Published in final edited form as:

Clin Nurs Res. 2005 August ; 14(3): 238–252.

Gastric Tube Placement in Young Children

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Abstract

In this study, the internal position of a nasogastric/orogastric tube was determined in 72 children, prior to an abdominal radiograph, by measuring CO₂ and pH and bilirubin of tube aspirate. Fifteen of the 72 tubes (20.8%) were incorrectly placed on radiograph. Using the suggested adult cutoff of pH 5, pH of aspirate correctly predicted misplacement outside the stomach in 7/28 (25%) of children and correctly predicted correct placement in the stomach in 34 of 40 children (85%). Using the suggested adult cutoff of bilirubin ≥ 5 mg/dL, bilirubin monitoring failed to identify either of two incorrectly placed tubes. In this study, using an algorithm of assuming stomach placement if the pH of aspirate is ≤ 5 and obtaining an abdominal radiograph when either no aspirate is obtained or the pH is > 5 would have resulted in 92% accuracy. Alternatively, obtaining an abdominal radiograph would result in nearly 100% accuracy.

Keywords

nasogastric tubes; children; feeding tubes; enteral tubes

In 1986 (the most current statistic available), Metheny, Spies, and Eisenberg estimated that approximately 1 million enteral (gastric and intestinal) tubes were being placed in adults and children in the United States annually. These numbers, which are probably higher now, reflect the fact that in acute care, when the gastrointestinal (GI) tract is functional, feeding by nasally or orally placed enteral tubes is preferred over total parenteral nutrition (TPN) and gastrostomy, even in the critically ill, as long as the need for assisted feeding is expected to be short-term. In the only known pediatric survey, 1 in 5 children in a large midwestern children's hospital had a small-bore enteral tube placed at some time during their hospitalization (M. Ellett, 1994). A second study in this pediatric population showed that 91% of the enteral tubes were used for feeding and 81% were gastric (M. L. C. Ellett & Beckstrand, 1999).

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Authors' Note: This study was supported by the Center for Enhancing Quality of Life in Chronic Illness (NINR P30 NR05035, Joan K. Austin, D.N.S., R.N., P.I.) and the General Clinical Research Center (M01 RR00750). The authors want to thank Phyllis Dexter, Ph.D., for her assistance in editing this article prior to submission.

REASON THE STUDY WAS UNDERTAKEN

Previous studies in children showed that between 20.9% and 43.5% of enteral tubes were placed incorrectly (M. L. C. Ellett & Beckstrand, 1999; M. L. C. Ellett, Maahs, & Forsee, 1998). When tubes are out of place, children can be seriously harmed, causing increased morbidity and occasionally even mortality. For many children who cannot take food orally, feeding by gastric tube is an essential lifesaving procedure; therefore, it is imperative that tube feeding in children be safe.

In a telephone survey of 113 Level II and III nurseries in five midwestern states published in 1996, Shiao and DiFiore found that 98% of nurses used the nose-ear-xiphoid (NEX) distance to calculate tube insertion distance and auscultation of insufflated air to determine the internal location of the tube once inserted. Many researchers have already concluded that simple auscultation is not a reliable method to assess tube position because injection of air into the tracheobronchial tree or into the pleural space can produce a sound indistinguishable from that produced by injecting air into the GI tract (Aronchick, Epstein, Gefer, & Miller, 1984; El-Gamel & Watson, 1993; Meguid, Gray, & Debonis, 1984; Metheny, McSweeney, Wehrle, & Wiersema, 1990; Miller & Sahn, 1986; Neumann, Meyer, Dutton, & Smith, 1995; Silberman & Eisenberg, 1982; Theodore, Frank, Ende, Snider, & Beer, 1984; Thomas & Falcone, 1998).

