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Nasogastric Tube Placement Verification In Pediatric and Neonatal Patients

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This article reports an evidence-based practice project using the Iowa Model of Evidence-Based Practice to Promote Quality Care for a common nursing procedure, nasogastric tube placement verification in children. Little research exists regarding the care of nasogastric tubes in children, and traditional verification methods prevail. Auscultation of air insufflation over the abdomen is still used to check placement in many settings, despite research dating back to the 1980s questioning this approach. X-ray remains the only certain way to verify placement, but getting an X-ray before each feeding would be costly and impractical. Additional bedside methods are needed. Project results demonstrate a decrease (93.3% to 46.2%) in the use of auscultation and improved use of other, more reliable methods to determine nasogastric tube placement. Changing practice can be challenging. However, with persistence and re-infusion, this project provides an important example of how the evidence-based practice process leads to excellence and improves patient care.

Pediatric nurses have always been strong advocates of providing high-quality patient care. The evidence-based practice process offers an opportunity to support updating nursing practice based on the strongest research evidence available, in combination with patient and family values and sound clinical judgment (Sackett, Straus, Richardson, Rosenberg, & Haynes, 2000). Using the evidence-based practice process results in improved patient outcomes, often while reducing costs, and provides an opportunity for bedside clinicians to demonstrate an important impact on health care. Traditional nursing practices provide a wonderful opportunity to question practice and potentially improve patient care, which can be very empowering for staff nurses.

Nasogastric (NG) tube placement is a routine procedure used for pediatric and neonatal patients. However, little research exists regarding the verification of NG tubes in children. Several clinical studies and anecdotal reports questioning the use of auscultation to verify NG tube placement have been reported, some dating back more than 20 years (Ghahremani & Gould, 1986). However, the vast majority of nurses continue to check NG tube placement by auscultation of air insufflation over the abdomen.

Purpose

The purpose of this evidence-based practice project was to improve and standardize NG tube placement verification practices used throughout a Midwestern children's hospital. An evidence-based practice approach was used to outline nursing practice and to minimize the risk of incorrectly placed NG tubes. The Iowa Model of Evidence-Based Practice to Promote Quality Care (Titler et al., 2001) provided a guide for completing the project, and support was provided through the Evidence-Based Practice Staff Nurse Internship (Cullen & Titler, 2004).

Evidence-Based Practice Process

The Iowa Model of Evidence-Based Practice to Promote Quality Care successfully promotes the integration of evidence into practice. The model shown in Figure 1 outlines the process for developing an evidence-based practice project. Identifying a practice problem or new knowledge triggers the evidence-based practice process. Leaders in the health care facility or on the nursing unit prioritize issues to be addressed and then assemble a team. The team selects, reviews, critiques, and synthesizes evidence in the literature. If the research evidence is sufficient, the team initiates change. If the evidence is insufficient, the team reviews other evidence or suggests more research. The team then pilots and evaluates the practice change to determine if the change worked or whether revisions are needed before integrating and applying the change in other clinical areas. Additional evaluation and dissemination of results is essential to fully integrate the change into practice.

This project began as a knowledge

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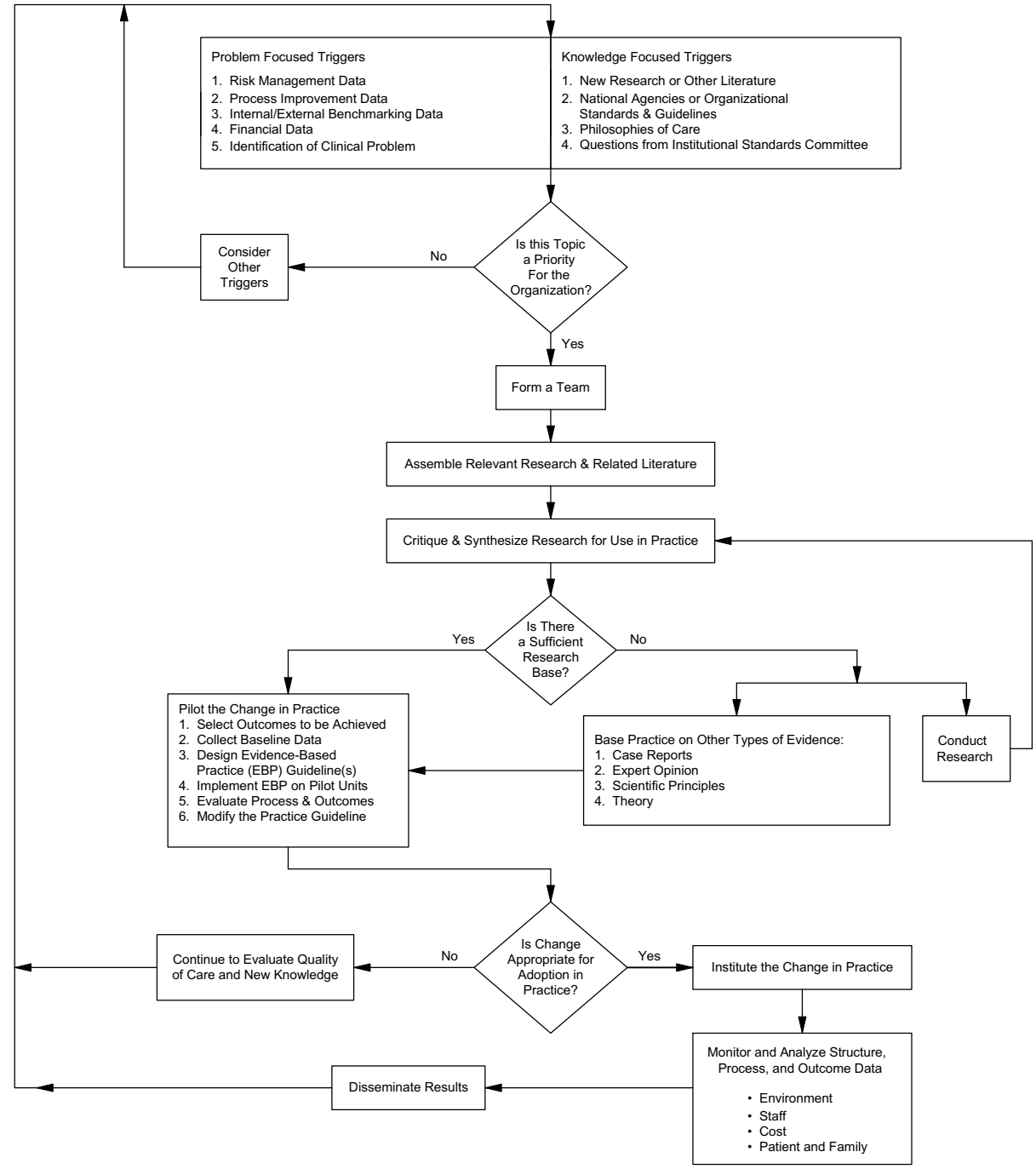
Objectives and the CNE posttest can be found on pages 25-26.

