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Predicting the Insertion Length for Gastric Tube Placement in Neonates

Marsha L. Cirgin Ellett, PhD, RN[professor],
School of Nursing, Indiana University, Indianapolis, IN.

Mervyn D. Cohen, MB, ChB[pediatric radiologist],
Department of Radiology, Riley Hospital, Indianapolis, IN.

Susan M. Perkins, PhD[associate professor],
Division of Biostatistics, Indiana University School of Medicine, Indianapolis, IN.

Coral E. Smith, MSN, RN, CNS, CPAN[research associate],
School of Nursing, Indiana University, Indianapolis, IN.

Kathleen A. Lane, MS[biostatistician], and
Division of Biostatistics, Indiana University School of Medicine, Indianapolis, IN.

Joan K. Austin, PhD, RN, FAAN[distinguished professor emerita]
School of Nursing, Indiana University, Indianapolis, IN.

Abstract

Objective—To compare error rates of three existing methods of predicting the gastric tube insertion length in a group of neonates < one month corrected age: age-related, height-based (ARHB); direct distance nose-ear-xiphoid (NEX); and direct distance nose-ear-mid-umbilicus (NEMU).

Design—Randomized controlled trial.

Setting—Five neonatal care units in a large midwestern city.

Participants—One hundred seventy-three hospitalized neonates.

Methods—Neonates were randomly assigned to one of three groups: ARHB, NEX, or NEMU. For primary analysis, only tubes placed too high with the tube tip in the esophagus or at the gastroesophageal junction were considered to be misplaced. For secondary analysis, a stricter definition was used, and low placements (pylorus or duodenum) were also considered to be misplaced. All radiographs were blinded and read by a pediatric radiologist.

Results—For the primary analysis, the differences in percentages of correctly placed tubes among the three methods was statistically significant (chi-square = 34.45; $p < 0.0001$), with both NEMU and ARHB more accurate than NEX (NEMU chi-square = 18.59, $p < 0.0001$; ARHB chi-square = 21.34, $p < 0.0001$). Using the stricter definition for placement, ARHB was not significantly different from NEX ($p = 0.0615$). A new ARHB equation was developed specific for neonates < 1 month corrected age.

Marsha L. Ellett Indiana University School of Nursing, 1111 Middle Drive, Rm. 439, Indianapolis, IN 46202-5107, mlellett@iupui.edu.

Disclosure

The authors report no conflict of interest or relevant financial relationships.

Callouts

Conclusions—Direct distance nose-ear-xiphoid should no longer be used as an NG/OG tube insertion-length predictor in neonates. Either NEMU for nasogastric/orogastric (NG/OG) tubes or the new ARHB equation for NG tubes should be used.

Key terms

nasogastric tube; feeding tube; enteral feeding; neonates; premature infants; randomized controlled trial

Feeding by a nasogastric/orogastric (NG/OG) tube is used when the gastrointestinal system of a neonate is functional and the need for assisted feeding is expected to be short-term. Previous research showed that between 5% and 55.6% of these tubes were misplaced, either in the esophagus or in the duodenum (Ellett & Beckstrand, 1999; Ellett, Croffie, Cohen, & Perkins, 2005; Gallaher, Cashwell, Hall, Lowe, & Ciszek, 1993; Tedeschi, Atimer, & Warner, 2004; Weibley, Adamson, Clinkscales, Curran, & Bramson, 1987; Ziemer & Carroll, 1978). Some of the reported error rates are unacceptably high. When tubes are out of place, neonates can be seriously harmed, causing increased morbidity and, occasionally, mortality (Dobranowski, Fitzgerald, Baxter, & Woods, 1992; Woodall, Winfield, & Bisset, 1987). For example, feeding through a NG/OG tube placed in the esophagus can result in aspiration, and feeding through a tube placed in the duodenum can lead to malabsorption, failure to gain weight, and diarrhea (Ferrer, Bauer, Torres, Hernandez, & Piera, 1999; Metheny et al., 1999). The difficulty of separating morbidity (and mortality) caused by NG/OG tube placement error from that associated with the primary illness in seriously ill neonates has prevented definitive studies; however, it is likely that tube placement errors prolong hospital stays and increase healthcare costs (Ellett & Beckstrand, 1999; Ellett, Croffie, Cohen, & Perkins, 2005; Ellett, Maahs, & Forsee, 1998).

