American Gastroenterological Association Technical Review on Tube Feeding for Enteral Nutrition

This literature review and the recommendations therein were prepared for the American Gastroenterological Association Patient Care Committee. Following external review, the paper was approved by the Committee on September 17, 1994. It serves as the foundation for the Association's official recommendations as given in the previous statement.

No disease process improves significantly with prolonged starvation. Whereas short periods (<7 days) of nutrient deprivation may be well tolerated by most patients depending on their starting point and present degree of catabolism, longer periods can be detrimental. During starvation, fat is the major source of calories stored in the body and is mobilized to meet the body's needs. However, glycogen has a small storage form (~900 kcal) and protein has no storage form so that during starvation, slow turnover proteins such as muscle must be cannibalized for energy and visceral protein support, which ultimately leads to organ function compromise.

Whereas tube feeding has been practiced in varying forms for more than 400 years, technical innovations during the past 2 decades have made the procedure more acceptable to patients and a less costly alternative to parenteral nutrition. Recent data on the occurrence of bacterial translocation from an enterally deprived gastrointestinal tract have focused renewed attention to use the gastrointestinal tract as soon as is safely possible. Gastroenterologists with varying amounts of training in nutrition support are asked to manage patients receiving enteral nutrition, including requests to place tubes endoscopically to feed patients. It is important to have a working knowledge of this area to be able to provide safe, efficacious, and cost-effective support to these patients.

Strictly speaking, enteral feeding refers to any form of nutrition delivered to the gastrointestinal tract. This review will focus on the role of tube feeding to the upper gastrointestinal tract. It will encompass the indications, contraindications, complications, potential sites for nutrient delivery, and different techniques of tube placement. Whereas some of the information may be appropriate for pediatric patients, this review focuses on the adult population.

How This Review Was Prepared

A review of the literature using MEDLINE was undertaken for each major topic. Relevant articles and textbooks were reviewed and assessed for quality, strengths, weaknesses, and clinical impact in a given area. Published abstracts were not considered. Every effort has been made to present data in a balanced fashion that underscores current practice or areas in need of further investigation. The review has been structured into sections based on common clinical questions that arise daily. Conclusions and clinical practice recommendations will follow each section. This review also will not provide illustrations of techniques discussed because several excellent textbooks and reports show these in more detail than space allows here.

When Should Tube Feedings Be Administered?

Tube feeding should be considered when the patient cannot or will not eat, the patient has a functional gut, and a method of access can be safely obtained. Mechanical obstruction is the only absolute contraindication to enteral feeding. Severe diarrhea, protracted vomiting, enteric fistulae, and intestinal dysmotility may provide special challenges to tube feeding but are not necessarily contraindications. However, it must be determined clinically what is safest and most efficacious for an individual patient.

While it is possible to maintain a person entirely on total parenteral nutrition, it is expensive and fraught with potential complications. It is now considered important to provide fuel to the intestine not only for growth and maintenance of the body but also to keep the local defense barrier of the intestine intact. Without intraluminal fuels, even while receiving total parenteral nutrition, intestinal integrity may deteriorate and, under stress, allow gut bacteria to colonize and systemically invade the body.

In rats, intravenous feedings or starvation leads to a decrease in mucosal protein, cellular proliferation, loss of villus height, and disruption of the tight junctions between intestinal cells with an increase in permeability. These changes result in the loss of the intestinal barrier function and may be manifested as bacterial trans-
location. Protein-malnourished animals can become more susceptible to lethal gut origin sepsis than normally nourished animals. Haskel et al. found bombesin effective in preventing bacterial translocation in both parenterally fed and elemental diet–fed rats. In the same study, bulk-forming dietary fiber seemed protective in the elemental rat model. In starvation, the barrier function of the intestine is maintained unless the host is stressed with an inflammatory stimulus. The applicability of these animal models to starvation, stress, and bacterial translocation in humans deserves further research.

In humans, several prospective randomized studies show that it is possible and beneficial to feed critically ill patients enterally. These studies, and a recent meta-analysis of studies comparing early enteral feeding with parenteral feeding in high-risk surgical patients, show reduced septic morbidity rates when enteral feeding is initiated early. In these surgical studies, a jejunostomy tube is placed at the time of initial operation. This approach is cost-effective and associated with lower morbidity. It is also possible to feed patients with head injury early after injury with endoscopically guided access. The dogma that patients symptomatic with inflammatory bowel disease must be on strict bowel rest seems to be incorrect and has not withstood closer scientific scrutiny.

A review of immunonutrition and enteral alimentation of the critically ill patient also concluded that the enteral route should be primary for nutrition support and that parenteral nutrition should be reserved for patients for whom enteral nutrition is contraindicated or is unable to supply their full nutritional needs.

Conclusions

A reasonable time frame for initiation of nutrition support is 1–2 weeks without nutrient intake and probably sooner in patients with increased degrees of undernutrition. Early enteral feeding is preferable to parenteral therapy when there are no contraindications. If oral intake is not possible, then tube feeding should be initiated, provided access can be safely obtained. Combinations of enteral and parenteral nutrition may be necessary to meet nutritional needs in some patients.

When Should Nasogastric or Nasoenteric Feeding Be Administered, What Are the Methods of Delivery, and What Are the Special Advantages, Disadvantages, and Problems With Each?

Nasoenteric tubes (NETs) technically refer to any feeding tube that is placed nasally into the esophagus and beyond. They should be referenced by the distal most location of the tube. Figure 1 shows the methods of access in current practice. In general, these tubes are used for short-term feeding in hospitalized patients but are occasionally used for prolonged periods in the outpatient setting.

Nasogastric tubes (NGTs) have many functions other than feeding. Small-caliber NGTs are used solely for feeding, whereas larger ones can be used to decompress the stomach, monitor gastric pH, and provide medications or feedings. The larger bore tubes can result in patient discomfort and frequent self-extubation. These tubes are suitable for short-term use; however, alternative methods should be considered for patients who need tube feedings for longer periods. Nasally placed tubes can cause local irritation, epistaxis, sinusitis, and other less common problems listed in Table 1.

Nasoduodenal and nasojejunal tubes have been widely marketed as better for long-term feeding compared with NGTs. Generally smaller in size compared with NGTs, they cause less discomfort, but clogging of the tubes with nutrients or medications is more prevalent. These tubes can be placed at the bedside by physicians or nurses or under fluoroscopic or endoscopic guidance; motility may be required to help pass the tube into the small
intestine. One series reported that only 12% were still in use at 6 weeks; 20% of the tubes never reached the distal duodenum.\textsuperscript{21}

Placing an NET is particularly hazardous in patients with altered consciousness. Cuffed endotracheal tubes are not protective against pulmonary intubation. Thus, in patients who cannot cooperate when placing the tube or do not cough if the tube is misdirected into the pulmonary tree, extra precautions should be taken.\textsuperscript{23} With one technique, the NET is initially passed to 25 cm, the level of the carina. The tube is checked for sounds of air exchange and/or placed under water to observe for air bubbles. If neither sign is present, the tube is advanced.\textsuperscript{22} Feeding should not begin until proper placement of the tube is verified. A recent innovation is a feeding tube that is attached to a specially adapted stethoscope. If the tube is inadvertently passed into the trachea, a "deafening" noise is heard through the stethoscope, and the tube can be pulled back and passage reattempted (T.O. Lipman, personal communication, August 1993).