Figure 1.
The Iowa Model of Evidence-Based Practice to Promote Quality Care



Reference
Titler, M.G., Kleiber, C., Steelman, V.J., Rakel, B.A., Budreau, G., Everett, L.Q., Buckwalter, K.C., Tripp-Reimer, T., & Goode C. (2001).The Iowa Model of Evidence-Based Practice to Promote Quality Care. Critical Care Nursing Clinics of North America, 13(4), 497-509.

focus trigger with new information suggesting use of a patient's height and a graph (graphic method) as a better method for determining depth of NG tube insertion in children (Klasner, Luke, & Scalzo, 2002). The team was developed to support the staff nurse as the project director through the Evidence-Based Practice Staff Nurse Internship. An extensive literature review was conducted, current practice was evaluated, and practice changes were implemented utilizing a variety of strategies. This change was evaluated at multiple points following implementation. This article reports some of the more interesting results and processes used to implement this change.

Synthesis of Evidence

The project began in 2003, with little evidence supporting use of height and the graphic method to determine proper insertion depth for NG tubes. Therefore, the project focus changed from measuring for tube insertion to using other evidence-based methods to ensure NG tube placement verification.

The traditional method of assessing NG tube placement has been auscultation over the abdomen after air insufflation because it is a simple and low-cost method (Eisenberg, 1994), is easy to perform (Metheny, Wehrle, Wiersema, & Clark, 1998), and was taught for years in nursing schools. Although this is a frequently used method in the clinical setting, research literature does not support the reliability of this method (Ellett, 2004; Ellett, Croffie, Cohen, & Perkins, 2005; Metheny, Aud, & Ignatavicius, 1998; Metheny, Meert, & Clouse, 2007; Swiech, Lancaster, & Sheehan, 1994; Winterholler & Erbguth, 2002), and malpractice cases have been based on this research (McWey, Curry, Schabal, & Reines, 1988; Metheny, Wehrle et al., 1998). The primary problem with auscultation is that sounds can be transmitted to the epigastrium regardless of whether the NG tube is placed in the lung, esophagus, stomach, duodenum, or proximal jejunum (Cannaby, Evans, & Freeman, 2002; Eisenberg, 1994; Ellett & Beckstrand, 1999; Gharib, Stern, Sherbin, & Rohrmann, 1996; Metheny, McSweeney, Wehrle, & Wiersema, 1990; Metheny, Wehrle et al., 1998).

The majority of research or evidence regarding the use of NG tubes is in adult patients and was pioneered by Norma Metheny in the late 1980s with scant evidence for pediatric patients, possibly due to ethical considerations (Wilkes-Holmes, 2006). Expanded search strategies included personally contacting experts about their work regarding NG tubes in pediatric patients (J. Beckstrand, personal communication, April 12, 2003; A.E. Klasner, personal communication, April 2, 2003 and April 3, 2003; N.A. Metheny, personal communication, April 2, 2003).

In adult patients, the rate of NG tube misplacement ranges from 1.3% to 89.5% (McWey et al., 1988; Niv & Abu-Avid, 1988), depending on how the error is defined, and averages about 4% (Ghahremani & Gould, 1986; Kearns, 1997). The prevalence of NG tube placement errors in children is difficult to determine because of the differing definitions across studies; however, rates of misplacement in children have been reported at 21% to 43.5% (Ellett & Beckstrand, 1999; Ellett et al., 2005; Ellett, Maahs, & Forsee, 1998), which is concerning for these vulnerable infants and children (Crisp, 2006). Poor reporting of tube misplacement has hindered the adoption of effective protocols to prevent such errors (Metheny et al., 2007). In children, several risk factors have been identified for initial tube misplacement or subsequent dislodgement, including age (younger), level of consciousness (comatose or semicomatose), abdominal distention, vomiting, and dysphagia (Ellett & Beckstrand, 1999; Ellett et al., 1998).