Review of Current Evidence for Practice

No specific research reference supporting the direct distance nose-ear-xiphoid (NEX) method of predicting the insertion length to insert an NG/OG tubes has been found. In 1978 Ziemer and Carroll found that an NG tube inserted using the NEX length in an unreported number of infants at autopsy reached just past the gastroesophageal sphincter. They found that if the tube was inserted using the length measured from the nose to the earlobe to a point halfway between the xiphoid process and the umbilicus (NEMU), it was properly positioned (see Table 1). Building on their work, Weibley, Adamson, Clinkscales, Curran, and Bramson (1987) prospectively documented OG tube placement by radiograph using both the NEX + 2 cm and NEMU measurements on 30 premature infants (28–36 wks gestational age). The NEX + 2 cm length was too short in 55.6% of the infants, and the NEMU distance was too short in 39.3% of infants. In contrast, Tedeschi, Atimer, and Warner (2004) used the NEMU insertion-length predictor to place 43 NG/OG tubes in 38 premature infants (25–35 wks gestational age). Two tubes (5%) were located in the distal esophagus and 41 (95%) were located appropriately in the stomach.

In 1993 Gallaher and colleagues took a different approach based on their review of 171 radiographs from 31 very low birth weight infants. They recommended the following minimal insertion lengths: 13 cm for infants weighing < 750 g, 15 cm for infants weighing 750–999 g, 16 cm for infants weighing 1000–1249 g, and 17 cm for infants weighing 1250–1499 g. Using these insertion lengths, they were able to decrease the error rate in their neonatal intensive care unit from 38% to 14%.

CALLOUT 1

Beckstrand and co-researchers (2007) studied 20 external measures (including NEX, NEMU, age, height/length, and weight) as possible insertion length predictors in 494 children 2 weeks to 19 years of age undergoing upper gastrointestinal endoscopy or esophageal manometric studies. Regression equations using height in age groups (age-related, height-based [ARHB]) were found to be the best predictors; by using these equations, it was estimated that 96.6% of NG/OG tubes would be placed in the stomach. The length of the shortest infant in this study was 44.5 cm and only five neonates were included (whether any were premature was unknown).

In summary, two studies showed the NEX insertion prediction distance was too short and the NEMU distance had mixed results. Weight has only been studied once in very low birth weight infants but is promising as a predictor, and regression on height in age groups has been studied once in a large sample that included few, if any, neonates. Thus, more work is needed to predict proper insertion length for NG/OG tubes in neonates.

Objectives

The results were part of a larger study examining gastric tube placement in children. The primary objective of this analysis was to compare the error rates of three existing methods of predicting the correct gastric tube insertion length in neonates < one month corrected age: ARHB method, NEX method, and NEMU method. A secondary objective was to develop a new ARHB equation specific to this age group because neonates comprised only 5 of 494 (1%) of children used to develop the method originally.

Methods

Design

A single-blind, randomized controlled trial was conducted. The neonates were randomly assigned to have their NG/OG tube inserted using one of the three insertion-length predictors if ≥ 44.5 cm in length: ARHB, NEX, NEMU or if < 44.5 cm in length: NEX or NEMU. The statisticians (third author and fifth authors) used a stratified block randomization strategy in which stratification was by use of acid-inhibiting medication (needed for a different aim of this trial) and length of neonate (< 44.5 cm vs. ≥ 44.5 cm). The random assignments were delivered to the research nurses in sealed envelopes. They opened the envelope just prior to inserting the NG/OG tube to determine which method to use.

Recruitment

Neonates were recruited from four neonatal intensive care units and one special care nursery from five urban midwestern hospitals. All neonates, irrespective of gestational age, hospitalized on one of the participating units requiring an NG/OG tube to be inserted were eligible unless: (a) they were deemed too ill to participate by their physician, nurse, or research nurse; (b) their medical condition could drastically affect their gastric acid-secreting ability (e.g., Zollinger-Ellison Syndrome or congenital achlorhydria); (c) they had had previous gastric surgery resulting in removal of part of the stomach; or (d) the NG/OG tube ordered by the physician had orifices further than 3 cm from the tip of the tube.

