meta-analysis,³⁹ 8 adult studies were reviewed to evaluate the effectiveness of capnography as a method to verify NG-EAD placement. The results of this review demonstrated that capnography is an effective method for differentiating respiratory and gastric tube

placement in adults. It is recommended, however, that capnography be combined with other bedside methods for NG-EAD verification, as it is not useful for discerning differences in esophageal, gastric, or intestinal placement.^{11,24,38}

Electromagnetic Device The real-time electromagnetic tracer uses specialized EADs and an external receiver to assist with tube position and placement. Powers and colleagues⁴⁰ demonstrated 100% success in NG-EAD placement using an electromagnetic device in the 18 children included in their investigation. The immediate detection and correction of airway placement in this study prevented any inadvertent airway intubations, and no complications were reported.⁴⁰ Additionally, although children were a small subset (9.2%) of the larger study, these researchers suggested that proper use of an electromagnetic device may eliminate or significantly reduce the need for radiographic confirmation of NG-EAD placement.⁴⁰ A limitation of this method is the diameter of the EAD—8F is currently the smallest tube that can be traced by using this device. An 8F EAD is not uniformly used in children because of the large tube size.

Tube Measurement Methods

The use of age-related, height-based (ARHB) measurement has emerged as a potential method for determining initial placement length of a gastric EAD. Use of charts derived from prediction equations based on the child's stature to determine insertion length of an EAD holds promise. Further investigation is

necessary to establish the utility and accuracy of this technique.⁴¹

Ellett et al²⁰ demonstrated differences in 3 commonly used methods for measuring tube length for correct gastric cavity placement in children. Of the 3 methods studied, the nose-ear-mid-umbilicus (NEMU) and the ARHB method were superior to the commonly used nose-ear-xiphoid (NEX) method for determining the NG-EAD length to be inserted.²⁰ In this study (N=103), Ellett et al²⁰ demonstrated high accuracy of the NEMU (97%) and the ARHB (89%) methods for correct EAD placement when compared with the reference standard of radiographic evaluation. In contrast, the NEX method demonstrated 59% accuracy when compared with radiographic evaluation.²⁰ Based on the findings and recommendations from this study, and recommendations of the Child Health Patient Safety Organization, the NEX method to determine NG-EAD insertion length is no longer recommended for use in children.^{1,21} The combination of a proper method of measurement for NG-EAD placement and use of age-specific equations may be a superior approach to determining length of NG-EAD insertion. Measurement of proper device length may be the first step in decreasing the potential for error when inserting NG-EADs.

Ultrasonography Reports of investigations into the use of ultrasound to determine NG-EAD placement, particularly in adults, are emerging. These studies acknowledge ultrasound to be a simple, non-invasive, radiation-free method for verifying location of an NG-EAD; however, gas interposition can render identification of the NG-EAD

and the device tip difficult.^{42,43} Using the specified search criteria and limitations set for this article, we found no studies evaluating the use of ultrasound for NG-EAD location and position verification in children, the population of interest.

Discussion

Current publications validate significant challenges surrounding the placement and ongoing verification of NG-EADs in children. This difficult problem requires attention. The potential devastation that can occur with tube misplacement and undetected dislodgement is significant. Even 1 misplaced or dislodged EAD can affect the patient, the patient's family, and the person placing the device. To minimize the use of radiographic imaging, it is imperative to develop additional reliable and practical methods for bedside assessment of NG-EAD placement and ongoing verification of device location in children.

Bedside placement of an NG-EAD is considered an innocuous procedure, yet it carries risk of serious and potentially lethal complications. The current methods used for bedside placement have success rates from 80% to 85%.⁴⁴ The need exists for a focused, collaborative approach to develop a reliable, user-friendly method to safely insert and continually verify correct NG-EAD placement in children. The NOVEL project seeks to address this need. Project goals include (1) further defining the challenges surrounding NG-EAD placement, (2) identifying potential solutions to those challenges, (3) defining the necessary components of provider education, and (4) identifying specific requirements neces-

sary to guide the development of technological solutions to address this issue.

Establishing Procedures and Protocols

Provider education to promote consistency in practice is an essential component of NG-EAD placement and ongoing verification of the device's location. The practice of obtaining an abdominal radiograph to confirm location of the device and its tip is generally driven by individual institution protocol. Device misplacement often occurs during bedside insertion and may go undetected for a prolonged period while waiting for the radiograph to be obtained and interpreted. Provider education for observation of patients and assessment for overt signs of NG-EAD misplacement are necessary to thwart complications associated with bedside NG-EAD placement.

In a survey of nurses in an adult intensive care unit (ICU), Metheny et al⁴⁵ exposed a lack of consistency among this group of specialized nurses regarding insertion and confirmation of NG-EAD placement. Survey results indicated that nurses did not place stylet devices as often as physicians did, but when a stylet was used, a radiograph was obtained to confirm placement 92.3% of the time compared with radiographic confirmation 57.5% of the time when a nonstyletted device was placed.⁴⁵ Nurses reported using a combination of air insufflation and auscultation, appearance of aspirate, and observation for respiratory distress as primary means of confirming NG-EAD placement, with only 11.4% of nurses surveyed

reporting that they check pH to verify location.⁴⁵ The study findings suggest that bedside nurses are unaware of current evidence and recommendations of professional organizations related to NG-EAD placement. Additionally, results of this study suggest marked inconsistency among ICU nurses on the technique used for NG-EAD placement. Although these data are from nurses in an adult ICU, the study findings are concerning in that it is often the bedside nurse who educates the patient's family on NG-EAD placement and ongoing verification.