In adults, only pH and bilirubin measurements of enteral tube aspirates have been shown both to reliably indicate tube position and to have inexpensive and simple bedside tests available (Metheny, Smith, & Stewart, 2000; Metheny, Stewart, et al., 1999), so pH and bilirubin content of aspirates were the primary focus of this preliminary pediatric study (see M. L. C. Ellett, in press, and Metheny, 1993, for comprehensive reviews of the tube placement literature). Because unsuspected respiratory placement is the most serious of tube placement errors and occurs at least 4% of the time (Harris & Huseby, 1989), the use of CO₂ monitoring to detect this type of error was explored clinically for the first time in children in this study. In two small studies of adults, Thomas and Falcone (1998) and Burns, Carpenter, and Truitt (2001) have previously found that a colorimetric CO₂ indicator device attached to the proximal end of a small-bore feeding tube reliably discriminated between tubes passed into the airway and those passed into the stomach.

The age range of birth to 7 years was chosen for this study because in infancy, the stomach is pear-shaped and lies in a transverse position. Infants also have rapid transit times and small stomach capacities (Verger, 1996). These differences gradually change so that by the age of 7 years, the shape and position of the stomach and the transit time through the GI tract approximate that of the adult (Metheny et al., 2000). Little is currently known about how the differences between adults and young children (≤ 7 years) may affect testing for tube location.

PURPOSE OF THE STUDY

To increase the safety of gastric tube feeding in children, knowledge development is required in at least three areas: predicting the insertion distance for placing a tube, determining the internal position of the tube once placed, and then maintaining the tube's correct position. This study addressed the second of these areas, the development of methods for determining the internal position of the tube without radiographic visualization. The specific purpose of this preliminary study was to test in young children three non-radiographic ways to determine the internal position of gastric tubes that would potentially be better than the method commonly used in practice. Factors expected to affect gastric pH, such as feeding status and acid-inhibiting medications, were also explored.

DESIGN

This study incorporated a cross-sectional design. Internal tube location was determined using the gold standard of radiographic placement. Eight hospital units of a large, midwestern, university-associated pediatric teaching hospital that drew children from the entire state of Indiana and surrounding states were the sites of data collection.

SAMPLE

The sample consisted of 72 hospitalized children 7 years of age or younger having a gastric tube already in place whose staff physicians had given permission for their patients to participate in this study. Children meeting these criteria were eligible unless (a) they were deemed too ill to participate by their physician, nurse, or researchers (e.g., unstable vital signs, unstable increased intracranial pressure, or respiratory distress); (b) their medical condition would drastically affect their gastric acid-secreting ability (e.g., Zollinger-Ellison Syndrome or congenital achlorhydria); or (c) they had had previous gastric surgery. This study was approved by the appropriate internal review board and scientific review committee.

The sample included 43 males (59.7%) and 29 females (40.3%) ranging in age from 3 days to 7 years 4.4 months (mean = 11.4 months). Fifty-eight (80.5%) were Caucasian, 10 (13.9%) African American, 2 (2.8%) Hispanic, 1 (1.4%) Asian, and 1 (1.4%) Indian. There were 68 nasogastric tubes (94.4%) and 4 orogastric tubes (5.6%). The majority of the tubes were size 6.5 or 8 French Neocare (Arrow International Corporation, Reading, PA; 61.4%), with the rest being size 8 to 12 French Argyle (30.0%) or 10 to 12 French Salem Sump (8.6%) tubes (Kendall Company, Mansfield, MA).

Sixteen of the children (22.2%) were fasting, 55 (76.4%) were being fed by tube, and 1 child was being fed orally (1.4%), with the tube being used for medication administration. Of those being fed, 33 (60%) were being fed by bolus, 11 (20%) intermittently, and 11 (20%) continuously. The pH of feeding formulas used during this study varied from 5.4 to 7.0. Thirty-three of the 72 children (45.8%) were receiving acid-inhibiting medication by tube and 39 (54.2%) were not.

METHOD

During rounds, the researchers consulted with staff for children meeting eligibility requirements. After explaining the study to parents and children (as age-appropriate) and obtaining informed consent, a researcher accompanied the child to the Radiology Department (unless radiographs were routinely performed at the bedside on that unit), where the location of the gastric tube was tested by (a) measuring CO₂ and (b) aspirating contents and measuring pH and bilirubin.