Many bedside techniques for passage of weighted tubes beyond the pylorus in patients in the intensive care unit are available and usually successful. Ugo et al. use the right lateral decubitus position with auscultation to track the tube into the small intestine.\textsuperscript{25} They report no placements into the pulmonary tree, and 85 of 103 tubes (83\%) were placed into the duodenum or beyond. However, only 44 of 103 of the tubes (43\%) were in the preferred positions of the third portion of the duodenum or beyond. Pharmacological aids to facilitate passage were not evaluated in this report. Heiselman et al. described an enteral feeding tube with a pH sensor that allowed immediate verification of the tube’s location by measurement of the pH on insertion. The radiograph and insertion pH profile were in agreement in 87\% of the cases.\textsuperscript{24}

Pharmacological assistance to help position tubes beyond the pylorus has been described most commonly using metoclopramide, a dopamine agonist. Whately et al. found that metoclopramide treatment before tube placement was superior to no drug in a small study using 8F tubes.\textsuperscript{26} Kalafarentzos et al. divided patients into three groups: placebo, metoclopramide treatment after tube placement, and metoclopramide treatment before tube placement.\textsuperscript{25} Using 8F tubes, metoclopramide administered before tube passage resulted in a 90\% success rate. Using 10F tubes, Kittinger et al. found metoclopramide treatment ineffective when infused after tube placement except in a small number of diabetic patients.\textsuperscript{26} Seifert et al. reported no significant benefit of metoclopramide treatment when infused 15 minutes before insertion of 12F tubes.\textsuperscript{27} In a recent study comparing weighted vs. unweighted 8F tubes, metoclopramide was given as an intravenous bolus 10 minutes before tube placement.\textsuperscript{28} Radiographs were obtained at 4 hours, 1 day, and 2 days if spontaneous passage had not occurred. The combination of preinsertion metoclopramide treatment and unweighted tubes was significantly better at all examination intervals. At 4 hours, 84\% of unweighted tubes passed into the duodenum compared with 36\% of the weighted tubes; at 1 day, 86\% vs. 48\%; and at 2 days, 92\% vs. 56\%, respectively. A poststudy trial showed no difference in tube passage rate between 10 mg and 20 mg of metoclopramide.

Erythromycin, a motilin agonist, is also a helpful prokinetic drug that facilitates tube positioning. In 1 study of antroduodenal manometry, either metoclopramide or erythromycin was used if the tube could not be guided fluoroscopically into the duodenum.\textsuperscript{29} Only 2 of 5 tubes passed with metoclopramide. Of the 3 metoclopramide failures and 5 other patients in whom erythromycin was infused intravenously (3 mg/kg during a period of 1 hour before tube placement), all 8 tubes passed into the duodenum.

At this time, no studies have tested the efficacy of cisapride, another promotility agent recently approved for use in reflux esophagitis by the Food and Drug Administration.

Radiological techniques have also been useful in placing NETs. In a retrospective study of 448 patients referred for 882 fluoroscopically guided tube placements during a period of more than 1 year, the tube was placed distal to the third portion of the duodenum in 86.6\%.\textsuperscript{30} These procedures were performed either in the department of radiology or at the bedside in the intensive care

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<th>Table 1. Potential Nasoenteric Tube Complications</th>
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<td>Arrhythmia</td>
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<td>Empyema</td>
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<td>Gastric perforation</td>
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<td>Myocardial infarction</td>
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<td>Rupture and leakage of mercury weight</td>
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<td>Epistaxis</td>
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<td>Gastrointestinal bleeding</td>
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<td>Nasal mucosal ulceration</td>
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<td>Pneumothorax</td>
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<td>Pyriform sinus perforation</td>
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<td>Tracheobronchial trauma</td>
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<td>Tube dislodgment</td>
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<td>Duodenal perforation</td>
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<td>Esophageal perforation</td>
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<td>Knotted tubes</td>
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<td>Nasal trauma</td>
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<td>Pulmonary aspiration</td>
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<td>Reflux esophagitis/ulceration/stricture</td>
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<tr>
<td>Tracheoesophageal fistula</td>
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<td>Tube obstruction</td>
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\textsuperscript{1284} AMERICAN GASTROENTEROLOGICAL ASSOCIATION GASTROENTEROLOGY Vol. 108, No. 4
unit with a portable C-arm fluoroscopy machine. Three patients with known cardiomyopathy died of arrhythmias, and 1 patient had a tube malpositioned in the tracheobronchial tree for a major complication rate of 0.4%.

Many devices are marketed for endoscopic placement of nasoduodenal and nasojejunal tubes. In addition, endoscopists' personal preferences and innovations are published as brief reports. In a study comparing NET placement with 3 tubes of different length (105-, 125-, and 145-cm polyurethane tubes), Mathus-Vliegen et al. showed that it is possible to place these tubes endoscopically in an average of 13 minutes. The majority of tubes passed distal to the duodenojejunal junction, but the smaller (standard length, 105 cm) tubes had minimal tube length available for fixation at the nose. It seems that all tubes passed at least into the duodenum. In general practice, an expectation of 85%–90% for successful endoscopic NET placement is reasonable. Endoscopic and fluoroscopic techniques may also be additive and not mutually exclusive.

Special problems related to tube feeding include gastroesophageal reflux and aspiration, which will be discussed in a later section. Tube clogging, dislodgment, and feeding intolerance are also important problems. The incidence of tube clogging from medications or nutrient solutions varies in the literature from 2% to 9%. New declogging catheters are generally successful in alleviating these obstructions, but occasionally a new tube must be placed. Tube dislodgment by either patients or staff can be a considerable problem and account for up to 60% of tube removals. The mean tube life span seems to be 10 days, which underscores the use of these tubes as short-term devices.

The assessment of feeding tolerance is important in the use of enteral nutrition, especially at the onset of enteral feedings. Stool frequency and consistency, abdominal distention, urinary output, vomiting, gastric residuals, and the presence of symptoms of pulmonary problems, including aspiration, are important parameters to follow. In addition, patients receiving enteral nutrition are at risk of not meeting nutritional goals because of cessation of feedings from presumed intolerance based on residual volumes (RVs) alone. Many reports recommend withholding feedings for at least 2 hours when obtaining a high RV or holding tube feedings until the RV decreases below a certain level. A recent study challenged this concept and concluded that the presence of a single high RV should not cause automatic cessation of tube feedings; often the next measured RV is normal. An RV of >200 mL obtained from nasogastric suctioning or >100 mL obtained through a gastrostomy tube should prompt concern about intolerance, but enteral feedings may be continued if repeated examinations and RVs are closely monitored. The higher the infusion rate is, the higher the expected RV. Positioning of the patient (supine vs. right lateral decubitus) had no impact on RV. Tubes <10F have been shown to be unreliable for the determination of RV. A 50–60-mL syringe allows accurate determination of RV, allows return of gastric contents after measurement, and does not cause collapse of the enteral feeding tube.

