Monitoring Feeding Tube Placement

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ABSTRACT: The purpose of this literature review is to describe currently available bedside methods to determine feeding tube placement. Described first are methods used at the time of blind insertion to distinguish between gastric and respiratory placement and gastric and small-bowel placement. Discussed next are methods used after feedings are initiated to determine if the tube has remained in the desired position in the gastrointestinal tract. Some of the methods are research-based, whereas others are opinion-based. The level of accuracy of the methods discussed in the review varies widely. No sure nonradiographic method exists to differentiate between respiratory, esophageal, gastric, and small bowel placement of blindly inserted feeding tubes in the fed or unfed state. However, a combination of some of the simpler and more accurate methods may be used to guide feeding tube placement during insertion and help identify the point at which an abdominal radiograph is most likely to confirm the desired location. In addition, methods described in this review can help determine when a radiograph is needed to confirm that a feeding tube has remained in the correct position after the initiation of feedings. Minimizing the number of radiographs taken to assure correct tube placement is important, especially in young children and in the critical care setting where the need for radiographs for other reasons is common.

Assuring that a tube is in a safe position before its use for feeding is of paramount importance; therefore, it is understandable why bedside methods to detect inadvertent placement of a feeding tube in the respiratory tract have been studied extensively, as have methods to differentiate between gastric and small bowel placement before starting feedings. Far less frequently studied have been bedside methods to assure that a tube has remained in the correct position in the gastrointestinal tract after feedings have been started; this is a concern because feeding tubes can dislocate from their intended positions, perhaps leading to complications such as aspiration and intolerance to feedings.[1,2]

The purpose of this article is to review information about clinically available bedside methods to predict feeding tube location. Omitted from this discussion are a number of detection methods that are not available for clinical use.[3–8] Some of the methods discussed below are research-based, whereas others are opinion-based.

Determining Placement of Newly Inserted Tubes Before Use for Feedings

Confirmation that a newly inserted feeding tube is correctly positioned is mandatory before initiating feedings or giving medications *via* the tube; a reliably obtained and interpreted radiograph that visualizes the entire course of the tube provides the best evidence. There have been multiple reports of x-rays being misinterpreted by physicians not trained in radiology.[9,10] For this reason, some institutions require confirmation from a radiologist that a small-bore feeding tube is correctly positioned before feeding. Small-bore tubes may cause few or no symptoms when incorrectly positioned; in addition, they usually need a stylet during insertion, increasing the risk for perforation through surrounding tissues. Although radiographic confirmation of correct placement is used less frequently with newly inserted large-bore nasogastric or orogastric feeding tubes, it may be necessary in high-risk patients (such as those who are unconscious, intubated, or uncooperative during the procedure). Some institutions mandate radiographic confirmation before feeding through *any* blindly placed feeding tube (regardless of size).

Even when radiographs are planned, a variety of bedside methods are used to check placement immediately after tube insertion; if results from these tests do not support correct positioning, the tube is usually removed and reinserted. In this way, the number of x-rays can be kept to a minimum. Although radiologic confirmation of correct tube

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placement is the "gold standard," not all institutions have a policy that mandates this method, and even if they do, they do not always adhere to it. In these situations, the tests described below take on added significance.

Ruling Out Inadvertent Respiratory Placement

Inadvertent respiratory placement of feeding tubes typically occurs in $<5\%$ of new tube insertions. For example, in a prospective study of 748 tube insertions in critically ill patients, 14 (2%) entered the tracheal tree.[11] Because this occurrence is infrequent, guessing a tube's location often leads to the correct conclusion; however, it also fails to identify the majority of misplaced tubes.[8] Among the bedside methods used to rule out inadvertent placement in the respiratory tract of patients with newly inserted feeding tubes are:

- Observing for signs of respiratory distress (such as coughing, choking, or cyanosis) or alert and conscious patients' inability to speak
- Observing the appearance of fluid withdrawn from the feeding tube
- Measuring the pH of fluid withdrawn from the feeding tube (this method works best if the patient has been fasting for several hours)
- Observing for a characteristic carbon dioxide waveform with capnography
- Auscultating over the epigastrium for air insufflated *via* the feeding tube
- Listening for a whooshing sound from the end of the tube when it is inserted near the level of the carina or observing for bubbling when the end of the tube is held underwater

Although these methods at times may have some degree of accuracy, they are generally not considered adequate to preclude the need for a reliably interpreted x-ray to rule out inadvertent respiratory placement, especially when narrow-bore tubes are used in critically ill patients.