To measure CO₂, the open end of the gastric tube was attached to a capnograph monitor (Novamatrix Tidal Wave Handheld Capnograph Monitor, Critical Care Concepts, Inc., Naperville, IL). All CO₂ measures were taken in non-crying children. If an initial reading > 1 mmHg was obtained in a child who had just stopped crying, the researcher would obtain a second reading after waiting for 30 seconds and record the second reading.

After CO₂ testing was completed, fluid was aspirated from the tube using a 3-mL syringe. If unsuccessful, 0.5 mL of air in neonates ($\leq$ 1 month), 1 mL of air in infants (> 1 month and $\leq$ 1 year) or 2 mL of air in older children (> 1 and $\leq$ 7 years), were injected through the tube prior to a second attempt to aspirate fluid. This process of injecting air and attempting to aspirate fluid was repeated a total of five times before recording that insufficient aspirate was obtained. A minimum volume of 0.5 mL was needed to obtain measures for both pH and bilirubin. If 1

mL was aspirated into the syringe, it was set aside and an additional 0.5 mL was aspirated into a second syringe. This second aspirate was used for testing. This procedure helped ensure that the tube was clear of any previous feeding or the water used for irrigation after the previous feeding that might affect the pH reading. In all cases in which 1 mL of aspirate was obtained, an additional .5 mL was also obtained. The pH of the aspirate was determined using a Beckman 240 pH/Temperature Meter (Beckman Coulter Instruments, Inc., Fullerton, CA) following the manufacturer's guidelines for precalibration and measurement, and the value (accurate to two decimal points) was recorded. When only a few drops of tube aspirate was obtained, pH paper was used. Metheny et al. (1993) compared pH monitor and pH paper readings in 794 tube aspirates and found that pH monitor readings averaged 0.5 units higher than pH paper readings. pH monitor readings were therefore used in this study whenever an adequate amount of aspirate allowed because of the greater precision of the readings. In children who were being bolus or intermittently fed, pH monitoring occurred just prior to a feeding; in children who were continuously fed, pH monitoring occurred at any time. Children who were fasting had been fasting for at least 3 to 4 hours (depending on whether they were fed every 3 hours or every 4 hours), children who were bolus fed had been fasting 2.5 to 3.5 hours, and children who were intermittently fed had been fasting at least 1 hour prior to pH readings.

After obtaining a pH reading, the sterile tube containing the aspirate was closed and the outside covered with a large label marked with the child's research identification number. This label protected the aspirate from direct light. The aspirate was transported immediately to the hospital's Chemistry Laboratory using the messenger tube system to obtain a bilirubin measure. The aspirate is stable at room temperature for 4 hours; however, testing for bilirubin in any fluid was routinely performed within 1 hour of being received in the laboratory 24 hours per day 7 days per week (personal communication, P. Vollmer, head of the Chemistry Laboratory, September 8, 2000).

The researcher made sure that an abdominal radiograph (for research purposes) showing actual tube placement was obtained within 15 minutes after tube position testing and that appropriate shielding was used to decrease the child's exposure to radiation. The child was then accompanied back to the unit. The radiograph was read immediately by a radiologist and then again for research purposes by the third author. Correct tube placement was defined as the tip and all orifices being within the stomach (between the lower esophageal sphincter and the pylorus). If tube placement was found to be incorrect on radiograph, the nurse or physician caring for the child was notified. Data about medications and feedings were obtained from the hospital record and recorded. For the purpose of this study, bolus feeding was operationally defined as receiving a feeding during 30 minutes or less, continuous feeding was defined as receiving feeding continuously during 24 hours, and intermittent feeding was defined as receiving a feeding for more than 30 minutes but not continuously.