Technology that will minimize or eliminate the need for frequent radiographs is needed to assist providers to accurately place and verify the location of an NG-EAD and its tip. It is likely that more than 1 technology or method may be needed to address this issue in children. The target populations—neonatal, pediatric inpatients and pediatric outpatients, those cared for at home or those children living in a long-term care facility—have unique and distinct challenges regarding NG-EAD placement and ongoing location verification. Each of these populations will most likely require different approaches to NG-EAD placement and ongoing verification of the location of the device and its tip. Should placement, maintenance, and ongoing verification of an NG-EAD become hazardous, risking the patient's health, consideration of alternative methods for delivery of nutrition and medications is necessary.

The ideal technology will provide equal, if not more accurate, NG-EAD placement when compared with the reference standard—radiologic imaging. The specificity and sensitivity of any new technology must be assessed with various populations of patients

to establish its usefulness in NG-EAD placement and ongoing location verification. The application of such technology could decrease health care costs related to NG-EADs, reduce the incidence of misplaced and displaced devices, and decrease the associated morbidity and mortality.

With a focus on patient safety, the ideal technology to verify insertion and maintenance of NG-EADs should incorporate the following features and advantages:

- Placement accuracy across a wide range of feeding tube sizes (5F–10F) commonly used in children
- Allow ongoing verification of the location of the device and its tip with accuracy
- Incorporate simple, user-friendly, portable technology
- Have a reasonable cost with durability for sustainable use
- Provide electromagnetic compatibility (eg, with pacemakers, subcutaneous medication pumps)
- Not require any change in the pliability and flexibility of the EAD

Future Direction and Long-Term Focus

Understanding the scope of the problem of placing NG-EADs and verifying their location, developing potential solutions, and actualizing their use is multifaceted. New technology to improve the accuracy and efficiency of placement and ongoing location verification is ideal; however, its development and market realization may be some years away. This fact should not, however, minimize the current need to address the challenges surrounding placement and use of NG-EADs.

It may be that development of best practice guidelines for NG-EAD placement and ongoing location verification by a multiprofessional, collaborative team is warranted. Best practice guidelines based on the available knowledge and evidence of current methods are necessary to decrease variability in practice for EAD placement, management of patients, and ongoing verification of device location. These guidelines would serve not only to establish best practice, but they would also establish a platform to educate health care providers, patients, and patients' family members who need to manage these devices outside of the acute care environment. It will be difficult to develop such guidelines for children until the actual number of NG-EADs placed in children is known. Additionally, the methods used for NG-EAD placement verification and ongoing management of device location vary in the inpatient and the outpatient environments.

To better describe the incidence of NG-EAD errors, it is necessary to develop universal terminology with operational definitions for misplacement, dislodgement, and/or displacement that transcends both children and adults. These terms currently appear to be used interchangeably in published reports, making it difficult to fully understand the extent of this clinical problem. Universal terminology is primary to understanding and defining the issue and would be an important first step to move the practice of placement and management of NG-EADs forward. Work is currently underway to address these and other components of this complex issue in children.

It is envisioned that development of alternative technologies will determine a new standard of care for verification of placement of gastric EADS. The long-term goal is to minimize radiologic exposure and to improve safety for all patients who require an EAD, with children among those at highest risk.

Conclusion

Although common practice, placement of NG-EADs at the bedside is not a benign procedure. This review demonstrates the long-standing challenges of correct initial placement of an NG-EAD and ongoing verification of the location in children. For those patients who require an NG-EAD, proper initial placement and reliable ongoing device location verification can markedly affect health outcomes. Best practice guidelines that include universal, operational terminology will be an important first step in addressing a difficult clinical problem. Technology with the potential to reduce risk and improve safety will have a significant effect on the care of children in both acute and nonacute care settings. A serious safety event resulting from a misplaced or dislodged NG-EAD is life-altering and can be psychologically devastating for the patient, the patient's family, and health care professionals involved. It is therefore imperative to engage multiprofessional collaboration, research, and technological innovation to find solutions to this long-standing clinical challenge. **CCN**

Acknowledgments

In addition to the authors, the NOVEL Project Work Group included Tor Alden, MS, member: Industrial Design Society of America, HS Design, Inc, representing: Association for the Advancement of Medical Instrumentation; Debra Ben Avram, CAE, chief executive officer, American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.); Tim Coghil, MD,

neonatologist; Sarah Lombardi, MPH, Project Management, American Association for Medical Instrumentation (AAMI) Foundation; Marilyn Flack, MA, executive director, AAMI Foundation; Praveen Goday, MBBS, CNSC, board of directors, A.S.P.E.N., North American Society for Pediatric Gastroenterology, Hepatology and Nutrition; Candice S. Moore, RN, BSN, CPN, home care liaison resource, Society of Pediatric Nurses; Linda Muir, MD, chair, pediatric section, A.S.P.E.N.; Mary Beth Priviteca, MS, MDesign, University of Cincinnati, College of Medicine; Deahna Visscher, parent; Kerry Wilder, RN, BSN, MBA, neonatal nurse, manager, Quality and Outreach Program, Children's Medical Center, Dallas, Texas; Jane Ann Yaworski, RN, MSN, A.S.P.E.N., Nurse.

Financial Disclosures

None reported.

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