Signs of respiratory distress or inability to speak. Although observing for signs of respiratory distress is a reasonable action, it is often ineffective in detecting a malpositioned tube, especially in unconscious or debilitated patients.[11–13] Respiratory symptoms are less likely with the use of small-bore soft tubes than with firm large-bore tubes; however, even large-bore tubes placed in the respiratory tract can fail to produce symptoms when the patient is unconscious or debilitated.[14] In the past, it was assumed that a feeding tube placed in the respiratory tract separates the vocal cords sufficiently to interfere with phonation. Apparently, however, this is not true (especially when soft small-bore tubes are used). For example, a case was reported in which a nasogastric tube (size not specified) was inadvertently passed into the respiratory tract of a recently extubated patient who remained alert and able to converse.[15]

Appearance of fluid withdrawn from the feeding tube. A commonly used method to assess feeding tube placement is observing fluid withdrawn from the tube to determine if it has the usual appearance of gastric juice. Obviously, this method only works if the observer can recognize gastric juice. A group of investigators observed the appearance of over 400 gastric aspirates from acutely ill adults before the introduction of feedings and described them as either clear and colorless (often with shreds of off-white to tan mucus), grassy green (because of refluxed bile acted upon by hydrochloric acid), light yellow (presumably caused by refluxed bile into a stomach with an alkaline pH), or brown (indicating blood partially digested by hydrochloric acid).[16] Harrison et al[17] described 9 gastric aspirates withdrawn from the feeding tubes of pediatric patients as being green in color. Aspirates withdrawn from feeding tubes inadvertently positioned in the tracheobronchial tree have been described as off-white mucus-containing fluid.[12] Aspirates with the appearance of pleural fluid (straw-colored and watery) have been obtained from feeding tubes inadvertently positioned in the pleural space.[18–23] In a number of these cases, the fluid was mistaken for gastric juice.[18,21,22,24] Occasionally, fluid withdrawn from a feeding tube inadvertently positioned in the pleural space may be blood-tinged (presumably because of trauma when the feeding tubes perforated the pleural space).[12] In a study in which staff nurses were asked to identify photographs of 6 respiratory specimens interspersed with 14 photographs of gastrointestinal secretions, they were successful in less than half the cases.[16] These findings, coupled with anecdotal reports in the literature, indicate that relying solely on the appearance of feeding tube aspirates to rule out inadvertent respiratory placement is unwise.

Because the esophagus typically contains little fluid, it is difficult to obtain an aspirate when the tube's ports are malpositioned in this site. On the rare occasions when fluid is present, it is probably either refluxed gastric juice or swallowed saliva; thus, appearance of the feeding tube aspirate would be of little benefit in ruling out esophageal placement. Of course, esophageal placement increases the risk for aspiration during enteral feedings.

Measuring pH of fluid withdrawn from feeding tube. Measuring the pH of fluid withdrawn from a feeding tube is helpful in differentiating between gastric and respiratory placement when gastric pH is low. In a study of more than 1200 gastrointestinal and respiratory secretions from fasting patients, it was found that 60% of the gastric aspirates had pH readings between 0 and 4, whereas none of the respiratory secretions had pH values <6[25] (Table 1). Over two thirds of the patients in this sample were receiving some type of gastric-acid–inhibiting drug. Other investigators have found that gastric pH readings are often low despite the administration of gastric-acid–inhibiting agents. For example, in a study of 36 adult patients, Griffith et al[26] found that most gastric pH readings were ≤ 5, with or without the use of gastric-acid–inhibiting agents. Investigators who evaluated gastric pH in critically ill children found that the nonfed gastric pH is similar to that observed in adults. For example, Gharpure et al[7] reported that the mean nonfed gastric pH in 53 critically ill children was 4.