DATA ANALYSIS

Descriptive information was tabulated for the sample for gender, age, race, tube characteristics, feeding characteristics, use of acid-inhibiting medications, and tube placement. The mean pH of the aspirate was compared among the four feeding methods using ANOVA and whether or not the child was receiving acid-inhibiting medications by *t* test. Sensitivity, specificity, positive predictive value, and negative predictive value for incorrect placement were calculated for the recommended pH cutoff of 5 (determined in fasting adults; Metheny, Eikov, Rountree, & Lengettie, 1999). A pH cutoff of 5 was chosen because at the time the study began, this was the latest published value. Children had not previously been studied. In addition, the analysis was repeated for the sample as a whole and separately for the children receiving or not receiving acid-inhibiting medications, using the optimal cutoff determined from the Classification and Regression Trees (CART) method of recursive partitioning using data from this study (Zhang

& Singer, 1999). Sensitivity, specificity, positive predictive value, and negative predictive value for incorrect placement were finally calculated for the recommended bilirubin cutoff of 5 mg/dL again determined in fasting adults. This value was chosen because this was the only published value at the time.

FINDINGS

TUBE PLACEMENT ERROR RATE

Radiographs documented that 15 of the 72 tubes (20.8%) were incorrectly placed. In 13 cases, the tube tip and/or orifices were in the esophagus, and in 2 cases, the tip and at least one of the tube's orifices were beyond the pyloric sphincter into the duodenum.

POSITION OF NG/OG TUBE

Tube aspirate was obtained in adequate amounts for pH measurement in 68/72 (94.4%) of cases either by pH monitor ($n = 50$) or pH paper ($n = 18$). As can be seen in Table 1, mean pH values ranged from 4.3 in bolus-fed children to 4.7 in intermittent and continuously fed children. This difference was not statistically significant (ANOVA, $p = .81$)

The values for pH obtained ranged from 1.4 to 8.5 overall, from 1.4 to 8.5 (mean = 4.6, standard deviation = 1.5) in the group receiving acid inhibitors, and from 1.6 to 7.0 (mean = 4.4, standard deviation = 1.4) in the group not receiving acid inhibitors. Whether or not the child was receiving an acid-inhibiting medication did not significantly affect the pH of aspirate (t test, $p = .61$).

Using the suggested pH cutoff of 5, pH monitoring under clinical use conditions (see Table 2) correctly identified 7/13 (53.9%) of tubes shown to be incorrectly placed outside the stomach (sensitivity) and correctly identified 34/55 (61.8%) of tubes shown by radiograph to be correctly placed in the stomach (specificity). pH monitoring likewise correctly predicted 7/28 (25.0%) of tubes shown to be incorrectly placed outside the stomach (positive predictive value) and correctly predicted 34/40 (85.0%) of tubes shown by radiograph to be correctly placed in the stomach (negative predictive value). Using the CART method of recursive partitioning, the optimal cutoff in this sample of children overall was found to be 5.15. Using this cutoff, the sensitivity was 7/13 (53.9%), specificity 38/55 (69.1%), positive predictive value 7/24 (29.2%), and negative predictive value 38/44 (86.4%). Repeating this analysis stratified by whether or not the children were receiving acid inhibitors, the cutoff was 5.9 in the acid-inhibitor group, with sensitivity 3/5 (60.0%), specificity 23/26 (88.5%), positive predictive value 3/6 (50.0%), and negative predictive value 23/25 (92.0%). The cutoff was 5.6 in the group not receiving acid inhibitors, with sensitivity 0/8 (0.0%), specificity 22/29 (75.9%), positive predictive value 0/7 (0.0%), and negative predictive value 22/30 (73.3%).

There was an adequate amount of tube aspirate obtained for bilirubin determination in 62/72 (86.1%) of cases (see Table 3). Values of bilirubin obtained ranged from ≤ 0.1 to 11.6 overall, with only 7 out of the 62 values above the minimum detectable level for the bilirubin monitor. The range was ≤ 0.1 to 11.6 in the acid-inhibiting medication group and ≤ 0.1 to 7.3 in the group not receiving acid inhibitors. Two tubes were found to be in the first part of the duodenum on radiograph. Using the suggested bilirubin cutoff of ≥ 5 mg/dL determined in fasting adults (Metheny et al., 2000), bilirubin monitoring failed to predict either of these incorrectly placed tubes. The tip of one of these tubes was through the pylorus on radiograph, but one or more of the tube's orifices could have remained in the stomach. The tip and all orifices of the second tube were definitely in the duodenum, which was dilated on radiograph. Because so few intestinal placements were found, no attempt to identify an optimal cutoff for bilirubin or the combination of pH and bilirubin was made. In addition, two tubes having a bilirubin > 5 mg/

dL (7.3 mg/dL and 11.6 mg/dL) were found to be correctly positioned in the stomach on radiograph. The tube of one of these children was being used for decompression while awaiting surgery for a suspected bowel obstruction, and the other was being fed continuously using a formula with a pH of 6.0.