Enteral feedings may be delivered by bolus, gravity, or pump-controlled techniques. Each modality has its own specific use and complications. Bolus feeding is the rapid administration of formula, usually by syringe, for a period of 5–10 minutes every few hours. To meet a patient's caloric needs, 300–400 mL may be necessary at one sitting. It is a reliable method of delivery for which a family member or the patient may be easily instructed for home usage. This method frees the patient from any mechanical device and is especially beneficial for the alert, active patient. It allows for accurate delivery of feedings over a specified amount of time; however, bolus feedings are more likely to generate high RVs.

Gravity feedings can be delivered via intermittent or continuous drip. The patient is dependent only on a bedside pole. The rate of delivery is not precise and can predispose the patient to gastroesophageal reflux and aspiration. Intermittent gravity feedings are generally the preferred modality for intragastric feedings. New closed enteral feeding systems allow the delivery of a specified amount of tube feeding measured out in a "drip" chamber, thus allowing the remainder of the feeding to be used later in the day. Alternatively, cans of tube feeding can be poured into a delivery system that is flushed and cleaned after each delivery.

Pump feedings require a mechanical device and a source of power. Feedings can be delivered via an intermittent or continuous schedule. Because the delivery is accurately controlled, high RVs and the risk of gastric aspiration should be decreased. A recent report noted that continuous intragastric feedings were safer with fewer episodes of diarrhea and aspiration compared with intermittent feedings. Continuous pump feedings are the preferred route for intrajejunal feedings. The jejunum secretes fluid in response to hyperosmolar solutions, and too rapid delivery of a hyperosmolar formulation results in abdominal distention, cramps, hyperperistalsis, and diarrhea.

Data favoring continuous over intermittent feedings are described in the critically ill. Continuous feedings in infants with diarrhea are associated with fewer fecal losses and more positive nitrogen balance and weight gain com-
pared with intermittent feedings. Energy expenditure, specifically diet-induced thermogenesis, is less with continuous feedings. Although continuous nasogastric nutrition seems to be effective prophylaxis of stress ulceration, the mechanism remains unknown.

Starting a patient on a specific enteral feeding regimen after tube placement generally follows an established protocol at each institution. These protocols vary with respect to initial flow rates and advancement, enteral formula dilution, and the use of either intermittent or continuous feedings. After percutaneous puncture of the stomach or surgical manipulation of the stomach or small intestine for tube placement, gastroparesis or ileus may occur. After bowel sounds are verified, some protocols call for feeding with water to ensure tolerance. Studies in healthy volunteers show tolerance of both elemental and complex tube feedings at starter flow rates up to 150 mL/h and starter osmolalities of up to 690 mOsm/kg. However, it would be inappropriate to extrapolate this information to an ill patient who may have both absorptive and motility disorders of the gastrointestinal tract. In most circumstances, isotonic, polymeric tube feedings are preferred.

Converting a patient from continuous to intermittent feedings has no defined regimen. Currently, many centers switch from a continuous to an intermittent method abruptly with volumes slowly increased as the patient shows tolerance. This may result in missed or reduced feeding periods and, therefore, hypocaloric feeding. An overlapping method of transition involves maintaining continuous feedings at lower rates as intermittent feedings are introduced. This results in improved nitrogen balance, early attainment of nutritional goals, and fewer diarrheal episodes, aspiration events, and hospital days than the intermittent method.

In addition to caloric intake, free water requirements must be considered. The average adult (age range, 20–75 years) with good renal function will maintain adequate hydration with 30–35 mL free water/kg of ideal body weight per day. Other factors such as cardiac, respiratory, and renal status; fever; and extragastrointestinal losses must be considered. To calculate the additional free water required, the sodium-free water content of the tube feeding must be known. This varies from product to product and ranges from 600 to 923 mL free water/1000-mL tube feeding. The total free water provided from the tube feeding is subtracted from the total free water that the patient requires. If the patient has no other source of hydration (i.e., intravenous fluids or medications), then the additional free water can be supplied as “flushes” through the feeding tube that also serve to facilitate tube patency.

Lastly is the issue of what to do with patients who must have their tube feeding interrupted for tests or other therapies. The provision of intermittent feedings at night rather than during the day has been particularly useful for patients on our rehabilitation service. This allows for more of the total nutritional prescription to be delivered. However, this also requires more nursing care during these late hours and vigilance for feeding-related problems such as aspiration. In those patients who are receiving continuous infusions, upward adjustments in the delivery rate over a period of hours may make up the expected deficit, but gastrointestinal intolerance may be a problem.

Conclusions

1. For the short-term (<30 days), NGTs or NETs are recommended instead of gastrostomy or jejunostomy tubes.
2. Tubes placed past the third portion of the duodenum, and especially past the ligament of Treitz, are associated with a decreased risk of aspiration.
3. The method of tube placement depends on local expertise. Simple bedside maneuvers are preferred. Endoscopically or fluoroscopically guided tube placement should be reserved for those patients for whom bedside techniques have not been successful.
4. Prokinetic drugs such as metoclopramide, cisapride, and erythromycin given before placement may be beneficial in positioning smaller nasoenteric tubes (8F or 10F) beyond the pylorus.
5. Intermittent gravity feeding is sufficient for most patients with NGT or gastrostomy tubes. Pump-controlled infusions are recommended for jejunal feedings.
6. For NGT feeding, a single elevated RV should alert attention to recheck the RV in 1 hour but should not cause automatic cessation of feeding.
7. In most circumstances, isotonic polymeric tube feedings are preferred.

When Should a Percutaneous-Guided Gastrostomy Be Used?

When it seems that a patient requires prolonged tube feeding (>30 days), a tube gastrostomy or enterostomy should be considered. Whereas gastrostomy and jejunostomy tubes have traditionally been in the purview of surgeons, other techniques have been refined during the past decade to allow these common procedures to be performed by gastroenterologists or radiologists. Available techniques include the following: (1) percutaneous gastrostomy (endoscopic [PEG] or radiological), (2) per-
scopic or radiological), (4) surgical gastrostomy, and (5) percutaneous gastrojejunostomy (PEG/J endoscopic or radiological), (3) percutaneous gastrojejunostomy (PEG/J endoscopic or radiological), (4) surgical gastrostomy, and (5) surgical gastrostomy. Each technique has its own risks and benefits and sometimes unique complications.

In 1980, Gauderer et al. reported endoscopically and percutaneously placing a 14F Pezzer catheter as a gastrostomy tube. Since introduction of this technique, many commercial kits and variations of the technique have been used. These include the pull, push, introducer (Russell), Versa, and primary button methods. The pull technique was originally described by Gauderer et al. The push technique is performed by pushing a tube assembly over a guidewire until the catheter emerges from the anterior abdominal wall and is pulled until the assembly is in the proper position. The introducer method, as described by Russell et al., is a variation of the Seldinger technique and places a J-wire into the stomach under endoscopic guidance. A dilating catheter is passed, and then a feeding tube is placed through a peel-away sheath. Whereas the push and pull techniques are generally more popular, two controlled trials comparing push and pull and push and introducer methods found little difference in success or complications of placement. The Versa PEG (Ross Products Division, Abbott Laboratories, Columbus, OH) is a combination of the push and introducer techniques. It requires the placement of stabilizing sutures (Brown/Mueller T-Fasteners; Ross Products Division, Abbott Laboratories) to affix the gastric wall to the peritoneum. While technically more demanding, it may be beneficial for selected patients with esophageal disease to not pull a bumper through the esophagus or to perform endoscopic removal of a bumper by endoscopy at a later time.