Procedures

This study was approved by the appropriate institutional review boards and the hospitals/units in which it was conducted. Two research associates were trained in all aspects of data

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¹Radiographic verification at the time of initial nasogastric/orogastric tube placement or tube change is necessary to ensure that the tube has not been misplaced.

collection by the principal investigator (PI) using a written protocol. They collected approximately 75% of the data. Other research nurses were trained by the two research associates using the same protocol and collected the other 25% of the data; the PI evaluated each prior to him/her being allowed to collect data independently. Inter-rater reliability was collected between each data collector and the PI approximately every 15th neonate per nurse. A research associate or research nurse obtained anthropometric data from the neonate. The neonate's length was obtained by marking with a washable marker on the underlying sheet the length from the most distal border of the head to the most distal border of the heel held perpendicular to the leg with the neonate lying flat, and then measuring the marked length with a paper tape measure after the neonate had been moved to the side of the sheet that allowed accurate measurement. The NEX and NEMU were measured by stretching the tube to be inserted from the tip of the nose to the bottom of the earlobe first to the xiphoid process (NEX) and then to the observed midpoint between the xiphoid process and the umbilicus (NEMU). In addition, birth date, term/preterm status, gestational age, weight, and acid-inhibiting medication use were obtained from the medical records of all neonates. Because all neonates were weighed daily, the Gallaher method was able to be tested in the very low birth weight neonates. Corrected age was calculated by subtracting the number of weeks/days premature from the chronological age in weeks/days (March of Dimes, 2010).

The nurse caring for the neonate was consulted to determine the standard method for inserting tubes (nasally or orally) in neonates in the specific unit. Enrolled neonates ≥ 44.5 cm in length were then randomly assigned to have their tube inserted using one of the three existing insertion-length predictors: NEX, NEMU, or ARHB. The ARHB equations used for this age group were OG tube insertion distance = $13.3 \text{ cm} + 0.19(\text{length in cm})$ and NG tube insertion distance = $14.8 \text{ cm} + 0.19(\text{length in cm})$ (Beckstrand, 2005). All three measurements were obtained on all neonates. Those less than 44.5 cm in length were randomly assigned to only the NEX or NEMU methods because this was the shortest length of children in the Beckstrand (2005) study, from which the original ARHB equations were developed. The tube was then inserted using the randomly assigned insertion-length predictor distance by either the research nurse or the nurse caring for the neonate. The nurse temporarily taped the tube in place.

Shortly after placement of the tube, an abdominal radiograph was obtained to show the internal location of the tube. Once the radiograph was read by a pediatric radiologist, neonatologist, or neonatal nurse practitioner (based on unit policy) using their normal criteria, the tube length was adjusted as necessary based on the healthcare provider's recommendation prior to use.

CALLOUT 2

Radiographs

All radiographs taken after initial placement of the tube were reviewed at a later time by a single board-certified pediatric radiologist, who was blinded as to the method used to estimate the required length of the tube. For each radiograph the location of the tip of the tube was classified into four locations:

1. Tube tip in the esophagus. If the tube tip was in the esophagus, then it was noted if the lower end of the tube was straight or curled back on itself with the tip pointing towards the head.
2. Tube tip in the region of the gastro-esophageal junction (GEJ).

²Direct distance nose-ear-xiphoid should no longer be used as an nasorogastic/orogastric tube insertion-length predictor in neonates.

3. Tube tip in the stomach.
4. Tube tip in the pylorus or the duodenum.

In addition, the length of tube below the diaphragm was measured when the tip was clearly visible. This was measured from the junction of the diaphragm with the left side of the adjacent vertebral body to the tip of the tube. Based on these measurements, the radiologist judged for each neonate whether use of the other two methods (or one method in the case of those neonates < 44.5cm in length) that were not actually implemented would have placed the tube tip in the stomach, assuming the tube would have followed the same trajectory. The principal investigator (first author) provided assistance so that he could remain blinded to the insertion method used. For tube tips in the esophagus, the radiologist measured the distance from the tube tip to the GE junction and estimated whether use of the other methods of estimating tube length would have resulted in the tip being in the stomach.

Definition of Correct Placement

For our primary analysis, only tubes that were placed too high with the tube tip in the esophagus or GEJ were considered to be misplaced, and tubes placed in the stomach, pylorus, or duodenum were considered correctly placed. This decision was made because tubes placed the same distance below the GEJ appeared to either curve to the left along the greater curvature of the stomach or to the right into or through the pylorus into the duodenum by chance. As a secondary analysis, we used a more strict definition of correctness whereby the tube tip was required to actually be in the stomach.