Although NG tubes are identified as being misplaced infrequently, significant adverse outcomes can result, such as aspiration pneumonia or pneumothorax (Burns, Carpenter, & Truwit, 2001). Tube misplacement into the lungs is most common and is estimated to occur in 5% of all NG tube insertions (Ellett, 2004), and feeding through an NG tube misplaced into the airway will result in pulmonary aspiration (Ellett et al., 1998). Even when the NG tube remains taped in place, the tube's distal tip could spontaneously shift upward or downward from its original position (Huffman, Pieper, Jarczyk, Bayne, & O'Brien, 2004; Metheny, Spies, & Eisenberg, 1986; Richardson, Branowicki, Zeidman-Rogers, Mahoney, & MacPhee, 2006), something that is even more likely with the soft, small-bore NG tubes (Sanko, 2004). When placing NG tubes, it is common to observe for coughing or cyanosis because they may indicate respiratory placement (Boyes & Kruse, 1992; Chen, Paxton, & Williams-Burgess, 1996; Metheny, Smith, & Stewart, 2000; Metheny & Titler, 2001; Swiech et al., 1994). However, studies have shown that the expected pulmonary symptoms may not be present to indicate there is a problem until shortly after the feeding has been initiated, as evidenced by symptoms such as shortness of breath, fever, and even respiratory arrest (Swiech et al., 1994). It is also important to remember that these signs may be absent in either unconscious patients or those with a poor gag reflex (Colagiovanni, 1999).

Soft, small-bore NG tubes are less likely to cause complications and also reduce the risk of aspiration because the lower esophageal sphincter is less compromised, decreasing the risk of reflux (Boyes & Kruse, 1992; Metheny, 1988), but they may migrate out of position, knot, occlude, or rupture (Williams & Leslie, 2004). Negative pressure generated when attempting to aspirate fluid can cause these flexible NG tubes to collapse. Certain types of NG tubes are reported to collapse in 50% of aspiration attempts (Gharib et al., 1996; Rakel, 2004). In these cases, nurses are unable to use aspiration of gastric contents as a method to verify NG tube placement (Ellett & Beckstrand, 1999; May, 2007; Metheny et al., 1986; Metheny, Stewart et al., 1999). In some situations, even if fluid is not obtained with aspiration, the NG tube is later found to be properly positioned by another verification method, usually X-ray (Swiech et al., 1994). However, aspiration of fluid alone is no guarantee that the NG tube is correctly placed in the stomach (Widmann, 1985).

Ellett (2004) published the following information regarding methods to determine NG tube placement that have been studied in adults: aspirating gastric contents and measuring the pH; measuring bilirubin, pepsin, and trypsin levels; examining the visual characteristics of the aspirate; placing the proximal end of the tube under water and observing for bubbles with expiration; measuring the carbon dioxide (CO_2) level at the proximal end of the NG tube; auscultating for a gurgling sound over the abdomen; and measuring the length from the nose to the proximal end of the tube. In the end, the conclusion for adult patients was that only pH and bilirubin of aspirates have proven to be reliable, inexpensive bedside tests. Aspiration of gastric contents and pH measurements are both simple and cost-effective ways to determine NG tube placement (Chen et al., 1996; Westhus, 2004). Based on the work completed

for adult patients (Rakel, 2004; Rakel et al., 1994), the pH of an aspirate obtained from the stomach would range from 1 to 4, unless the patient is receiving an H_2 receptor antagonist, a proton pump inhibitor, antacids, or tube feedings, any of which would falsely increase the pH of the aspirate and make pH analysis less reliable (May, 2007). For both adults and children, use of pH testing as the only verification method is inadequate because of overlap in pH among sites (Ellett & Beckstrand, 1999; Metheny, Stewart et al., 1999). The pH method is usually effective in differentiating between gastric and respiratory or gastric and intestinal placement of an NG tube because gastric fluid typically has a much lower pH than either intestinal or respiratory fluid (Chen et al., 1996; Metheny et al., 1990). However, the pH method is less effective in distinguishing between intestinal and respiratory fluids because both have higher pH values (Metheny et al., 2000). Another method for bedside verification of NG tube placement is by aspiration of gastric contents and assessing color (clear, light yellow, or light green) (Freer & Lyon, 2005; Weibley, Adamson, Clinkscales, Curran, & Bramson, 1987). A third bedside verification method is confirming the tube is secured and verifying the mark on the tube is at the point it exits the nare (Freer & Lyon, 2005; Metheny, 2006; Metheny et al., 2007; Metheny & Stewart, 2002; Metheny & Titler, 2001; Viall, 1996; Weibley et al., 1987).

Using more than one bedside assessment method to verify NG tube placement is superior to any single placement-verification method used alone (Arbogast, 2002; Bockus, 1993; Ellett & Beckstrand, 1999; Metheny & Meert, 2004; Metheny, Reed, Berglund, & Wehrle, 1994). If there is ever a doubt regarding NG tube placement following completion of bedside placement verification methods, the licensed independent practitioner should be consulted about obtaining an X-ray (Ellett, 2004; Grant & Martin, 2000; May, 2007; Metheny & Titler, 2001; Sanko, 2004; Williams & Leslie, 2005), or the NG tube should be removed and a new one placed (Wilkes-Holmes, 2006).

X-ray remains the only 100% reliable method to document NG tube placement (Ellett, 2004; Ellett, et al., 2005; Marderstein, Simmons, & Ochoa, 2004; Metheny et al., 2007), but it must show the full course of the tube and where the tip and ports are located (Ellett & Beckstrand, 1999; Kearns, 1997; Metheny, 1988; Metheny, Stewart et al., 1999), and it only confirms tube positioning at the exact time of the X-ray (Wilkes-Holmes, 2006). The use of X-rays to verify NG tube placement at the beginning of every feed or simply as a means to ensure correct NG tube placement is not practical, could be inappropriate, dangerous, and costly (Christiansen, 2001; Ellett, 2004; May, 2007; Metheny, 1988; Metheny et al., 1993). X-rays are not only expensive and expose patients to radiation, a greater concern in young children than in adults (Premji, 2005), but also require licensed independent practitioner interpretation and usually cannot be done in outpatient settings (Bercik et al., 2005; Eisenberg, 1994). However, periodic chest or abdominal X-rays may be helpful for NG tubes used for a longer length of time in order to help detect tube misplacement, knot formation, or clinically silent aspiration (Ellett et al., 1998; Ellett et al., 2005; Gharib, et al., 1996; Metheny et al., 1986). Sometimes patients have chest or abdominal X-rays taken for other reasons, which might also reference correct NG tube placement, and should be taken advantage of when available (Metheny & Titler, 2001).