Skin level gastrostomy tubes (e.g., button-type) have generally been used as PEG replacement devices placed into a mature tract. Their use as a potential office procedure has been reported. A recent "one-step button" technique has been released and provides another option for initial placement, but no comparison studies to other insertion techniques are available.

Davis et al. retrospectively studied whether surgeons who perform endoscopy or gastroenterologists obtain the same results when endoscopically placing gastrostomies. While there were minor differences in major and minor complications, they were not statistically significant. The gastroenterology group had a slightly higher minor complication rate.

In the largest single center study, PEG placement was successful in 95% of 314 consecutive patients. There was a 1% procedure-related mortality and 3% and 13% major and minor complication rates, respectively. This compares favorably with reports of 16% and 13.5% complications with operative gastrostomy (OG) from two commonly quoted series. Taylor et al. performed a population-based cohort study in 97 patients referred for PEG. Complications occurred in 70% of patients, but 88% of these were minor problems (e.g., tube dislodgment, wound infection, and stomal leak) that occurred mostly in the first 3 months. They found an increased mortality in older patients, males, and diabetics. The probability of surviving 30 days, 1.5 years, and 4 years was 78%, 35%, and 27%, respectively. This study is unique in that it questions whether PEGs are indicated when a patient is unlikely to survive more than 30 days after the PEG placement. Although a reasonable suggestion, it is often not possible to predict a patient's clinical course so accurately. There are also instances in which alert patients request another option to an NET even though they know their death is imminent. One example is placement of a PEG to be used for gastric drainage in a patient with untreatable bowel obstruction from cancer. In addition, ethical dilemmas over placing gastrostomy tubes in patients in persistent vegetative states abound. In this circumstance, the opinions of the hospital ethics committee and the patient's family and any known information about advance directives should be considered before tube placement. Usually the debate over tube feeding occurs after the tube placement and after feedings have been provided for a period of time, and the family or physicians believe that further care is futile and feeding should be discontinued. Legally, there is no difference between withdrawing and withholding tube feeding; however, discontinuing tube feeding is a more emotional issue because it is known that the patient's death may be accelerated.

In an interesting 28-day prospective comparison of the effectiveness of PEG vs. NGT feeding in patients with neurological dysphagia, PEG was found to be superior to NGT feeding. Most treatment failures in the NGT feeding group were related to tube dislodgment. The NGT group received 55% of their prescribed feedings compared with 93% in the PEG group. Minor aspiration occurred in 2 patients with PEGs and in none of the patients with NGTs. They concluded that PEGs were safe, effective, and acceptable for long-term enteral nutrition compared with NGT feeding. However, they also concluded that if a patient tolerated NGT feeding, it was not necessary to perform a PEG simply for access.

Recommendations vary as to when to start tube feeding after PEG placement. Some patients are fed after 24 hours, but in uncomplicated placements, continuous water infusion can be started at 50 mL/h after 2 hours.
if bowel sounds are present. If water infusion is tolerated for 4 hours, a full-strength polymeric formula is begun at 50 mL/h and advanced 25 mL every 12 hours as tolerated. A transition is made to intermittent feeding after tolerance is shown at the maintenance rate. Recommendations for PEG care have been previously reported.63

Complications of PEG placement are generally minor and easily handled. After introduction of the PEG, wound infections are common but easily treated with antibiotics. A prospective, randomized, double-blind study showed a significant reduction (25%) in wound infections if patients received a single preprocedure, prophylactic dose of 1 g of cefazolin or were already receiving antibiotics.64

Two potentially serious complications of PEG placement deserve mention: necrotizing fasciitis and colocutaneous fistulas. Necrotizing fasciitis has been reported in only a few patients.65–68 It is characterized by significant necrosis of the superficial fascia layers. If not diagnosed and treated aggressively via surgical debridement, associated mortality is high. The condition usually becomes evident 3–14 days after the procedure with high fever, skin edema, and cellulitis and eventually crepitance. The reported patients have been in poor nutritional condition with other diseases such as diabetes mellitus, cardiac disease, and obesity. Lack of prophylactic antibiotics, a small abdominal incision, excessive traction on the PEG, and obesity are possible contributing etiologies.68,69 Colocutaneous fistulas are rare complications of PEG placements.70–74 They are usually not detected until months after the initial placement, often when the first tube is replaced. Then feeding suddenly causes severe diarrhea that resembles tube feeding; further investigation leads to the discovery of the fistula. Removal of the catheter and careful observation may be all that is required.

Pneumoperitoneum is a common finding post-PEG placement.75–77 In the absence of peritoneal signs, it should not cause concern and does not preclude initiation or continuation of feeding. If there is any question about the position of the tube or presence of a fistula, then it is appropriate to obtain a radiological contrast study to confirm its location.

"Buried bumper syndrome" is another complication of PEGs.78 While reported most often with Sacks-Vine gastrostomy kits (Ross Laboratories), which have since been removed from the market, this complication can occur with many other PEG tubes that have rigid internal bumpers. This can result when too much pressure is maintained between the inner and outer bumpers and allows for pressure necrosis and ulceration to cause the tube to migrate slowly from the stomach out towards the anterior wall. Careful catheter care with attention to bumper tension limits this complication.

Removal of PEG tubes either intentionally or inadvertently can occasionally lead to problems. The removal of a PEG tube is usually followed by prompt closure of the gastrocutaneous fistula. However, Bender and Levison reported 2 patients with persistent fistulae, one of whom required surgical closure; the other developed pneumoperitoneum and peritonitis after an attack of vomiting.79 On laparotomy, the latter patient had a separation of the stomach from the anterior abdominal wall, and the gastric fistula had not closed. These cases underscore the need for patient education and follow-up even after PEG removal. Unintentional removal of a PEG within the first week can be managed by replacing the PEG endoscopically.80 This has avoided complications of peritonitis and the need for possible laparotomy.

Several methods are used to remove PEG tubes, depending on the configuration of the inner bumper. Some tubes are designed to be pulled through the stoma, whereas stiff or rigid bumpers are best managed by endoscopic removal. Korula and Harma advocate simply cutting the tube externally at skin level and allowing the tube to pass in the stool.81 In contrast, we have experienced some patients who have required operative intervention for obstruction with significantly more morbidity inflicted than endoscopic removal would have caused (D. F. Kirby, unpublished observations, December 1992).

Conclusions

1. Gastrostomy tubes are justified for patients who need tube feeding for more than 30 days. The patient’s underlying disease and local expertise must be considered when deciding between types of placement (operative or percutaneous endoscopic or radiological gastrostomy).

2. Knowledge of several placement methods and familiarity with a variety of tubes optimizes placement in patients with esophageal disease that may complicate standard insertion techniques.

3. Attention to detail before, during, and after placement can help limit complications.

How Does Surgical or Radiological Gastrostomy Tube Placement Compare With Percutaneous Endoscopically Guided Gastrostomy Tube Placement?