Data Analysis

Descriptive statistics were calculated, including means and standard deviations for continuous variables and number and percent in each category for categorical variables. One-way analysis of variance (ANOVA) models were used to compare neonate characteristics of age and height across the three insertion methods. Chi-square tests or Fisher's exact tests as appropriate for small sample sizes were used to compare categorical patient characteristics such as gender, ethnicity and race (see Table 2). All analyses were performed on an intention to treat basis. For the primary objective, chi-square tests were used to compare the correct placement rates between the insertion methods. Following a significant overall comparison of the three methods, pairwise comparisons were made also using chi-square tests. Exact logistic regression was used to model misplacement to obtain confidence interval estimates for odds ratios (both crude and adjusted for the two stratification factors) comparing the three methods. A t-test was used to compare the measurement lengths between stomach and intestinal placements for tubes deemed long enough to enter the intestine. Because all possible methods were calculated for each neonate and the radiologist was able to use this information to decide the tube position even for the methods not actually used (which we will refer to as the "non-randomized" method), exact pairwise McNemar's tests were used to compare misplacement rates across the three methods using both randomized and non-randomized data. The p-values from the McNemar's tests were adjusted using Bonferroni's multiple comparison method.

For the secondary objective, to create a new ARHB prediction equation for neonates of all lengths, first, univariate linear regression was used to predict the distance from the mouth to the GEJ using various neonate characteristics using those children with placements at or lower than the GEJ. Those significant at the $\alpha = 0.15$ level were included in multivariate models. Next, stepwise and backward selection methods were used to create a final regression model with all independent variables significant at the $\alpha = 0.05$ level. The intercept was then adjusted so that the tip of the tube would be placed in the ideal location in the middle of the stomach.

Results

Overall, 1,428 neonates met inclusion criteria. In 78.4% of neonates ($n = 1,120$), neonatologists agreed to allow the family to be approached regarding study participation. Reasons given for physician refusal included neonate was too ill and/or complicated social situation. Also, in some cases the staff physician was not available to give permission. In 16.6% of the neonates in which physician permission was received to approach the family, parent(s) provided informed consent; reasons given for refusal included radiation exposure of radiograph for research purposes, national coverage of neonatal deaths due to medication overdoses, and neonate had been through too much already. The final overall recruitment rate was 15.4% (representing 93.1% of neonates whose parents provided informed consent) because in some cases the neonate's condition improved allowing progression to oral feeding, the unit was too busy for nurses to allow study participation, or neonates were discharged home with the tube in place after parental consent was received but before the neonate could participate in the study.

The sample consisted of 173 hospitalized neonates (< 1 month corrected age) requiring placement of an NG/OG tube. There were 155 NG tubes and 18 OG tubes placed in neonates (see Table 2). There were 66 tubes placed by each of the NEMU and NEX methods, but only 41 by the ARHB as this method could not be used in the 57 neonates who were less than 44.5 cm, the shortest length used in the Beckstrand (2005) study. Thus, it was not unexpected that the ARHB neonates were significantly older than the neonates using the other methods ($p = 0.0342$ vs. NEMU, $p = 0.0017$ vs. NEX) and significantly longer ($p = 0.0013$ vs. NEMU; $p = 0.0003$ vs. NEX). There were no other significant differences among the three insertion methods on patient characteristics. In addition, there were no significant differences between the three insertion methods on patient characteristics in neonates ≥ 44.5 cm.

Of the tubes inserted, 92% using NEMU, 100% using ARHB, and 61% using NEX were correctly placed in the stomach, duodenum, or pylorus regions (see Table 3). During insertion, one tube in a neonate curled back on itself in the esophagus, leaving the tip of the tube near the entrance to the respiratory tract. This placement error would not have been known prior to feeding through this tube without the abdominal radiograph required as part of this study. Based on the intention-to-treat principle, we treated this case as a placement error when calculating the error rate. The differences in percentages of correctly placed tubes among the three methods was statistically significant (chi-square = 34.45; $p < 0.0001$), with both NEMU and ARHB being more accurate than NEX (NEMU chi-square = 18.59, $p < 0.0001$; ARHB chi-square = 21.34, $p < 0.0001$). There was no statistically significant difference between NEMU and ARHB methods (Fisher's exact $p = 0.1540$). From an exact logistic regression model, the estimated odds ratio (unadjusted) was 7.81 (95% CI 2.66–28.23), indicating that if NEX rather than NEMU was used as the insertion-length predictor, the odds were 7.8 times greater that the tube would be misplaced on insertion, leaving the tip and/or pores in the esophagus or GEJ. Performing the analyses using only the neonates who were ≥ 44.5 cm and thus able to be randomized using the ARHB method did not substantially alter the results. Adding the two stratification factors, use of acid-inhibiting medications and length (< 44 cm, ≥ 44.5 cm), to the exact logistic regression model also did not substantially change the results.