Given the reported frequency of NG tube misplacement found in the literature for pediatric patients, the value of obtaining X-ray verification of NG tube placement upon insertion may outweigh the expense and radiation exposure an X-ray would cause a child or neonate (Ellett & Beckstrand, 1999; Kearns, 1997; Metheny, 1988; Metheny, Eikov, Rountree, & Lengettie, 1999; Richardson, et al., 2006). There are some new non-invasive magnetic imaging techniques being studied for visualizing the placement of NG tubes, so X-rays would not be needed. However, more research is necessary before practice changes to these techniques (Bercik et al., 2005). In addition to new imaging techniques, use of height as a parameter for insertion length (Beckstrand, Ellett, & McDaniel, 2007) offers some promise, but more research is needed, particularly for ongoing placement verification. The literature also suggests verifying NG tube placement following initial tube insertion, at least once per shift with continuous feedings, before each intermittent feeding, and before medication administration (Bockus, 1993; Bowers, 2002; Colagiovanni, 1999; Eisenberg, 1994; Metheny, 1988; Metheny, Clouse et al., 1994; Metheny, Reed et al., 1994; Metheny et al., 1993; Metheny & Titler, 2001; Viall, 1996).

Table 1.
Pediatric Nasogastric Tube Standard of Practice

1. Verification of NG tube placement is *required* at the following times:
   a. After initial tube insertion.
   b. Before each intermittent feeding.
   c. Before medication administration.
   d. Once a shift (or every 8 hours) with continuous feedings.

2. Verification methods
   a. Upon initial NG tube placement, an X-ray is recommended to confirm proper placement before initiation of feedings or medication administration. X-ray is *required* in PICU (American Association of Critical-Care Nurses, 2005).
   b. If an X-ray was not obtained, verify NG tube placement by two of the following methods:
      i. Confirm the mark on the tube is at the point it exits the nare. (Remove and replace the NG tube if it is not marked and will be used for feedings and/or medication administration.)
      ii. Aspirate small amount of gastric contents and evaluate color (clear, light yellow, or light green).
      iii. Test aspirate pH (unless patient is receiving an H_2 receptor antagonist or proton pump inhibitor) using pH paper (on units with competencies maintained for pH testing at the point of care) or laboratory analysis (stomach placement: pH 1-4).

Practice Change: Hospital Policy

Based on the evidence in the literature, the pediatric standard of practice, briefly described in Table 1, was updated and will continue to be reviewed at least every three years per hospital policy. When an aspirate cannot be obtained from an NG tube, nurses can use any or all of the strategies listed in Table 2 (Metheny, Wehrle et al., 1998) to help facilitate obtain-

Table 2.
Strategies to Help Facilitate Obtaining an Aspirate

1.	Use a larger-sized syringe (to decrease the pressure created by the plunger).
2.	Reposition the patient (to move the NG tube away from the stomach wall).
3.	Instill a small amount of air (to move the NG tube away from the stomach wall). If instillation of air is unsuccessful, the NG tube may be kinked or dislodged and should be removed and replaced.
4.	Wait 5 to 30 minutes before trying again to obtain an aspirate.

Table 3.
Project Timeline

February 2003: Project Initiation
February 2003-December 2003: Literature Review and Synthesis
October 2003: Pre-Survey
November 2003-February 2004: Revise Pediatric NG Tube Standard of Practice
March 2004: Post-Survey
January 2007: Follow-Up Survey

ing an aspirate to verify NG tube placement.

Occasionally, an aspirate cannot be obtained. If all bedside methods are tried and found to be unsuccessful in verifying NG tube placement, a nurse may instill 1 to 2cc of sterile water and observe the patient for symptoms of aspiration (such as apnea, bradycardia, coughing, decreased oxygen saturations, shortness of breath, cyanosis, or discolored sputum) (Freer & Lyon, 2005). If no symptoms of aspiration are observed, the nurse may proceed with the feeding while continually observing the patient for symptoms of aspiration. Water is not instilled in patients in the neonatal intensive care unit (NICU) because fluid intake and output need to be very closely controlled (Verklan & Walden, 2004). If there is a doubt regarding NG tube placement following completion of bedside placement verification methods, the licensed independent practitioner should be consulted about obtaining an X-ray.

Implementation Strategies

Implementing practice changes can be difficult and requires multiple reinforcing and interactive strategies to be effective (Greenhalgh, Robert, MacFarlane, Bate, & Kyriakidou, 2005; Rogers, 2003; Titler, 2008; Titler & Everett, 2001; van Achterberg, Schoonhoven, & Grol, 2008). This project was no exception; the timeline is outlined in Table 3. Nurses throughout the pediatric division completed a baseline questionnaire to assess current practices, knowledge, and reported complications related to NG tube cares. It was evident that practice was neither standardized nor evidence-based as demonstrated in Figures 2 and 3.

Education was provided to the nurses by sharing existing evidence using a PowerPoint™ presentation, a one-page flier, and a poster that was displayed to highlight policy changes and clarifications. Each unit identified a "change champion" to educate colleagues about the practice changes. The unit change champions were sent reminders and updates via e-mail and periodically attended team meetings. After the NG tube policy revisions were approved, the online documentation system was updated to reflect the new policy. The updated documentation system also provides a reminder for nurses about frequency of cares related to NG tubes. Moving the policy change through to integration is one challenge of implementing evidence-based practice changes. To accomplish this goal, education continues at the unit level through various strategies, including yearly competencies (written or demonstration), orientation for new nurses, and NG tube practice quality improvement monitors.