No tubes were placed in the respiratory tract on radiograph. CO₂ readings were obtained in all 72 (100%) of cases. The values were 0 mmHg in 71 (98.6%) of cases and 2.0 mmHg in the 1 (1.4%) remaining case. These values were well below Thomas and Falcone's (1998) suggested cutoff of ≤ 15 mmHg in adults.

DISCUSSION

A 21% error rate is unacceptably high for a clinical setting. According to health care providers' reports, 98% of enteral tubes are placed using the NEX method of predicting insertion distance (Shiao & DiFiore, 1996). This method specifies a distance that appears to be too short (87% of misplacements were found to be esophageal) for young children, leaving the tip and/or orifices of the gastric tube in the esophagus predisposing to aspiration pneumonia. Auscultation for a gurgling sound, the method that health care providers reportedly use to assess for placement errors at the bedside (Shiao & DiFiore, 1996) does not appear to predict these errors well. Many researchers have concluded that simple auscultation is not a reliable method to assess tube position because injection of air into the tracheobronchial tree or into the pleural space can produce a sound indistinguishable from that produced by injecting air into the GI tract (Aronchick et al., 1984; El-Gamel & Watson, 1993; Meguid et al., 1984; Miller & Sahn, 1986; Neumann et al., 1995; Silberman & Eisenberg, 1982; Theodore et al., 1984; Thomas & Falcone, 1998).

The sample size of 72 children was inadequate for testing four feeding conditions—fasting, bolus, intermittent, and continuous. This was, however, a preliminary study to determine whether or not future study in a larger sample was justified.

The lack of intestinal placements is attributed to the use of NEX for insertion length prediction; as previously stated, NEX appears to be too short a distance in young children. This lack precluded being able to use the data from this study to identify a cutoff level for bilirubin in children.

The reason for no respiratory placements was probably because the tubes of the children in this study were already in place. Obvious respiratory placements causing the child distress would have been identified immediately at the time of tube insertion and corrected, and any unsuspected respiratory placements could have already caused symptoms leading to discovery and repositioning of the tube before enrollment in this study. The purpose of testing CO₂ in this study was to detect any unsuspected respiratory placements; according to the literature, these occur up to 4% of the time in adults, but it is unknown how often they occur in children.

Using Metheny, Stewart, et al.'s (1999) adult cutoff of pH 5, only 25% of tubes that were predicted to be incorrectly placed on radiograph were actually incorrectly placed (positive predictive value), and 85% of tubes that were predicted to be correctly placed on radiograph were correctly placed (negative predictive value). Using the optimal cutoff of pH 5.15 found in this study improved the positive predictive value slightly from 25% to 29% and the negative predictive value from 85% to 86%.

Mean pH levels of aspirate were not significantly different for the different methods of feeding (fasting, bolus, intermittent, or continuous). Compared with the mean pH of 3.9 in fasting adults (Metheny et al., 1997), the fact that fasting young children had a mean pH of 4.6 suggests that anatomic and physiologic factors may have some effect on pH that merits further testing.

Metheny, Eikov, et al. (1999) found a similar mean pH of 4.3 in 90 gastric tube aspirates in 39 neonates, about half of whom were fasting.

Metheny and Stewart (2002) recently recommended that a pH cutoff of 6 be used in adults who are being continuously fed. The number of children ($n = 11$) who were being continuously fed in this study precluded meaningful investigation of this pH cutoff value. Whether or not the child was receiving an acid-inhibiting medication did not significantly affect pH of aspirate statistically or clinically.