The major perceived advantage of endoscopic gastrostomy compared with other placement techniques is
convenience. Whereas most physicians who perform the
endoscopic version believe that their technique is supe-
rior to surgical placement, all data do not support this
impression. In a prospective, randomized trial of endo-
scopic vs. OG, no significant difference was found be-
tween OG (using local anesthesia) and PEG with regard
to tube function, morbidity, or mortality.\textsuperscript{82} In this study,
the cost of a PEG was $700 less than OG; however, this
cost advantage narrowed to approximately $100 if the
tube required repeat endoscopy for a tube change and a
second PEG insertion. In a retrospective review, 100
patients 70 years of age or older were separated into
two unmatched groups of OG placement and endoscopic
placement.\textsuperscript{83} PEGs had a lower mortality (0 vs. 4\%) and
morbidity (10\% vs. 22\%) rate compared with OG.

Grant reviewed 125 PEGs and 88 Stamm gastrosto-
mies retrospectively and found that PEG reduced opera-
tive time, expense, incidence of complications, and use of
general anesthesia and required less recovery time before
use.\textsuperscript{84} He concluded that PEG is the procedure of choice
for gastric feeding access.

Despite the available data on comparability of endo-
scopic and surgical gastrostomy placement, some differ-
ces should be considered. Unlike the previously men-
tioned trial, most OGs are performed under general
anesthesia in an operating room. A second incision re-
quires healing and may develop infections or other comp-
lications compared with a PEG. Feedings are usually
withheld until there are bowel sounds, and the gastroin-
testinal tract function is confirmed by passage of flatus
or stool. Local expertise will be an important criterion
for preferred techniques in a given community.

The procedure for placement of surgical gastrostomy
has undergone several modifications since the first
planned gastrostomy was placed by Sedillor in 1837. The
Stamm gastrostomy is considered the standard today.\textsuperscript{85,86}
The procedure can be part of a major abdominal proce-
dure or performed for feeding access alone; it may be
performed under general or local anesthesia. More re-
cently, laparoscopic gastrostomies have been performed
in a few patients, although a comparison with OG and
PEG is needed.\textsuperscript{87–89} Because most laparoscopic proce-
dures are performed in an operating room, the cost will
likely be higher than a PEG.

Multiple references appear in the literature about non-
endoscopic or radiological methods of tube placement,
but these methods have not been adequately and prospec-
tively compared with either operative or endoscopic
placement.\textsuperscript{90–94} For the present time, local expertise and
availability continue to be deciding factors in choosing
the method of gastrostomy placement.

Another surgical option is cervical pharyngotomy,
which was described more than 40 years ago as an opera-
tive procedure that could provide enteral access to pa-
tients with oropharyngeal cancers.\textsuperscript{95} In 1985, a percuta-
neous approach was reported\textsuperscript{96} that has some use in
patients with dysphagia or cancer who have altered swal-
lowing mechanisms. The small-caliber feeding tube (7F)
is a limiting factor in nutrient product selection and
medication delivery. One unique complication is feeding
into the hypopharynx if the tube migrates from the stom-
ach to the back of the throat. Careful securing and moni-
toring of the catheter limits this problem.

Conclusions

For gastric access using conscious sedation, PEG
is usually preferred. OG is comparable but is more expen-
sive and requires more recovery time. Radiological gas-
astrostomy placement should be considered when PEG
placement is undesirable, such as when esophageal ob-
struction is present.

When Should Jejunostomy Tubes Be
Used?

Regardless of the method of placement, the main
indications for use of a jejunostomy include tracheal aspi-
ration, reflux esophagitis, gastroparesis, insufficient
stomach from previous resection, postoperative feeding
during major operative procedures, and, occasionally, ac-
cess in a patient with unresectable gastric or pancreatic
cancer. The proposed advantage of this type of tube is
decreased risk of aspiration. Percutaneous endoscopic je-
junostomy and gastrojejunostomy were originally de-
scribed by Ponsky and Aszodi.\textsuperscript{97} The terms are often
misleading because the smaller “jejunal” tube is usually
placed into the proximal duodenum. The early versions
were small tubes that clogged easily or recoiled into the
stomach. In a retrospective comparison of 100 surgical
gastrostomies (OGs) and 133 radiological jejunostomies,
introduced through the stomach into the distal duode-
um, Ho et al. report significantly fewer complications
in the radiological group.\textsuperscript{98} There was an 8\% aspiration
rate with the OG vs. 0 with the radiological approach.

Endoscopic studies using PEJs have not fared as well
because they have introduced tubes into the proximal
duodenum rather than the distal duodenum or jeju-
num.\textsuperscript{99,100} It is important to evaluate these procedures
for their ability to get the tube in the proper position
for a more accurate evaluation of the technology.\textsuperscript{101} In
two different trials using an over-the-wire technique to
place a PEG/J (combined gastric access and jejunal feed-
ing), it was possible endoscopically to place the feeding
tube deeply into the distal duodenum or jejunum.\textsuperscript{102,102a}
These trials are preliminary but show that aspiration
associated with tube feedings is virtually eliminated when tubes are in desirable positions. These studies were performed mostly in patients with head injuries in which a defect in gastric emptying during the first several weeks can be found. After that time, the tubes can often be converted to gastrostomy tubes.

Placement of a true PEJ has been described in 10 patients with a history of partial gastrectomy. Another report describes an endoscopically guided jejunostomy in which a colonoscope was passed into the jejunum and guided selection of a jejunostomy site in the left hypochondrium. A recent radiological method has yielded a direct percutaneous jejunostomy tube.

At this time, data suggest that adequate placement of the tube in the distal duodenum or beyond can markedly decrease the risk of aspiration. However, a major obstacle will continue to be easy and reliable placement and maintenance of a functioning tube.

The first surgical jejunostomy was performed by Seward in 1878. Procedures currently performed include the following: Witzel jejunostomy, needle catheter jejunostomy, serosal tunnel jejunostomy, Roux-En-Y jejunostomy, button jejunostomy, and percutaneous peritoneoscopic jejunostomy. The multiplicity of procedures bespeaks the need for an optimal procedure, and further refinements of this technique are likely. However, it is very convenient to place a jejunostomy feeding tube during an operative procedure so that enteral nutrition can be started soon after surgery. This is a safe and efficacious procedure and may help to limit the progression to bacterial translocation in a highly vulnerable population.

One of the major drawbacks of jejunostomy feeding is the lack of data regarding jejunostomy feeding as a long-term feeding option. It has also been assumed that elemental diets are mandatory through a jejunostomy tube. In the smaller size tubes, less viscous elemental diets may be preferable, but in the larger jejunostomy tubes (≥7F), standard isotonic polymeric formulas are surprisingly well tolerated. Complications of jejunostomy feeding include obstruction of the tube, wound drainage and infection, peritoneal leakage, unintentional removal, diarrhea, and volvulus.

**Conclusions**

1. In patients who are known to have a previous history of tube feeding–related aspiration pneumonia or reflux esophagitis, jejunal access is appropriate.
2. A standard isotonic polymeric tube feeding formula is appropriate for most situations, including jejunal feeding.
3. Whereas intermittent gravity feeding is sufficient for most patients with NGTs or gastrostomy tubes, pump-controlled infusions are recommended for jejunal feedings or gastrostomy feedings performed by continuous infusion.