Evaluation

Project evaluation compared baseline data with post-implementation data. After implementing the practice change, nurses were given a questionnaire to re-assess NG tube practices. The questionnaire addressed both nursing knowledge and nursing process. Nursing knowledge about signs and symptoms of NG tube misplacement was evaluated. Pediatric nurses were knowledgeable about signs and symptoms of NG tube misplacement both before and after implementation of the practice change, but knowledge was determined to be somewhat higher in the post-questionnaire (correctly answered items regarding various signs and symptoms of aspiration, 87.6% pre: n = 312/356 to 94.4% post: n = 272/288).

Nursing care of pediatric patients with an NG tube was assessed through a nursing process questionnaire. A large number of nurses (n = 83/89; 93.3%) on the pre-questionnaire responded that they check NG tube placement by auscultation of air insufflation over the abdomen. The same was true on the initial post-questionnaire (n = 69/72; 95.8%); however, there was also a demonstrated increase in the number of nurses checking NG tube placement through three additional measures: verifying that the measured mark is aligned at the nare, aspirating gastric contents, and measuring the pH of the aspirate using evidence-based approaches. These numbers are similar to the 86% of nurses who regularly use auscultation to check NG tube placement reported by Persenius, Larsson, and Hall-Lord (2006). On the most recent follow-up questionnaire, only 46.2% (n = 48/104) of nurses responded that they use auscultation to check NG tube placement. These numbers demonstrate that ongoing re-infusion is helpful and continues to be necessary for practice changes to be integrated in the daily actions of nurses working at the bedside.

Overall, questionnaire results indicated improvement in nurses utilizing evidence-based verification methods (see Figure 2). Adverse outcomes related to NG tube misplacement are difficult to track due to the low incidence of aspiration pneumonia related to NG tube misplacement in children. No incidents of aspiration pneumonia were reported from the pediatric units within the children's hospital before or after the project was implemented.

Staff nurses in the NICU had the most difficulty adopting the practice change. These nurses had not yet transitioned away from using auscultation of air insufflation over the abdomen as a way to verify NG tube placement. Barriers to change included the financial cost and physiological stress of obtaining an X-ray prior to

Figure 2.
Methods Used to Verify NG Tube Placement

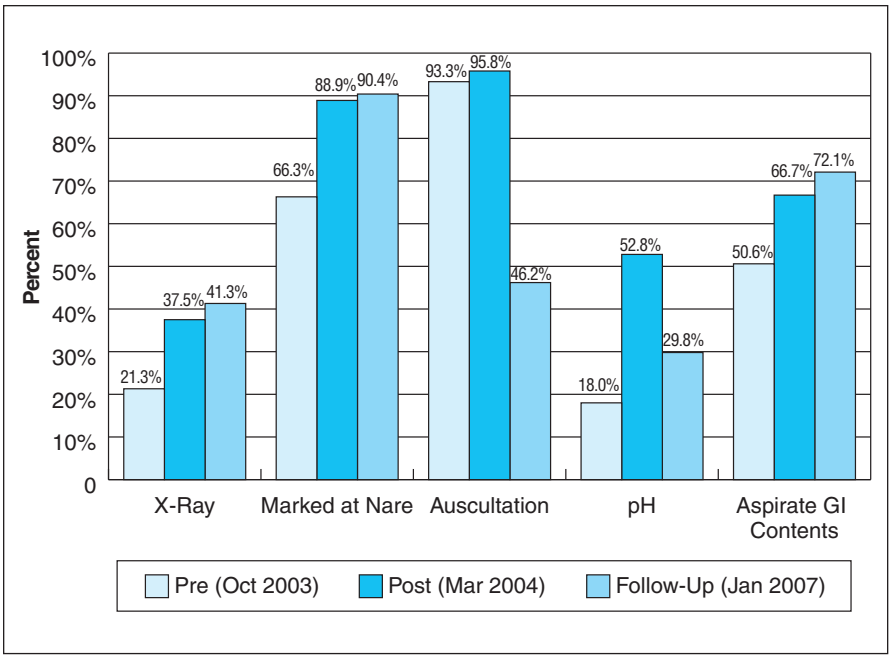
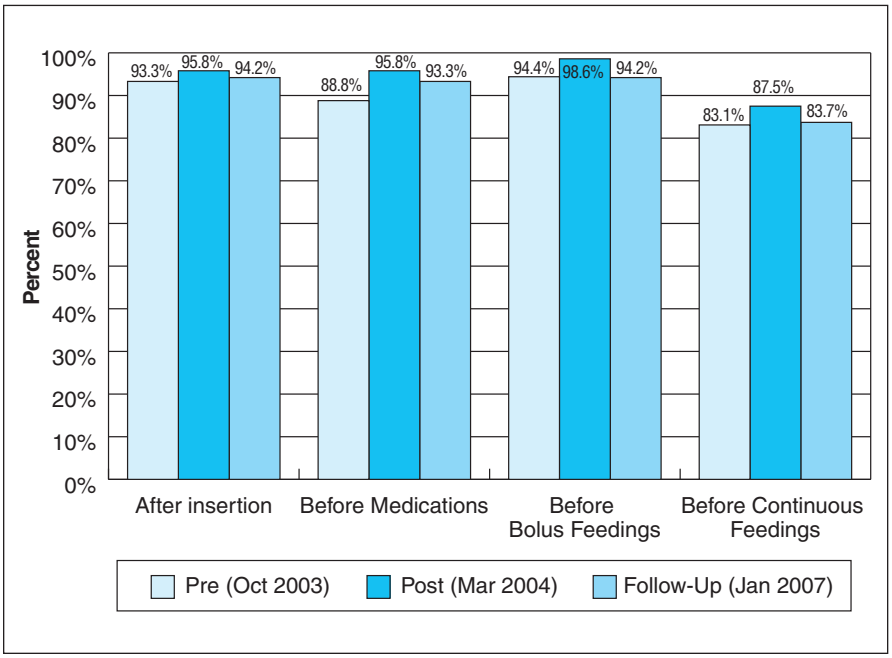


Figure 3.
Times When NG Tube Placement is Checked



each intermittent feeding (often 8 times per day), and a concern about the ability to obtain an aspirate in neonatal patients. Theoretically, the inability to aspirate fluid is expected to be more likely to occur in children because the tubes used for children are smaller in diameter than those used for adults, and therefore, more likely to collapse (Ellett, 2004). The smaller gastric fluid volumes of neonates may also cause difficulty when trying to obtain an aspirate in children (Khair, 2005).