In addition, we explored using the stricter definition of treating only tubes actually placed in the stomach as correctly placed. By switching to the stricter definition, one tube placed by the NEMU method and nine tubes placed by the ARHB method were now considered misplaced (see Table 3). The only difference in findings between the two definitions is that ARHB was no longer significantly different than NEX (chi-square = 3.50, $p = 0.0615$).

There were 73 neonates who had measurements from the diaphragm to the tip along the curvature of the tube over 4.5 cm that would indicate the tube was potentially long enough to enter the pylorus/duodenum regions. No difference ($p = 0.1532$) in this curved length was seen on average between the 64 tubes that stayed in the stomach (mean $\pm$ sd: 6.2 ± 1.3) and the 9 that entered the pylorus/duodenum region (mean $\pm$ sd: 6.8 ± 1.3).

At the end of the study, the radiologist was able to determine where the tube tip would have been located if placed by one of the non-randomized methods. This calculation was possible for the tube location in 80% (370 of the 462) of the neonate insertion method combinations. If either of the non-randomized methods was longer than the method used to place the tube, the location of the tube tip could not be recalculated if the tip was already in the stomach. This was the reason for 80% rather than 100% of neonate insertion method combinations being calculated. Of the 370 measurements, 87% (58/67) of ARHB, 92% (121/132) of NEMU, and 33% (57/171) of NEX measurements did or would have placed the tube in the stomach while 100% (67/67) of ARHB, 92% (122/132) of NEMU, and 33% (57/171) of NEX measurements did or would have placed the tube in the stomach, duodenum, or pylorus regions. The stomach misplacement rates were significantly higher using the NEX method than either the ARHB or NEMU methods ($p < 0.0001$ for both), while the ARHB and NEMU methods were not significantly different from each other ($p = 1.0000$). The misplacement rates for the less strict definition of placement in stomach, pylorus and duodenum regions were significantly different between each pair (ARHB-NEMU $p = 0.0234$; ARHB-NEX $p < 0.0001$; NEMU-NEX $p < 0.0001$).

Weights were obtained on all neonates, allowing the Gallaher and colleagues (1993) method to be tested in the 9 neonates weighing ≤ 1500 g who participated in this study. Using this method, predicted insertion lengths placed the tube in the stomach in 7/9 (78%) premature infants. Both errors were long but exact location was indeterminate.

Because the original ARHB regression equation in Beckstrand (2005) for children < 28 months only included children at least 44.5 cm long and few neonates, various demographic characteristics (i.e., length, weight, age, race, and gender individually and in combination) were investigated for developing a new ARHB regression equation specifically for this age group. When restricted to the 124 neonates in whom the NG tube was correctly placed in the stomach/pylorus/duodenum regions and tube measurements from the lower border of the diaphragm on radiograph along the curve of the tube were available, length of the neonate alone was found to be the best predictor for insertion length of the tube ($r^2 = 0.45$, $p < 0.0001$), leading to this final ARHB regression equation: ideal NG insertion length = $1.95 + 0.372$ [length of neonate in cm]. The intercept of 1.95 is actually an original intercept value of -1.05 (from the model predicting distance to GEJ), with 1.5 cm added to make sure all pores on the tube from which feeding formula would flow were properly positioned in the stomach and an additional 1.5 cm added to place the tube in the midpoint of the stomach, which we deemed as the ideal location (i.e., between 1.5 cm to 4.5 cm from the GEJ, further details provided below). If an NG tube to be inserted in a neonate has orifices further from the tip than 1.5 cm, the intercept calculation would need to be modified as follows: (a) the length added to make sure all the pores were in the stomach would change; and (b) the upper border of the ideal location would need to be adjusted which would change the length added to put the tube in the middle of the stomach. Figure 1 shows the scatter plot of the predicted and actual insertion lengths, along with lines indicating the target placement range. Points between the two lines indicate tubes that were ideally located in the stomach. Those greater than GEJ + 4.5 cm (i.e., to the left of the GEJ + 4.5 line in the plot) indicate tubes that were placed in the stomach but beyond the ideal location. Points less than GEJ + 1.5 cm (i.e., to the right of the GEJ + 1.5 line in the plot) indicate tubes that were placed in the stomach

short of the ideal location. Table 4 shows the insertion distance for the NG tubes for each length included in our sample using the new ARHB equation.