When gastric pH is ≥6, using pH to predict tube location is of no benefit. In this situation, it is impossible to differentiate between gastric and respiratory placement. Another problem is that the pH of a feeding tube aspirate cannot detect tube placement in the esophagus; for example, anecdotal reports indicate that the pH of fluid withdrawn from tubes in the esophagus may be as low as 1 (likely because of refluxed gastric juice) or as high as 7 (presumably because of recent swallowing of saliva).[27] Still another problem is occasional difficulty in withdrawing fluid from feeding tubes.[17,28] Insufflating air through the tube before attempting to withdraw fluid increases the probability of success[29]; in several studies, investigators have been able to aspirate fluid from 85% or more of feeding tubes in the gastrointestinal tract.[4,30] Of course, it is easier to aspirate fluid from firm large-diameter tubes than from soft small-bore tubes. Contrary to common belief, it is also possible to withdraw fluid from feeding tubes inadvertently positioned in the lung or pleural space.[12,18–23]

When pH indicator strips are used to measure acidity or alkalinity, it is important to assure that the strip has an appropriate pH range (such as 1 to 10); pH papers that do not have this range lack sufficient sensitivity to be useful.[31,32] It also helps if the strip has multiple color squares for comparison with the colorimetric chart provided with the strip.

Tubes with built-in pH probes have also been tested and used clinically; however, most of the reports deal with their ability to differentiate between gastric and small bowel placement rather than between gastric and respiratory placement.[33–36] As in using aspirate pH to determine tube placement, a pH probe is of no benefit in differentiating between respiratory and gastric placement when gastric pH is ≥6. In addition, a pH probe tube cannot rule out esophageal placement.[35] Additional drawbacks to pH probe tubes are increased cost and the need to train personnel in their use.

Table 1
pH ranges of gastrointestinal secretions withdrawn from feeding tubes of fasting patients and tracheobronchial secretions/pleural fluid collected during suctioning and thoracentesis

Tubesite	pH 0–4	pH 5–6	pH ≥ 7
Stomach* (n = 519)	60.2%	18.3%	21.5%
Small bowel* (n = 490)	1.0%	5.1%	93.9%
Tracheobronchial secretions and pleural fluid (n = 275)	0.0%	0.7%	99.3%

*No oral or tube-administered feedings were given within the previous 4 hours; at least 1 hour had elapsed since any medications were given orally or by tube (with the exception of antacids, which were not given within previous 4 hours); tubes were flushed with 30 mL of air before aspiration of fluid for pH testing. Adapted from Metheny NA, Aud MA, Ignatavicius DD. Detection of improperly positioned feeding tubes. *J Health Risk Manag.* 1998;18:37–48, with permission of the American Society for Healthcare Risk Management.

Capnography. This method is based on the premise that a feeding tube inadvertently positioned in the respiratory tract will reveal a characteristic exhaled carbon dioxide waveform.[37,38] Although this concept has been recognized for many years, there has been a renewed interest in testing its efficacy in critically ill patients.[39–41] This method requires that the feeding tube be inserted to the level of the midesophagus before being connected to end-tidal carbon dioxide monitoring equipment. If carbon dioxide is detected, respiratory placement is suspected; if not, the tube is assumed to be in the esophagus. Using a 2-step radiograph approach, Kindopp et al[39] tested capnography in 100 feeding tube placements in an intensive care unit. In 11 cases in which the feeding tube entered the tracheobronchial tree, a normal capnographic tracing was observed. In contrast, in the 86 cases in which the feeding tube entered the esophagus, capnography displaced a "purging warning." In the 3 remaining placements, radiography indicated the tube was coiled in the oropharynx (causing either a "no purging/no capnogram" result or a "purging" warning). The authors listed potential limitations to capnography. One is the possibility that a normal capnogram would not appear if a feeding tube in the tracheobronchial tree were not perfectly patent. Another is that a tracheally-placed feeding tube would not show a normal capnogram if the eyelet holes were at the level of the cuff of the endotracheal or tracheostomy tube. Other clinicians have cautioned that capnography is of questionable benefit with small-bore feeding tubes that can become clogged with the lubricant used for insertion.[37] Although Kindopp et al[39] reported success with the use of capnography, they still recommended that 1 radiograph be obtained and reviewed after tube placement to ascertain final position before use; they pointed out that the tube's tip could be positioned in the esophagus (thus predisposing to regurgitation and aspiration).