In the NICU, a quality improvement project assessed the ability to obtain an aspirate, which may include a scant amount of residual formula from the previous feeding (Arbogast, 2002). Nurses were reminded of the methods that could be used to assist in obtaining an aspirate (see Table 2). Out of 232 feedings, an inability to obtain an aspirate occurred only five times; 97% of the feedings had an aspirate obtained on the first attempt, while 98% of feedings had an aspirate obtained by the second attempt after some manipulation, numbers similar to those reported by Metheny et al. (1989). When an aspirate could not be obtained, NICU nurses were taught to observe the patient carefully during the feeding for signs and symptoms of aspiration (Freer & Lyon, 2005).

After sharing the results of these quality improvement data and after providing additional education to the NICU staff, an audit assessed compliance with this procedure. To verify that nurses were marking the tube, the NG tube at the bedside was reviewed to see if a mark was present. After six months, 86% of NICU patients with NG tubes had their tubes marked appropriately. Audits continue on a monthly basis, with the most recent audit showing 98% compliance with marking the tube.

Challenges with Outcome Measures

Patients with an incorrectly placed NG tube are at high risk of aspiration (Chen et al., 1996). However, there appears to be a lower incidence of aspiration pneumonias in pediatric patients compared to adult patients, possibly due to sampling limitations with quality improvement and the fact that there has been less research conducted in the vulnerable pediatric patient population. Lack of data demonstrating a problem with aspiration pneumonia made project implementation and evaluation more difficult.

Next Steps

This evidence-based practice project has identified additional areas for practice improvement. NG tube placement is known to be a painful and distressing procedure. Despite knowing that NG tube placement is uncomfortable, it is usually done without analgesia or anesthesia. Currently, information is being gathered about the amount of pain and distress pediatric patients experience during NG tube insertion. The information will be shared with a multidisciplinary committee to improve pain management.

The amount of research regarding NG tubes in children has been increasing over recent years, but prac-

tice changes adopting use of this evidence have not occurred at the same rate. Despite the fact that auscultation is ineffective, changing long-standing traditional nursing care practices can be difficult. This project demonstrated that verification of NG tube placement in children and neonates is a complex patient care issue, and that more research is needed to support many pediatric nursing practices. Despite the challenges, basing practice on the best available evidence will improve patient care. The key to evidence-based practice is involving the staff who "do the work" to ensure their input in problem-solving and process changes, closing the gap between research and practice.

References

Arbogast, D. (2002). Enteral feedings with comfort and safety. *Clinical Journal of Oncology Nursing, 6*(5), 275-283.

American Association of Critical-Care Nurses. (2005). *Practice alert: Verification of feeding tube placement.* Retrieved December 30, 2008, from http://classic.aacn.org/AACN/practiceAlert.nsf/Files/VOFTP/$file/Verification%20of%20Feeding%20Tube%20Place ment%2005-2005.pdf

Beckstrand, J., Ellett, M.L.C., & McDaniel, A. (2007). Predicting internal distance to the stomach for positioning nasogastric and orogastric feeding tubes in children. *Journal of Advanced Nursing, 59*(3), 274-289.

Bercik, P., Schlageter, V., Mauro, M., Rawlinson, J., Kucera, P., & Armstrong, D. (2005). Noninvasive verification of nasogastric tube placement using a Magnet-tracking system: A pilot study in healthy subjects. *Journal of Parenteral and Enteral Nutrition, 29*(4), 305-310.

Bockus, S. (1993). When your patient needs tube feedings: Making the right decisions. *Nursing, 23*(7), 34-42.

Bowers, S. (2002). All about tubes: Your guide to enteral feeding devices. *Nursing, 30*(12), 41-47.

Boyes, R., & Kruse, J. (1992). Nasogastric and nasoenteric intubation. *Critical Care Clinics, 8*(4), 865-878.

Burns, S.M., Carpenter, R., & Truwit, J.D. (2001). Report on the development of a procedure to prevent placement of feeding tubes into the lungs using end-tidal CO_2 measurements. *Critical Care Medicine, 29*(5), 936-939.

Cannaby, A., Evans, L., & Freeman, A. (2002). Nursing care of patients with nasogastric feeding tubes. *British Journal of Nursing, 11*(6), 366-372.

Chen, C.A., Paxton, P., & Williams-Burgess, C. (1996). Feeding tube placement verification using gastric pH measurement. *Worldviews on Evidence-Based Nursing, 3*(1), 79-85.

Christensen, M. (2001). Bedside methods of determining nasogastric tube placement: A literature review. *Nursing in Critical Care, 6*(4), 192-199.

Colagiovanni, L. (1999). Nutrition: Taking the tube. *Nursing Times, 95*(21), 63-64, 67, 71.

Crisp, C.L. (2006). Esophageal nasogastric tube misplacement in an infant following laser supraglottoplasty. *Journal of Pediatric Nursing, 21*(6), 454-455.