As noted above, to develop the equation above a minimum and maximum length the tube should be inserted into the stomach was selected. The minimal distance selected was 1.5 cm because all tubes used in this study had orifices within 1.5 cm of the tip of the tube. The maximal distance selected was 4.5 cm. No literature reference could be found for the direct distance between the GEJ and pylorus for neonates. Post hoc, to verify that our ideal stomach location was reasonable for this population, the pediatric radiologist measured the distance between the GEJ and the pylorus of 20 infants ≤ 3 months chronological age undergoing upper gastrointestinal barium (UGI) studies for medical reasons in 2009 (as none were done in neonates < 1 month chronological age). Both the GEJ and pylorus were visible on UGI radiographs using contrast. The mean distance was 3.93 cm, the median was 3.7 cm, and the standard deviation was 0.80 cm, and although there was a large standard deviation due to the differences in the shape of the stomach, the 4.5 cm range between the GEJ and pylorus was supported as 85% of the distances measured < 4.5 cm. Using the 3 cm target range, 94/124 (75.8%) of the tubes were ideally placed in the stomach; 15/124 (12.1%) were placed short of the ideal and 15 (12.1%) were beyond the ideal (14 in the stomach and 1 at the pylorus). A regression equation for OG placement could not be developed because there were too few orally placed tubes ($n=18$). For infants older than 1 month, the ARHB NG and OG regressions equations for 1–28 months should be used (Beckstrand, 2005).

CALLOUT 3

Discussion

A major finding from this first randomized clinical trial involving a large sample of neonates ($n = 173$) was that 92% of NG/OG tubes using NEMU, 100% using ARHB, and 61% using NEX were correctly placed in the stomach, duodenum, or pylorus regions and 91% of NG/OG tubes using NEMU, 78% using ARHB, and 61% using NEX were correctly placed in the stomach only. This means that 39% of tubes inserted using NEX were placed with the tube tip ending either in the esophagus or GEJ. Both NEMU and ARHB were statistically superior to NEX as an NG/OG tube insertion-length predictor in neonates when the less restrictive definition of tube placement error was used. ARHB was not significantly different from either NEMU or NEX when the more restrictive definition of tube placement error was used. Assuming the true percentages of correct placements in the stomach/duodenum/pylorus were as we observed in this study, we had 99% power to detect an association between placement method and correct placement using a chi-square test (two-sided, level of significance .05). Conservatively using Fisher Exact tests (two-sided, level of significance .017) to estimate power for all pair-wise differences, we had $> 96\%$ power when comparing NEX to NEMU or ARHB, but only 2% power when comparing NEMU to ARHB. The fact that at the end of the study the radiologist, who was blinded to the insertion method used to place the tube, was able to determine the tube tip position in 80% of the 462 child-insertion method combinations demonstrating that 87% of ARHB, 92% of NEMU, and 33% of NEX measurements did place or would have placed the tube in the stomach helps to validate the results using this randomized method. These results are similar to those of Tedeschi et al. (2004) and Weibly et al. (1987), who, in descriptive studies involving smaller samples of premature infants, also found NEMU to be the superior NG/OG tube insertion-length predictor when NEMU and NEX were compared. NEX should no longer be used as

³Either nose-ear-midumbilicus for nasogastric/orogastric tubes or the new age-related height-based equation for nasogastric tubes should be used.

an insertion length predictor for placing NG/OG tubes in neonates because of the significant risk of the tube tip and orifices ending in the esophagus or the GEJ, increasing the likelihood of the neonate aspirating feeding formula.

Fifty-seven neonates were shorter than the minimal length of infants participating in the original study in which the ARHB equation was developed (Beckstrand et al., 2005), so the ARHB method was not used to predict the insertion length to place the NG/OG tube in these neonates. To address this knowledge gap, a new regression equation using length was developed that would be applicable to all neonates < 1 month corrected age between 35 and 56.5 cm. Table 4 allows the healthcare provider to find the neonate's length in column 1 and determine the recommended length to insert the NG tube in the same row horizontally in column 2. Alternatively, the new regression equation can be entered into the hospital's computer system or in personal digital assistants allowing healthcare providers the ability to insert the neonate's length and obtain the desired NG tube insertion length.

The likelihood of a tube tip passing through the pylorus needed to be determined. Clearly tubes with a length in the stomach less than the distance from the GEJ to the pylorus could not pass through the pylorus. For tubes with adequate length to theoretically pass through the pylorus there was no significant difference in lengths between those who did and did not enter the duodenum. This suggested that errors in estimating desired total tube length were extremely important if the length is too short (tube tip will be in the esophagus or GEJ), but probably of lesser importance if the estimated tube length was too long.