Thomas and Falcone[42] attached a colorimetric carbon dioxide indicator device to the proximal end of small-bore feeding tubes to determine if they could distinguish between respiratory and gastric placement in 10 critically ill, mechanically ventilated trauma patients. Each patient had 1 tube inserted by the nasogastric route and 1 through the endotracheal tube; all of the transtracheal insertions showed color changes consistent with the presence of carbon dioxide, but none of the nasogastric placements resulted in a color change. Of course,

Table 2
*Examples of published cases of feeding tubes inadvertently positioned in the lung**

Author/date	Patient	Method used to test placement	Actual tube location (determined by radiography)	Complications
Metheny et al, 1998[25]	70-Year-old woman	Auscultation for insufflated air	Right lower lobe of lung	Respiratory distress after infusion of 500 mL of formula (death)
Metheny et al, 1998[25]	50-Year-old man	Placement of proximal end of tube underwater and observing for bubbling	Left lower lobe of lung and pleural space	Severe respiratory distress after administration of 300 mL of formula; eventually required surgical removal of left lower lobe
Kolbitsch et al, 1997[61]	50-Year-old man	Auscultation for insufflated air; aspiration of 2 to 3 mL of thin light yellow fluid	Pleural perforation in the right inferior lobe	Right-sided capsulated pneumothorax
El-Gamel and Watson, 1993[62]	13-Month-old child	Auscultation for insufflated air	Right bronchus	Hydropneumothorax after infusion of enteral formula
Hendry et al, 1986[9]	79-Year-old man	Auscultation for insufflated air	Right mainstem bronchus	Pneumothorax and septicemia after instillation of medications
Hendry et al, 1986[9]	75-Year old man	Chest x-ray (misinterpreted initially)	Left lung and pleural space	Septicemia and multiple organ failure after infusion of formula (death)
Lipman et al, 1985[20]	61-Year-old man	Auscultation for insufflated air	Right lung	Pneumonitis and hydrothorax after infusion of formula into lung (death)
Miller et al, 1985[63]	68-Year-old woman	Auscultation for insufflated air	Right mainstem bronchus, pleural space	Pleural effusion (2 L) after administration of formula
Schlorlemmer and Battaglini, 1984[13]	80-Year-old woman	Auscultation for insufflated air	Left mainstem bronchus and pleural space	Pneumothorax after infusion of formula
Torrington and Bowman, 1981[14]	43-Year-old man	Auscultation for insufflated air	Left mainstem bronchus	Sepsis and empyema after infusion of 4 L of formula (death)
Siemers and Reinke, 1976[64]	58-Year-old woman	Auscultation for insufflated air	Posterior mediastinum and left pleural space	Pleural effusion and pneumomediastinum after infusion of formula
Harris, 1993[65]	30-Year-old man	Not described	Right mainstem bronchus	Adult respiratory distress syndrome after administration of charcoal into lung

*Adapted from Metheny NA, Aud MA, Ignatavicius DD. Detection of improperly positioned feeding tubes. *J Health Risk Manag.* 1998;18: 37–48, with permission of the American Society for Healthcare Risk Management.