In this study, a bilirubin < 5 mg/dL was not always helpful in predicting tubes ending in the stomach because, on radiograph, two tubes were at least partially positioned in the duodenum. On the other hand, a bilirubin ≥ 5 mg/dL was also not helpful in predicting tubes ending in the intestine because in both cases in which the bilirubin was ≥ 5 mg/dL, the tubes were actually in the stomach. In one case, this result could easily be explained by the child's diagnosis of suspected bowel obstruction. The other case, however, could not be as easily explained, suggesting the possibility that some young children may have bile reflux. The small numbers of tubes incorrectly placed in the duodenum and those with bilirubins ≥ 5 mg/dL that were in the stomach suggest the need for a future study of young children having intestinal tubes in place.

Although no respiratory placements were found in this study, CO₂ monitoring merits future testing in a large sample of children having enteral tubes inserted to determine how well it will detect unsuspected respiratory placement. For this study, tubes were already inserted and used prior to the test; consequently, these CO₂ results were expected.

APPLICATION

Gastric tubes were incorrectly placed in 21% of young children. Errors usually involved placement in the esophagus. NEX is the method generally used by nurses to estimate the distance to insert the tube, and auscultation is the method reportedly used to determine the internal position of the tube at bedside (Shiao & DiFiore, 1996). This error rate mandates finding a more accurate method for predicting the distance to insert gastric tubes and finding a more accurate method or combination of methods to determine the internal position of the tubes once inserted. Such a study funded by the National Institute of Nursing Research is just beginning. In this larger study of 300 children, the four feeding conditions explored in this study will be adequately tested.

In the meantime, in this study it was found that use of the following algorithm: (a) if the pH of tube aspirate was ≤ 5 , assume correct placement in the stomach (34 children correctly identified); and (b) if either the pH was > 5 (28 children) or no aspirate was obtained (4 children), obtain an abdominal radiograph to determine tube position, would have resulted in 66/72 children (92%) eventually having correct placement in the stomach. Obtaining an abdominal radiograph to determine gastric tube placement would result in nearly 100% accuracy. The increased safety provided by obtaining periodic radiographs to determine internal gastric tube location must be weighed against the accumulated radiation exposure for the child and the costs incurred.

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Table 1*Effects of Feeding on Gastric pH (n = 67^a)*

-
- pH in fasting children ($n = 14$)
    - range = 1.6–8.5, $M = 4.6$, $SD = 2.0$
  - pH in fed children
    - pH in children fed bolus ($n = 31$)
      - range = 1.8–6.4, $M = 4.3$, $SD = 1.2$
  - pH in children fed intermittently ($n = 11$)
    - range = 1.4–6.0, $M = 4.7$, $SD = 1.1$
  - pH in children fed continuously ($n = 11$)
    - range = 3.0–6.0, $M = 4.7$, $SD = 1.3$
-

^aThe tube in one child in whom pH of aspirate was obtained was being used for medication instillation only.

Table 2
 Ability of pH Testing to Detect Radiographically Documented NG/OG Placement in Children ≤ 7 Years

pH	Stomach	Non-Stomach
≤ 5	34	6
>5	21	7

Aspirate obtained 68/72 cases (94.4%)

Range = 1.4–8.5, $M = 4.5$, $SD = 1.4$

Sensitivity: 7/13 (53.9%)

Specificity: 34/55 (61.8%)

Positive predictive value: 7/28 (25.0%)

Negative predictive value: 34/40 (85.0%)

Table 3 Ability of Bilirubin Testing to Detect Radiographically Documented NG/OG Placement in Children ≤ 7 Years

Bilirubin	Intestinal	Non-Intestinal
≥ 5 mg/dL	0	2
< 5 mg/dL	2	58

Aspirate obtained 62/72 cases (86.1%)

Range = < 0.1 –11.6 mg/dL, median = $< .1$

Sensitivity: 0/2 (0%)

Specificity: 58/60 (96.6%)

Positive predictive value: 0/2 (0%)

Negative predictive value: 58/60 (96.6%)