Limitations

One limitation of this study was the low recruitment rate of 15.4%. This was a very vulnerable population with several layers of protective gatekeepers. From the limited biographical data that could be collected without parental consent, there is no evidence that neonates who participated in the study varied in any way from those who did not. A second limitation is we lacked power to detect differences between ARHB and NEMU. A third limitation was that the original ARHB regression equation could not be used with shorter (more premature infants). The new ARHB regression equation is expected to remedy this limitation. A fourth limitation was that only 9 neonates weighed ≤ 1500 g at the time of study participation, allowing only two of Gallaher's four categories to be tested.

Future Research

The newly developed ARHB regression equation ($NG = 1.95 + 0.372(\text{length in cm})$) needs to be validated in another sample of premature infants. Also, the Gallaher method of predicting insertion length by weight groups in low birth weight infants deserves further study. These research needs could be accomplished in one study that compares NEMU, the new ARHB equation, and the weight method in neonates < 1 month corrected age. Such a study should be undertaken by healthcare personnel in a newborn intensive care unit who know how to care for these very fragile infants with minimal stress. In addition, the direct distance from the GEJ to the pylorus in neonates deserves further study.

Recommendations for Practice

Radiographic verification at the time of initial NG/OG tube placement or tube change is necessary to ensure that the tube has not been misplaced by curling in the esophagus or ending in the esophagus, pylorus, or duodenum. This radiograph should be read by an appropriately trained healthcare provider prior to using the tube for feeding or medication instillation.

As this is the third study demonstrating that the NEX insertion-length predictor is too short in infants plus the 39% error rate in this study (with all errors resulting from the tube tip ending in either the esophagus or GEJ), this method should no longer be used to estimate the distance to insert NG/OG tubes in neonates to protect the safety of children until additional well-designed validation studies can be conducted (Weibly et al., 1987; Ziemer & Carroll, 1978). Either NEMU for NG/OG tubes or the new ARHB equation for NG tubes should be used while awaiting the results of the future studies. NEMU should be measured from the tip of the nose to the ear lobe to the observed midpoint between the xiphoid and the umbilicus. Both the new regression equation specific to neonates and Table 4 to facilitate use are provided.

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Figure 1.
Scatter plot from which the age-related, height-based (ARHB) regression equation for neonates was developed.

Table 1

Research evidence for predicting the length to insert a nasogastric/orogastric (NG/OG) tube in children (including neonates).

Researchers (Year)	Sample Design	Results	Conclusions	Strengths Weaknesses
Ziener & Carroll (1978)	Unreported number of infants at autopsy Prospective descriptive	NG tube inserted using the NEX method reached just past the cardiac sphincter. If the tube was inserted using the nose to ear lobe to mid-umbilicus (NEMU) method, the tube was properly positioned.	The NEMU method should be used to predict the insertion length to place NG tubes in infants.	First study comparing NEX and NEMU prediction methods in infants Number of infants studied not reported. A red rubber tube was used.
Weibly et al. (1987)	30 premature infants (28–36 wks gestational age) Prospective comparative	NEX + 2 cm length was too short in 55.6% of the infants, and the NEMU length was too short in 39.3% of infants.	NEMU was superior to NEX + 2 cm, but neither was optimal.	Study was stronger because error was decreased by inserting the tube using both the NEX and NEMU method in each infant.
Gallaher et al. (1993)	171 x-rays in of 31 very low birth weight infants were reviewed retrospectively. Then after instituting the new guidelines, 117 x-rays from 27 infants were reviewed. Retrospective and prospective review of x-rays	Recommended the following minimal insertion lengths: 13 cm for infants < 750 g, 15 cm for infants weighing 750–999 g, 16 cm for infants weighing 1000–1249 g, and 17 cm for infant weighing 1250–1499 g	Using these insertion lengths, they were able to decrease the error rate in their neonatal intensive care unit from 38% to 14%.	Study focused on very low birth weight infants. First study to investigate weight as a method of predicting OG tube insertion length.
Tedeschi et al. (2004)	43 tubes were passed in 38 premature infants (25–35 wks gestational age). Prospective descriptive	NEMU length was used resulting in two tubes (5%) being located in the distal esophagus and 41 (95%) being located in the stomach	Recommended use of NEMU to predict the length to insert a NG tube.	Found NEMU to be a better predictor than Weibly et al. had.
Beckstrand et al. (2007)	Studied 20 external measures including NEX, NEMU, age, height, weight as possible insertion length predictors in 494 children 2 weeks to 19 years 4 months) undergoing upper gastrointestinal endoscopy or esophageal manometric studies. Prospective descriptive	Regression equations using height in age groups (age-related height-based [ARHB]) were found to be the best predictors of optimal placement of the endoscope or manometric probe in the stomach. The age groups were—1 to 28 months, 29 to 100 months, 100 – 121 months, and > 121 months.	Age-specific regression equations using the child's height/length have the potential to predict accurately the distances to the body of the stomach in 98.8% of children 0.5 to 100 months of age and in 96.5% of children > 100 months. The next best choice was the NEMU length.	Large sample size with sophisticated data analyses Researchers did not use recommended method to insert NG/OG tubes. They also did not present the regression equations in a form easily usable in practice.