this study was not representative of actual clinical situations, and one must interpret the results carefully before relying solely on them to distinguish between respiratory and gastric placement. Other investigators have used colorimetric devices attached to feeding tubes of 53 mechanically ventilated patients to observe for carbon dioxide; no color change was observed in the 52 nasogastric insertions but change was evident in the 1 tracheobronchial insertion.[40] No testing was done in spontaneously breathing patients. Observing for a colorimetric change is probably less precise than relying on the appearance of a carbon dioxide waveform.[37]

Auscultation for air insufflated through the feeding tube. Auscultating for air insufflated through a feeding tube has been used for many years to attempt to differentiate between placement of a feeding tube in the stomach and the respiratory tract. However, the efficacy of this method is highly questionable.[43,44] Although there is no evidence that the auscultatory method is effective for ruling out respiratory placement, there are multiple anecdotal reports of its ineffectiveness.[9,24,25,45–48] In several cases in which the results falsely indicated correct tube placement, feedings were started and led to disastrous results[25] (Table 2). In a retrospective study of 9 tubes inadvertently placed in the respiratory tract, auscultation by nurses and physicians failed to predict misplacement in 8 of the 9 cases.[12] A tragic case was reported in which a large-bore nasogastric tube was inserted into the brain of a patient who had undergone a transsphenoidal pituitary resection; 2 nurses reported being able to hear air insufflated through the tube while auscultating the epigastrium.[48] According to hearing the air and being able to aspirate several milliliters of serosanguineous fluid from the tube, they did not believe the tube was malpositioned.

In a study of 134 tube insertions, investigators found that auscultation for insufflated air had a sensitivity of only 45% in determining whether the tubes were above or below the diaphragm; they did not report if any of the tube insertions were made into the respiratory tract.[8]

Listening for a whooshing sound from the end of the tube when it is inserted near the level of the Carina, or observing for bubbling when the end of the tube Is held underwater. Some clinicians find it helpful to hold the proximal end of a feeding tube inserted to a level proximate to the carina and listen for a loud whoosh of air upon expiration (presumably indicating placement in the trachea).[28,49–51] Although no harm can come from this maneuver, its efficacy has not been established. In the past, some clinicians tried submerging the proximal tip of a newly inserted feeding tube in a glass of water, assuming that bubbling would indicate respiratory placement; however, this method is flawed because the stomach also contains air and could falsely indicate respiratory placement. More importantly, wedging of the tube's ports in the airway could produce a false-negative. Such a case is described in Table 2. Therefore, this method is not recommended.

Distinguishing Between Gastric and Small Bowel Placement

After respiratory placement has been ruled out and gastric placement confirmed, it is sometimes necessary to advance the tube into the small bowel before initiating feedings (depending on the patient's needs). If small bowel feedings are indicated, the next task is to differentiate between gastric and small bowel placement; the efficacy of a number of methods has been evaluated for this purpose:

- Observing the appearance of fluid withdrawn from the feeding tube
- Measuring the pH of fluid withdrawn from the feeding tube
- Use of tubes with built-in pH probes
- Auscultating for air insufflated *via* the feeding tube
- Negative pressure felt when attempting to aspirate fluid from the feeding tube

Observing the appearance of aspirates to differentiate between gastric and intestinal placement. As described earlier, gastric juice may be clear and colorless (often with shreds of off-white to tan mucus), grassy green (because of refluxed bile acted upon by hydrochloric acid), light yellow (presumably because of refluxed bile into a stomach with an alkaline pH), or brown (indicating blood partially digested by hydrochloric acid).[16] In contrast, aspirates from a small bowel tube are generally more transparent and of a thicker consistency than are gastric aspirates. More importantly, small bowel aspirates often appear bile-stained, ranging in color from light to dark golden yellow or brownish-green. Several groups of investigators have found the use of aspirate appearance beneficial primarily because small bowel secretions often have distinctive bile staining.[7,16,28]

To determine how the appearance of aspirates from newly inserted feeding tubes could be used to distinguish between gastric and small bowel tube placement, investigators showed 30 staff nurses 100 photographs of aspirates from fasting acutely ill, adult patients.[16] The nurses were accurate in 81% of their predictions before reviewing a list of expected appearances of gastric and small bowel aspirates, and accurate in 90% of their predictions after viewing such a list.