**What Are the Major Problems Associated With Tube Feeding?**

**Aspiration**

Aspiration is one of the most important and controversial complications associated with tube feeding. The prevalence of aspiration pneumonia varies in the literature from 2% to 95%, and the criteria for aspiration in many reports are poorly defined. Issues that need to be considered include the following: (1) differentiation of aspiration from oropharyngeal or gastric contents, (2) the effect of tube size and presence across upper and lower esophageal sphincters, (3) the effect of body position on gastric reflux and aspiration, (4) the effect of underlying disease (e.g., poor gastric emptying with head trauma or diabetes mellitus), (5) establishment of gut access for short-term and long-term use, (6) intermittent vs. continuous feeding regimens, and (7) the possible advantage of jejunostomy feeding over nasogastric or gastrostomy feeding.

**Oropharyngeal versus gastric aspiration.** Lazarus et al. analyzed the literature regarding aspiration from 1978 to 1989 when either long-term gastric or jejunal feedings were used in patients with severe neurogenic oropharyngeal dysphagia. They were unable to state clearly that one method of feeding was superior to the other, perhaps because of marked differences in patient populations, poorly designed data collection methods, small sample sizes, and inadequate definitions for aspiration. In patients with severe transfer dysphagia who are aspirating their oral secretions, it is hard to know which feeding method is best because the main source of pulmonary aspiration is not being addressed. A case report using a radionuclide as a salivagram was effective in documenting oral aspiration in an infant with recurrent pneumonia being fed by a PEG. Huxley et al. studied pharyngeal aspiration in humans by placing Indium chloride into the pharynx in 20 normals and 10 patients with depressed consciousness. Forty-five percent of normals and 70% of patients aspirated pharyngeal secretions.

The reported prevalence and mortality associated with aspiration varies. Cameron et al. reviewed 47 patients with documented aspiration and found a 62% mortality rate. In contrast, a recent prospective evaluation of the risk of aspiration in 276 patients reported a prevalence of 4.4% with an overall mortality of 17%. Advanced
age and location in the hospital (intensive care unit vs. ward) were major risk factors, and patients on medical and surgical wards were at higher risk for aspiration than those in intensive care units.

**Tube size and position.** Limited data exist on the relationship between tube positions and reflux. A tube passed through the pharynx may lead to more transient relaxations of the lower esophageal sphincter, and this may promote gastroesophageal reflux. In a small study of patients referred for PEG placement, pre-PEG and post-PEG esophageal manometric studies and 24-hour pH monitoring were performed. In all 7 patients, the lower esophageal sphincter pressure increased and the reflux score decreased after PEG placement. One patient was restudied after a month and did not maintain the initial post-PEG improvement.

It is unclear if tubes should be positioned routinely across the pylorus. Most studies are too small to be truly meaningful, and one randomized, prospective study was flawed by lack of documentation of where the "post-pyloric" tubes were and whether aspirations were from salivary or gastric secretions. We have had no gastric recovery of tube feeding colored with methylene blue when the tube tips are placed in the third portion of the duodenum and beyond. In a recent randomized study of gastric vs. jejunal tube feeding in critically ill patients, patients fed jejunally had a lower rate of pneumonia (0 vs. 10.5%), received a significantly higher amount of their prescribed caloric intake, and had greater increases in prealbumin levels than patients fed by continuous gastric feeding.

**Body position.** In a series of ventilated patients with NGT, the supine position and the length of time kept in that position correlated with the number of recorded tracheal aspiration episodes. Another study showed that NGT feedings were associated with a higher incidence of aspiration in the supine position and that the semirecumbent position decreased the incidence of reflux and aspiration by 34% but did not prevent it.

**Effect of underlying disease.** In choosing a method of access, underlying disease pathophysiology must be considered. Examples include the high incidence of gastric emptying dysfunction associated with head trauma in which elevations of intracranial pressure may be elevated. Nasogastric feeding in this population or in a diabetic patient with gastroparesis is not likely to be tolerated and can lead to gastric distention and aspiration.

**Short-term versus long-term feeding.** Choosing a route of access involves considerations of short-term vs. long-term requirements for feeding. It may be that those patients with a higher risk for reflux before the index illness have a higher risk of aspiration thereafter and that there may not be a significant difference between NGT feeding and gastrostomy feeding.

In a prospective study, 70 elderly patients fed by NGT in a skilled nursing facility were found to have agitation and self-extubation as early and late problems in 67% and 39% of patients, respectively. Aspiration pneumonia occurred in 23% of these patients early and 44% late. This was compared with gastrostomy complications consisting of aspiration pneumonia (56% early and 56% late), tube dysfunction (50% early and 38% late), and agitation and self-extubation (44% early and 0 late). Patients with agitation and self-extubation are best managed by gastrostomy, but aspiration is still a considerable problem. Another study retrospectively reviewed 109 patients in a nursing home fed by gastrostomy. Twenty-three percent of patients aspirated, and the only risk factor that they could identify was a previous history of pneumonia; jejunostomy placement should be considered in such patients.

Fay et al. retrospectively evaluated differences between long-term feeding by PEG and NET. Within 14 days of tube placement, nonfatal aspiration pneumonia occurred in 6% and 24% of the patients with PEG and NET, respectively. There was no explanation for this significant difference, but after 2 weeks, the cumulative risk of aspiration by either technique did not differ. Except for higher NET replacement rates, there were no significant differences in complications or in patient nutrition, performance, or survival during a mean follow-up period of 192 days for PEG and 141 days for NET. They suggested that PEGs should not be placed for those patients tolerating NET feeding.

**Feeding regimens.** Intermittent feeding is preferred for nasogastric feedings because the stomach can act as a reservoir, does not require a pump, and may be more physiological. In contrast, continuous feeding is standard for jejunal feeding. A study of 34 neurosurgical patients fed by NGTs reported no significant differences between intermittent and continuous feeding, including aspiration. Mullan et al. followed 276 tube-fed adults who received their feeding through a variety of tubes by continuous drip, which they believe avoids the risk of aspiration. The incidence of aspiration by tube type in this study is as follows: nasoenteric, 3.8%; gastrostomy, 6.5%; and jejunostomy, 5.6%. Cohen et al. reported significant lower esophageal sphincter pressure and scintigraphic differences between rapid bolus (250 mL tube feeding and 10 mL of water for a period of 15 minutes) and continuous feeding (80 mL/h). Placement of gastrostomy tubes showed no significant effect on basal lower esophageal sphincter pressure, but rapid bolus feed-
ing decreased lower esophageal sphincter pressure to incompetent levels and was associated with free gastro-
esophageal reflux to the sternal notch. These changes were not found with the patients fed by the continuous method. Rapid bolus and intermittent methods are different in that the intermittent infusion usually runs 30—
60 minutes.

Potential advantage of jejunostomy feeding. Few studies are actually available to evaluate jeju-
nostomy feeding as a long-term option. This may in part be due to resistance of nursing homes to use these feed-
ings because they are not always able to provide the required level of care. Welz et al. followed 100
patients who underwent surgical jejunostomy placement and examined the risk of aspiration. They noted elimi-
nation of aspiration in 16 of 18 patients with preoperative aspiration and in all patients with known feeding-related preoperative aspiration. More comparative data are needed as well as true documentation of the source of aspiration as being oropharyngeal or tube feeding—related.