Table 2

Comparison of neonate characteristics by three placement methods

	ARHB (n=41)	NEMU (n=66)	NEX (n=66)	p-value
Gender, n(%)				0.5794
Male	20 (48.8%)	39 (59.1%)	36 (54.5%)	
Female	21 (51.2%)	27 (40.9%)	30 (45.5%)	
Corrected age (mo), mean $\pm$ sd	-0.68 $\pm$ 0.62	-0.99 $\pm$ 0.77	-1.14 $\pm$ 0.77	0.0071
Term, n(%)				0.2720
Preterm	38 (92.7%)	64 (97.0%)	65 (98.5%)	
Full term	3 (7.3%)	2 (3.0%)	1 (1.5%)	
Length (cm), mean $\pm$ sd	48.0 $\pm$ 2.7	45.6 $\pm$ 3.9	45.3 $\pm$ 4.3	0.0007
Race, n(%)				0.8636
White	19 (46.3%)	33 (50.0%)	33 (50.0%)	
African American	19 (46.3%)	29 (43.9%)	26 (39.4%)	
Other	3 (7.3%)	4 (6.1%)	7 (10.6%)	
Ethnicity, n(%)				0.5972
Hispanic	6 (14.6%)	6 (9.1%)	6 (9.1%)	
Non-Hispanic	35 (85.4%)	60 (90.9%)	60 (90.9%)	
Acid-inhibiting medication use, n(%)				0.2180*
On	3 (7.3%)	7 (10.6%)	2 (3.0%)	
Not on	38 (92.7%)	59 (89.4%)	64 (97.0%)	
Tube type, n (%)				0.0582
NG	40 (97.6%)	55 (83.3%)	60 (90.9%)	
OG	1 (2.4%)	11 (16.7%)	6 (9.1%)	

Note.

* *p*-value from Fisher's exact test;

ARHB = age-related, height-based; NEX = direct distance nose-ear-xiphoid; NEMU = direct distance nose-ear-mid-umbilicus; NG = nasogastric; OG = orogastric.

Table 3

Radiographic location of nasogastric/orogastric (NG/OG) tube by insertion-length predictors in neonates*

	NEX (n=66)	NEMU (n=66)	ARHB (n=41)	p-value
Placement in Stomach/Duodenum/Pylorus	40 (60.6%)	61 (92.4%)	41 (100%)	<0.0001 ^{a,b}
Placement in Stomach	40 (60.6%)	60 (90.9%)	32 (78.0%)	0.0002 ^a

Note.

* Neonates: Infants < 1 month corrected age;

^a p-value comparing NEX and NEMU < 0.05;^b p-value comparing NEX and ARHB < 0.05;

ARHB = age-related, height-based; NEX = direct distance nose-ear-xiphoid; NEMU = direct distance nose-ear-mid-umbilicus.

Table 4

Nasogastric Tube (NG) Insertion Length: Birth to 1 Month Corrected Age

Neonate's Length (cm) ^a	NG Tube Insertion Length (cm)
35.0 – 35.5	15.0
36.0 – 37.0	15.5
37.5 – 38.0	16.0
38.5 – 39.5	16.5
40.0 – 41.0	17.0
41.5 – 42.0	17.5
42.5 – 43.5	18.0
44.0 – 45.0	18.5
45.5 – 46.5	19.0
47.0 – 47.5	19.5
48.0 – 49.0	20.0
49.5 – 50.5	20.5
51.0 – 51.5	21.0
52.0 – 53.0	21.5
53.5 – 54.5	22.0
55.0 – 55.5	22.5
56.0 – 56.5	23.0

Note. Prediction equation: Predicted NG tube insertion length (cm) = 1.950 cm + 0.372*length (cm);

^a Find the neonate's length in column 1 and determine the recommended length to insert the NG tube in the same row horizontally in column 2.