Cullen, L., & Titler, M.G. (2004). Promoting evidence-based practice: An internship for staff nurses. *Worldviews on Evidence-Based Nursing, 1*(4), 215-223.

Eisenberg, P.G. (1994). Nasoenteral tubes. *RN, 57*(10), 62-70.

Ellett, M.L. (2004). What is known about methods of correctly placing gastric tubes in adults and children. *Gastroenterology Nursing, 27*(6), 253-261.

Ellett, M.L.C., & Beckstrand, J. (1999). Examination of gavage tube placement in children. *Journal of the Society of Pediatric Nurses, 4*(2), 51-60.

Ellett, M.L.C., Croffie, J.M.B., Cohen, M.D., & Perkins, S.M. (2005). Gastric tube placement in young children. *Clinical Nursing Research, 14*(3), 238-252.

Ellett, M.L.C., Maahs, J., & Forsee, S. (1998). Prevalence of feeding tube placement errors and associated risk factors in children. *MCN: The American Journal of Maternal/Child Nursing, 23*(5), 234-239.

Freer, Y., & Lyon, A. (2005). Nasogastric tube aspirate pH values associated with typical enteral feeding patterns in infants admitted to an NICU. *Journal of Neonatal Nursing, 11*(3), 106-109.

Ghahremani, G.G., & Gould, R.J. (1986). Nasoenteric feeding tubes: Radiographic detection of complications. *Digestive Diseases and Sciences, 31*(6), 574-585.

Gharib, A.M., Stern, E.J., Sherbin, V.L., & Rohrmann, C.A. (1996). Nasogastric and feeding tubes: The importance of proper placement. *Postgraduate Medicine, 99*(5), 165-168, 174-176.

Grant, M.J.C., & Martin, S. (2000). Delivery of enteral nutrition. *AACN Clinical Issues: Advanced Practice in Acute and Critical Care, 11*(4), 507-516.

Greenhalgh, T., Robert, G., MacFarlane, F., Bate, P., & Kyriakidou, O. (2005). *Diffusion of innovations in health service organisations: A systematic literature review.* Malden, MA: BMJ Book and Blackwell Publishing.

Huffman, S., Pieper, P., Jarczyk, K.S., Bayne, A., & O'Brien, E. (2004). Methods to confirm feeding tube placement: Application of research in practice. *Pediatric Nursing, 30*(1), 10-13.

Kearns, P.J. (1997). Evaluation of diagnostic tests: Verification of feeding tube placement using electromagnetic principles. *Nutrition in Clinical Practice, 12*(1, Suppl), S61-S65.

Khair, J. (2005). Guidelines for testing the placing of nasogastric tubes. *Nursing Times, 101*(20), 26-27.

Klasner, A.E., Luke, D.A., & Scalzo, A.J. (2002). Pediatric orogastric and nasogastric tubes: A new formula evaluated. *Annals of Emergency Medicine, 39*(3), 268-272.

Marderstein, E.L., Simmons, R.L., & Ochoa, J.B. (2004). Patient safety: Effect of institutional protocols on adverse events related to feeding tube placement in the critically ill. *Journal of the American College of Surgeons, 199*(1), 39-47.

May, S. (2007). Critical care. Testing nasogastric tube positioning in the critically ill: Exploring the evidence. *British Journal of Nursing, 16*(7), 414-418.

McWey, R.E., Curry, N.S., Schabal, S.I., & Reines, H.D. (1988). Complications of nasoenteric feeding tubes. *American Journal of Surgery, 155*(2), 253-257.

Metheny, N. (1988). Measures to test placement of nasogastric and nasointestinal feeding tubes: A review. *Nursing Research, 37*(6), 324-329.

Metheny, N.A. (2006). Preventing respiratory complications of tube feedings: Evidence-based practice. *American Journal of Critical Care, 15*(4), 360-369.

Metheny, N.A., Aud, M.A., & Ignatavicius, D.D. (1998). Detection of improperly positioned feeding tubes. *Journal of Healthcare Risk Management, 18*(3), 37-48.

Metheny, N.A., Clouse, R.E., Clark, J.M., Reed, L., Wehrle, M.A., & Wiersema, L. (1994). pH testing of feeding-tube aspirates to determine placement. *Nutrition in Clinical Practice, 9*(5), 185-190.

Metheny, N.A., Eikov, R., Rountree, V., & Lengettie, E. (1999). Indicators of feeding tube placement in neonates. *Nutrition in Clinical Practice, 14*(6), 307-314.

Metheny, N.A., McSweeney, M., Wehrle, M.A., & Wiersema, L. (1990). Effectiveness of the auscultatory method in predicting feeding tube location. *Nursing Research, 39*(5), 262-267.

Metheny, N.A., & Meert, K.L. (2004). Monitoring feeding tube placement: A review. *Nutrition in Clinical Practice, 19*(5), 487-495.

Metheny, N.A., Meert, K.L., & Clouse, R.E. (2007). Complications related to feeding tube placement. *Current Opinion in Gastroenterology, 23*(2), 178-182.

Metheny, N.A., Reed, L., Berglund, B., & Wehrle, A. (1994). Visual characteristics of aspirates from feeding tubes as a method of predicting tube location. *Nursing Research, 43*(5), 282-287.

Metheny, N.A., Reed, L., Wiersema, L., McSweeney, M., Wehrle, M.A., & Clark, J. (1993). Effectiveness of pH measurements in predicting feeding tube placement: An update. *Nursing Research, 42*(6), 324-331.

Metheny, N.A., Smith, L., & Stewart, B.J. (2000). Development of a reliable and valid bedside test for bilirubin and its utility for improving prediction of feeding tube location. *Nursing Research, 49*(6), 302-309.

Metheny, N., Spies, M., & Eisenberg, P. (1986). Frequency of nasoenteral tube displacement and associated risk factors. *Research in Nursing & Health, 9*(3), 241-247.