In a pediatric study in which 68 gastrointestinal aspirates were obtained from unfed children in an attempt to differentiate between gastric and small bowel feeding tube placement, the presence of a clear yellow aspirate from 25 postpyloric tubes was found to have a positive predictive value of 89% and a negative predictive value of 98%; only 2 of the 43 gastric aspirates were yellow (and were presumably caused by reflux of fluid from the duodenum into the stomach during the tube insertion procedure).[7] Welch et al[28] reported that when a feeding tube moved from the stomach to the duodenum, a change in aspirate color to yellow had a positive predictive value of 100%; however, the negative predictive value was only 29%.

Measuring the pH of fluid withdrawn from the feeding tube. Gastric juice typically has a much lower pH than do small bowel secretions. For this reason, pH can be a useful adjunct in differentiating between gastric and small bowel placement in fasting patients. Ninety-four percent of 490 small bowel aspirates from acutely ill adults had pH values ≥ 7, whereas only 22% of 519 gastric aspirates had pH values this high. About two-thirds of the population described in Table 1 was receiving some type of gastric-acid–inhibiting agent. Although the use of gastric-acid–inhibiting agents increases gastric pH, the overall mean difference is not large; for example, 445 gastric specimens collected from patients who received either H_2-receptor antagonists or proton pump inhibitors had a mean pH of 4.34 ± 0.14; in contrast, the pH of 235 gastric specimens collected from patients not receiving these agents was 3.33 ± 0.01.[52]

The striking difference between gastric and intestinal pH is most helpful during the insertion procedure to determine when a feeding tube has passed from the stomach into the duodenum. In a pediatric population, Gharpure et al[7] found a mean pH of 4 in 43 prepyloric aspirates, as opposed to a mean pH of 7 in 25 postpyloric aspirates, $p < .001$. No difference was observed in the pH of prepyloric aspirates obtained from patients receiving or not receiving H_2 receptor blocking agents and proton pump inhibitors. Other investigators concur that serial changes in aspirate pH and color are useful bedside indicators of movement from a feeding tube from the stomach to the small bowel.[26]

A high pH should not be used as the sole indicator of gastric *vs* small bowel tube placement; however, it is an indication that it is time to obtain a radiograph to establish small bowel placement.

Use of a specialized tube with a built-in pH probe. The ability of feeding tubes with built-in pH probes to distinguish between gastric and small bowel placement has been demonstrated. For example, Heiselman et al[36] obtained insertion pH readings for 24 critically ill patients requiring feeding tubes and compared these results with x-rays taken concurrently; the x-ray and pH profiles were in agreement in 21 of 24 (87.5%) of the cases. As found in other studies, the accuracy of the pH sensor was not affected by the concurrent use of histamine blockers. The major advantage of this tube is that fluid aspiration is not required; the major disadvantage is that it costs considerably more than an ordinary tube and requires training of personnel in its use. The higher cost becomes more significant when tubes need frequent replacement (as when a confused patient pulls out the tube repeatedly). When a high pH reading is obtained, it is impossible to tell where the tube is located (stomach *vs* small bowel).

Auscultation for insufflated air via *the feeding tube.* Several groups of investigators have reported being able to detect sound differences as a feeding tube is advanced from the stomach to the small bowel.[53,54] However, this method's efficacy has not been established under controlled conditions. Welch et al[28] found that the ability of sound changes to detect tube location during 106 tube insertions was questionable.