Diarrhea

The most common complication of enteral feeding is diarrhea; its incidence has been reported as low as 2.3% and as high as 68%. However, the different definitions of diarrhea used by investigators make it very difficult to interpret data. Multiple studies have only examined the number of stools per day but do not address stool weight or volume. Multiple etiologies for diarrhea are postulated, and its genesis may be a multifactorial process. Causes include concurrent use of antibiotics or other diarrhea-inducing medications, altered bacterial flora, formula composition, rate of infusion, hypoalbuminemia, and enteral formula contamination. The overall condition of the patient seems to be the most important factor. The more critically ill patients are more predisposed to tube feeding—induced diarrhea. Multiple physiological factors may be involved, including infection, alterations in motility, absorption, blood supply, and hormonal-cytokine influence.

Medications. Multiple medications are routinely prescribed to hospitalized patients. Antibiotic-associated diarrhea can result from the overgrowth of Clostridium difficile or other bacteria and candida. In addition, sorbitol-based liquids and medications containing magnesium may contribute to diarrhea.

Altered bacterial flora. Theoretically, reduced gastric and small bowel motility may lead to small intesti-
tinal bacterial overgrowth and an alteration in intestinal microflora. In addition, acid-suppressive medications such as histamine₂-blockers and omeprazole may permit bacterial overgrowth. Bacterial colonization of the gastro-
intestinal tract begins when gastric pH exceeds 4.0. Heyland et al. found that gastric colonization could be prevented with an acidified enteral feeding; however, the effect on nosocomial infection rates and diarrhea is not known. In this study, there were no complications of this therapy, such as gastrointestinal bleeding. Unfortunately, it is difficult to look specifically at gastric pH and overgrowth as a definitive cause for diarrhea when multiple other medical problems, such as adynamic ileus and hyperperfusion of the intestinal mucosa, are concurrently present in a critically ill patient.

Formula composition. The composition of formula may affect the incidence of diarrhea. Both formula osmolality and rate of delivery may be associated with diarrhea. Normal volunteers can tolerate full-strength, isotonic polymeric small bowel tube feedings at rates up to 340 mL/h without significant diarrhea. In this study, those subjects who developed some diarrhea had elevated stool magnesium concentrations. Because tube feedings are tolerated at such a high rate in normals, tube feeding—induced diarrhea in the critically ill may reflect altered physiological function. An increased incidence of diarrhea was observed in a randomized, prospective trial of critically ill, mechanically ventilated patients who received hyperosmolar feedings at higher infusion rates. The investigators concluded that higher osmolation and infusion rates can contribute to the incidence and duration of diarrhea in ill patients.

The use of fiber-containing formulas to control diarr-
hea related to tube feeding is unsettled. Short-chain fatty acid generation by fiber fermentation leads to an increase in sodium and water absorption. Short-chain fatty acids are absorbed from the colonic lumen and ionized at the intracellular level to hydrogen and fatty acids. The intracellular hydrogen is exchanged for luminal sodium, and the intracellular fatty acids are exchanged for luminal chloride. Water passively follows Na⁺ absorption, resulting in a net absorption of Na⁺, Cl⁻, and water.

In a prospective trial, no difference in stool weight or frequency was found when fiber was added to the enteral formula of patients in a long-term care facility. A comparison of a fiber-supplemented enteral formula to a fiber-free enteral formula in tube-fed head injured pa-
tients reported no difference in bowel function. Diarr-
hea occurred no more frequently in a fiber-free formulation group when 100 acutely ill patients receiving tube feeding for an average of 15.8 days via continuous infusion were randomized to either a fiber-free enteral formula or to a formula-containing fiber. In addition, antibiotic usage was most strongly associated with the
incidence of diarrhea. Another study also found no significant difference in diarrheal episodes between critically ill patients receiving isotonic enteral feeding and those receiving enteral feeding supplemented with fiber.151

**Hypoalbuminemia.** Some data suggest that hypoalbuminemia predisposes patients to diarrhea by decreasing osmotic pressure and causing edema in the intestinal mucosa. Critically ill patients with a serum albumin level of <2.6 g/dL may experience diarrhea with standard enteral nutrition.152 Conversely, a retrospective study of 88 patients stratified by serum albumin (≤2.5 g/dL) concluded that hypoalbuminemia was not a factor in tube feeding tolerance and diarrhea.153 Furthermore, tolerance of both peptide-based and free amino acid enteral formulation was documented in geriatric, hypoalbuminemic patients.154 Low albumin levels may simply be identifying the sickest patients who are most susceptible to diarrhea for many reasons. Therefore, the contribution of hypoalbuminemia in tube feeding tolerance is unsettled.

**Formula contamination.** If the enteral solution becomes contaminated, a large number of microorganisms enter the patient's gastrointestinal tract, possibly precipitating diarrhea. One investigator noted that residual enteral formula in feeding systems obtained immediately after feeding patients contains 10^3–10^6 bacterial counts, usually gram-negative bacilli.155 This was attributed to reusing bag-type containers and infusion tubes. However, the relationship between bacterial contamination of enteral feedings and diarrhea in patients fed through the stomach is questionable secondary to the protective mechanism of gastric acid. This relationship has not been evaluated in patients given jejunal feedings; however, a prospective analysis of all tube feeders in an intensive care unit receiving tube feeding via a routine (nonsterile) protocol vs. an aseptic protocol noted no difference in the prevalence of diarrhea.156

Drug absorption and metabolism may be interrupted or altered during tube feedings. Phenytoin binds to nasogastric tubing at the pH of enteral formulations, resulting in less drug delivery.157 However, direct investigation of phenytoin absorption determined by serum concentrations obtained after drug administration given concurrently with various enteral formulations note no interference in bioavailability.158 Additional studies evaluating theophylline, propranolol, diazepam, and cimetidine again note no interference of drug absorption with standard enteral feedings.159 However, a loss of drug potency of >19% was noted for a cephalexin suspension mixed in Sustacal (A. H. Robins, Richmond, VA), Dimetapp elixir (A. H. Robins, Madison, NJ), Robitussin Expectorant (A. H. Robins, Madison, NJ), Sudafed syrup (Burroughs Wellcome, Research Triangle Park, NC), Mellacril syrup (Sandoz Pharmaceuticals, East Hanover, NJ), Thorazine concentrate syrup (SmithKline Beecham, Pittsburgh, PA), Mandelamine suspension (Parke-Davis, Morris Plains, NJ), Feosol elixir (SmithKline Beecham), potassium chloride liquid, medium-chain triglyceride oil, or Neo-calglucon solution (Sandoz Pharmaceuticals).150 Resistance to warfarin has been reported secondary to vitamin K in enteral feedings.161

Hepatic and intestinal microsomes can be influenced by diet, possibly impacting on drug metabolism. Rats fed a fat-free diet have decreased hepatic cytochrome P450 content. Additionally, hepatic cytochrome P450 content is decreased in rats administered a high nitrogen, low-fat elemental diet.162 Human data suggest that a diet with at least 10% of calories derived from fat is necessary to prevent changes in drug metabolism.163 Although drug interactions are noted in vitro and occasionally in vivo, the clinical significance and magnitude of this problem seems to be small.