Metheny, N., & Stewart, B.J. (2002). Testing feeding tube placement during continuous tube feedings. *Applied Nursing Research, 15*(4), 254-258.

Metheny, N., Stewart, B.J., Smith, L., Yan, H., Diebold, M., & Clouse, R.E. (1999). pH

and concentration of bilirubin in feeding tube aspirates as predictors of tube placement. *Nursing Research, 48*(4), 189-197.

Metheny, N.A., & Titler, M.G. (2001). Assessing placement of feeding tubes. *American Journal of Nursing, 101*(5), 36-45.

Metheny, N., Wehrle, M.A., Wiersema, L., & Clark, J. (1998). Testing feeding tube placement: Auscultation vs. pH method. *American Journal of Nursing, 98*(5), 37-42.

Metheny, N., Williams, P., Wiersema, L., Wehrle, M.A., Eisenberg, P., & McSweeney, M. (1989). Effectiveness of pH measurements in predicting feeding tube placement. *Nursing Research, 38*(5), 280-285.

Niv, Y., & Abu-Avid, S. (1988). On the positioning of a nasogastric tube [Letter to the editor]. *The American Journal of Medicine, 84*(3), 563-564.

Persenius, M.W., Larsson, B.W., & Hall-Lord, M.L. (2006). Enteral nutrition in intensive care: Nurses' perceptions and beside observations. *Intensive and Critical Care Nursing, 22*(2), 82-94.

Premji, S.S. (2005). Enteral feeding for high-risk neonates: A digest for nurses into putative risk and benefits to ensure safe and comfortable care. *Journal of Perinatal & Neonatal Nursing, 19*(1), 59-73.

Rakel, B. (2004, September). *Piloting the practice changes.* Paper presented at the meeting of the 3rd Annual Advanced Practice Institute: Promoting Adoption of Evidence-Based Practice, Iowa City, Iowa.

Rakel, B.A., Titler, M., Goode, C., Barry-Walker, J., Budreau, G., & Buckwalter, K.C. (1994). Nasogastric and nasointestinal feeding tube placement: An integrative review of research. *AACN Clinical Issues in Critical Care Nursing, 5*(2), 194-206, 218-219, 223.

Richardson, D.S., Branowicki, P.A., Zeidman-Rogers, L., Mahoney, J., & MacPhee, M. (2006). An evidence-based approach to nasogastric tube management: Special considerations. *Journal of Pediatric Nursing, 21*(5), 388-393.

Rogers, E.M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Sackett, D.L., Straus, S.E., Richardson, W.S., Rosenberg, W.M., & Haynes, R.B. (2000). *Evidence-based medicine: How to practice and teach EBM* (2nd ed.). Edinburgh: Churchill Livingstone.

Sanko, J.S. (2004). Aspiration assessment and prevention in critically ill enterally fed patients: Evidence-based recommendations for practice. *Gastroenterology Nursing, 27*(6), 279-285.

Swiech, K., Lancaster, D.R., & Sheehan, R. (1994). Use of a pressure gauge to differentiate gastric from pulmonary placement of nasoenteral feeding tubes. *Applied Nursing Research, 7*(4), 183-189.

Titler, M.G. (2008). The evidence for evidence-based practice implementation. In, R.G. Hughes (Ed), *Patient safety and quality: An evidence-based handbook for nurses.* (AHRQ Publication No. 08-0043). Retrieved January 22, 2009, from http://www.ahrq.gov/qual/nurseshdbk/

Titler, M.G., & Everett, L.Q. (2001). Translating research into practice: Considerations for critical care investigators. *Critical Care Nursing Clinics of North America, 13*(4), 587-604.

Titler, M.G., Kleiber, C., Steelman, V.J., Rakel, B.A., Budreau, G., Everett, L.Q., et al. (2001). The Iowa model of evidence-based practice to promote quality care. *Critical Care Nursing Clinics of North America, 13*(4), 497-509.

van Achterberg, T., Schoonhoven, L., & Grol, R. (2008). Nursing implementation science: How evidence-based nursing requires evidence-based implementation. *Journal of Nursing Scholarship, 40*(4), 302-310.

Verklan, M.T., & Walden, M. (Eds.). (2004). *Core curriculum for neonatal intensive care nursing* (3rd ed.). Philadelphia: W.B. Saunders Publishing Company.

Viall, C.D. (1996). Location, location, location…NG tube placement. *Nursing, 26*(9), 43-45.

Weibley, T. T., Adamson, M., Clinkscales, N., Curran, J., & Bramson, R. (1987). Gavage tube insertion in the premature infant. *Maternal Child Nursing, 12*(1), 24-27.

Westhus, N. (2004). Methods to test feeding tube placement in children. *MCN, The American Journal of Maternal/Child Nursing, 29*(5), 282-287.

Widmann, W. (1985). Complications of nasoenteric tubes [Letter to the editor]. *Journal of the American Medical Association, 254*(1), 54.

Wilkes-Holmes, C. (2006). Safe placement of nasogastric tubes in children. *Paediatric Nursing, 18*(9), 14-17.

Williams, T.A., & Leslie, G.D. (2004). A review of the nursing care of enteral feeding tubes in critically ill adults: Part 1. *Intensive and Critical Care Nursing, 20*(6), 330-343.

Williams, T.A., & Leslie, G.D. (2005). A review of the nursing care of enteral feeding tubes in critically ill adults: Part 2. *Intensive and Critical Care Nursing, 21*(1), 5-15.

Winterholler, M., & Erbguth, F.J. (2002). Accidental pneumothorax from a nasogastric tube in a patient with severe hemineglect: A case report. *Archives of Physical Medicine and Rehabilitation, 83*(8), 1173-1174.