Regardless of whether sound changes are observable during tube passage, there is no evidence to support the use of auscultation to distinguish between gastric and small bowel placement of stationary tubes. However, there are 2 studies that have suggested its ineffectiveness for this purpose.[30,55] For example, 115 recordings of sounds generated by air insufflation through feeding tubes of 85 acutely ill adult patients were played for skilled nurses; their opinions as to tube location (gastric *vs* small bowel) were compared with actual tube location as determined by radiography. Correct classification of position was quite low (34.4%).[55]

Negative pressure felt when attempting to aspirate fluid from the feeding tube. Inability to aspirate air insufflated into a feeding tube has been suggested as indicative of postpyloric tube placement. For example, in a pediatric study of 75 feeding tube insertions, investigators found that the inability to aspirate at least 2 mL of a 10-mL bolus of air was predictive of small bowel intubation with 99% certainty.[17] They concluded this method might obviate confirmatory abdominal x-rays in patients with intact airway protective reflexes. However, this method failed to detect 1 tube in the stomach; in addition, it would likely not detect a tube with its ports in the esophagus. In a study of 106 new tube insertions in adults, investigators insufflated a 60-mL bolus of air and attempted to aspirate air back into the syringe.[28] When tubes were positioned in the stomach, it was usually possible to withdraw at least 40 mL of air; in contrast, it was usually possible to aspirate <10 mL of air when tubes were positioned in the small bowel. This maneuver was found to have a positive predictive value of 86% and a negative predictive value of 45% in signaling advancement of a feeding tube from the stomach to the small bowel.[28]

Use of ultrasonography. Investigators attempted to determine the ability of ultrasonography to predict transpyloric placement of feeding tubes in 26 tube insertions in 14 pediatric patients.[56] In 17 of the 26 cases, there was full agreement between ultrasonography and radiographs; 10 of the tubes were placed past the pylorus and 7 were in the stomach. The investigators found it was easier to use ultrasonography in neonates than in older children. An obvious advantage of ultrasonographic determination of tube location is the lack of exposure to ionizing radiation (more of a problem for young children than for adults). The investigators concluded that ultrasound images more accurately distinguish the gastric antrum from the proximal duodenum than does radiography. Disadvantages are the need for special equipment, need for an experienced clinician to identify location of the tube, and <100% agreement with radiography. A case was reported in which sonography was able to detect a malpositioned feeding tube causing esophageal perforation in a neonate, as compared with radiography, which failed to detect the malpositioned tube.[57]

Determining Feeding Tube Placement After Feedings Have Been Started

After feedings have been started, it is necessary to assure that the tube has remained in the desired position (either the stomach or the small bowel). This is a difficult task without the benefit of radiography; nonetheless, it is important because feeding tubes may dislocate either upward or downward during prolonged use. For example, a feeding tube in the small bowel may dislocate upward into the stomach, and one that is meant to remain in the stomach may migrate downward into the small bowel. Worst of all, the tip of either a gastric or a small bowel tube may dislocate upward into the esophagus. Obviously, x-rays cannot be obtained several times a day to confirm that a tube has remained in the correct placement; therefore, clinical observations are important to detect tubes that have become dislocated. Some methods that have been suggested to help determine if a tube has remained in its correct position following the introduction of feedings include

- Determining if the external length of the tubing has changed since the time of the confirmatory radiograph
- Observing for changes in gastrointestinal residual volume
- Observing for negative pressure when attempting to withdraw fluid from the feeding tube
- Observing the appearance of aspirates from feeding tubes
- Measuring pH of feeding tube aspirates

Determining if the External Length of the Tubing Has Changed Since the Time of the Confirmatory Radiograph

Marking the tube as it exits from the nares or mouth can serve as an indication of whether or not the tube has been partially removed by force (as when pulled out by a confused or agitated patient or by movement in bed). However, it is of no help in determining when the distal tip has spontaneously shifted upward or downward because coiling of the tube within the gastrointestinal tract often permits distal tip movement without altering the visible length of tubing extending from the naris or mouth. Because there is no risk involved with marking the tube and observing for a length change, it is a reasonable action to help detect a change in tube position.

Observing for Changes in Gastrointestinal Residual Volume

Small bowel residual volumes are almost always <5 mL (as opposed to gastric residuals, which are usually higher). For example, in a study of 25 neurointensive care adult patients who were randomly assigned to gastric or duodenal feedings *via* 10 French tubes, the daily mean residual volumes in the duodenal group ranged from 0 to 5 mL, as opposed to 0 to 40 mL for the gastric group.[58] Although these differences were not statistically significant, they appear to be clinically significant; that is, the mean small bowel residual volume was <2.5 mL over the 10-day period, whereas the mean gastric residual volume over the same period was close to 15 mL.

Some authors recommend checking residual volumes from small bowel tubes primarily as a method to check tube placement.[52,59] For example, if a patient with a small bowel feeding tube develops a large residual volume, it may be an indication that the tube's ports have dislocated upward into the stomach.

Observing for Negative Pressure When Attempting to Withdraw Fluid From the Feeding Tube

As discussed earlier, several reports have suggested that observing for a negative pressure when attempting to withdraw fluid from a newly inserted gastrointestinal feeding tube is helpful;[17,28] however, no reports were found that recommended this method to determine placement during feedings. It would seem reasonable, however, that the same principle would apply during feedings. A precaution is that a similar negative pressure might be felt if the tube's ports were inadvertently positioned in the esophagus.

Observing the Appearance of Aspirates From Feeding Tubes

A study of 80 continuously tube-fed adults revealed that aspirates from nasogastric and nasointestinal tubes usually look like formula (although the formula is more apt to look curdled when mixed with gastric juice and bile stained when mixed with intestinal secretions).[60] In an attempt to detect postpyloric tube placement by examining aspirates from the feeding tubes of 28 fed pediatric patients, investigators found that the positive predictive value of a clear yellow color was 100%, whereas the negative predictive value was 86%.[7] In the same study, all 18 gastric aspirates from fed patients were colorless or white with a curdled appearance (presumably caused by the action of gastric acid and pepsin on milk proteins).[7] The authors pointed out that determination of color is subjective, and the accuracy of this test may depend on the experience of the clinician. Investigators have shown that the accuracy of color in predicting tube placement improves with training.[16]

Measuring pH of Feeding Tube Aspirates

Because most enteral formulas have a pH close to 6.6, it is reasonable to assume that the presence of enteral formula would raise the pH of gastric contents. For example, a study of 39 acutely ill neonates showed that fasting gastric pH was higher within 1 hour after feeding than when the infants had been fasting for 4 or more hours (4.66 *vs* 3.92, $p = .07$).[5]

Because an intermittent feeding is likely to have partially emptied from the stomach before the next scheduled feeding, it is reasonable to test gastric pH at this time. In contrast, testing an aspirate's pH is less helpful during continuous feedings. Despite this, it does no harm to measure pH of a feeding tube aspirate when routine residual volumes are measured. At times, useful information can be obtained. For example, in a study of 80 continuously tube-fed acutely ill adults, there was a statistically significant difference in the mean pH values of the 55 gastric and 25 small bowel aspirates (5.7 ± 0.1 and 6.6 ± 0.1, respectively, $p < .001$).[60] A feeding-tube aspirate with a pH ≤ 6 was a more likely indicator of gastric than of small bowel placement. Because a pH ≤ 5 is unlikely in a small-bowel aspirate, it should raise some concern that the tip of a nasointestinal tube has dislodged into the stomach.[52]

In a study of critically ill tube-fed children, the mean pH of 18 gastric aspirates was 5; in contrast, the mean pH of 10 small bowel aspirates was 6.6. A pH test strip value ≥6 had a positive predictive value of 80% and a negative predictive value of 89% for postpyloric tube position.[7]

Conclusion

In conclusion, the review of the literature has not found any sure nonradiographic method to differentiate respiratory, esophageal, gastric, and small-bowel placement of small-bore feeding tubes in the fed or unfed state. However, a combination of some of the simpler and more accurate methods may be useful to guide feeding tube placement during insertion and help identify the point at which an abdominal radiograph is most likely to confirm the desired location. Minimizing the number of radiographs taken before achieving placement is important, especially in young children and in the critical care setting where the need for radiographs for other reasons is common. In addition, the methods described above to monitor tube placement during feedings can help determine when a radiograph might be needed to confirm that a feeding tube has remained in the correct position.

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