Metabolic complications of tube feeding include hyperglycemia, electrolyte abnormalities, vitamin and trace element deficiencies, and abnormal liver tests. This may be a problem with specialized enteral formulations if they are used for the improper patient population. Hyperglycemia may occur secondary to the high carbohydrate load of specific enteral formulations. This is especially a problem for the ill or elderly patient who may be insulin resistant. The use of a high osmolar formulation (>600 mOsm/kg) may result in dehydration and hypernatremia.164 Present commercial formulations (300–600 mOsm/kg) have decreased this problem, but patients on a fluid-restricted diet or with renal concentrating difficulties are still at risk. Other less common complications are reported, including the development of abnormal liver tests associated with the use of an elemental formulation.165

**Conclusions**

1. To limit the risk of aspiration during tube feeding, the following should be considered for each patient. For gastric feeding, (A) raise the head of the bed 30°–45° during feeding and for 1 hour after, (B) use intermittent or continuous feeding regimens rather than the rapid bolus method, (C) check gastric residuals regularly, and (D) consider jejunal access in patients with recurrent tube feeding (not oropharyngeal) aspiration or in critically ill patients with a higher risk of gastric motility dysfunction (e.g., head
trauma). For small bowel feeding, (A) know where the feeding port of the NET or PEJ truly is (the closer to the ligament of Treitz, the better) and (B) episodes of severe vomiting or coughing can displace some nonsurgical tubes, and radiographs may be required to verify current tube position.

2. Diarrhea is a common but poorly defined complication of enteral feeding.

3. Concurrent medication use, including sorbitol-based drugs (e.g., theophylline elixir) and antibiotics, is commonly associated with diarrhea in the tube-fed population.

4. Critically ill patients are at risk for diarrhea from multifactorial etiologies.

5. Fiber probably has little role in controlling tube feeding–related diarrhea.

6. While metabolic problems may be less frequent with enteral nutrition as compared with parenteral nutrition, careful attention to fluid and electrolyte management can minimize significant metabolic complications.

**What Is the Role of Special Tube Feeding Formulations?**

Although one or two formulas meet most patients’ needs, a wide range of specialty products may offer advantages in certain disease states. Enteral formulations are divided into seven separate classifications, including blenderized, lactose-containing, lactose-free, elemental, modular, specialized, and supplemental.

**Blenderized Diets**

Blenderized formulations are a combination of table foods with added vitamins and minerals. They contain a generous amount of fiber and must be delivered through a larger bore NET or a PEG. Although blenderized formulas are commercially available, patients can be instructed in the preparation of a balanced regimen using blenderized foods from their kitchen.

**Lactose-Containing/Lactose-Free Diets (Polymeric Diets)**

Formulations containing lactose are rarely used today. Many patients referred for enteral feedings have genetic or acquired lactase deficiency. The use of a product containing lactose would result in abdominal distention, cramping, and diarrhea.

Lactose-free mixtures are the basic feeding formulations and are designed for long-term usage. They generally provide 1 kcal/mL and are isotonic, although they may be concentrated to 1.5–2.0 kcal/mL. A standard formulation has 12%–20% of its calories from protein, 45%–60% of its calories from carbohydrates, and 30%–40% of its calories from fats. They contain complex forms of carbohydrates, fats, and proteins and require some degree of digestion and absorption.

**Elemental Diets (Monomeric and Oligomeric Diets)**

Elemental or chemically defined formulations are designed for use in patients with “limited” digestive capacity. This may include diseases in which the bowel’s absorptive capacity is functionally or surgically reduced, such as Crohn’s disease or short bowel syndrome. They are delivered as free amino acids alone (monomeric) or free amino acids, dipeptides, and tripeptides (oligomeric) that can be absorbed via active transport mechanisms without preliminary intraluminal hydrolysis. They may be combined with easily absorbed fats (medium-chain triglyceride oil) and/or carbohydrates (maltodextrins). Elemental diets are fiber-free, and because of the presence of multiple small particles, they are highly osmotic. The efficacy of elemental formulations has been controversial for many years.

Intact proteins or large peptides are hydrolyzed by the brush-border enzymes, whereas dipeptides and tripeptides can be directly absorbed by the enterocyte. Significantly slower absorption of peptides with 4–5 amino acids has been documented as compared with peptides with 2–3 amino acids. There is no advantage in using an elemental diet in a patient with a normal gastrointestinal tract. Elemental diets are much more expensive than polymeric formulas, and the poor taste usually precludes adequate oral ingestion and necessitates tube feeding. Newer flavor packets are available and may improve the taste and patient acceptance.

**Specialty Diet Products**

Specialty formulations are available for the patient with unique nutritional requirements. Widespread use of enteral feedings and an expanding knowledge of specific disease processes have led to an explosion in the development of multiple specialty products. These products are more expensive than standard enteral nutrition and may lead to complications if used inappropriately.

Glutamine is a nonessential, neutral amino acid derived from skeletal muscle breakdown. It is essential for rapidly dividing cells, and it is actively metabolized by the small intestine, where it serves as both a nitrogen donor for nucleic acid synthesis and an energy source. It has been shown to maintain small bowel mucosa when placed in parenteral solutions as compared with glutamine-free parenteral formulations.
glutamine-fortified parenteral solutions have increased jejunal villus height, weight, and DNA content as compared with glutamine-free parenterally fed controls.\textsuperscript{169} Nitrogen balance in physically stressed patients is improved after glutamine supplementation.\textsuperscript{170,171} However, glutamine may be contraindicated in patients with liver failure and/or hepatic encephalopathy because intestinal glutamine metabolism is responsible for approximately 50\% of the ammonia released into the portal vein.\textsuperscript{172} Large trials showing the value of a glutamine-fortified enteral formulation in a stressed population are pending.

Arginine is a nonessential amino acid that, in supra-physiological amounts, has been shown to increase nitrogen retention, accelerate wound healing, and enhance immune functions. In animal studies, arginine supplements increase blood mononuclear response to concanavalin A and phytohemagglutinin.\textsuperscript{173} Other studies showed increased thymic weight and slowed thymic involution that normally occurs after injury\textsuperscript{174} as well as improved wound healing and survival to bacterial challenge.\textsuperscript{175} Arginine has been found to enhance lymphocyte blastogenesis and increase CD4 lymphocyte populations in a preoperative surgical population.\textsuperscript{176} Postsurgical cancer patients who were tube-fed an enteral diet containing arginine, structured lipids, RNA, and menhaden oil (rich in ω3 fatty acids) improved in vitro immune responses and nitrogen balance compared with controls fed a standard enteral diet.\textsuperscript{177} A randomized, prospective study in patients operated on for upper gastrointestinal malignancy reported that patients given postoperative tube enteral nutrition supplemented with arginine had fewer infections and other complications and a decrease in hospital days compared with patients given standard postoperative tube enteral nutrition.\textsuperscript{178} Further confirmation of the beneficial effects of arginine and other immune-stimulating nutrients is needed.

**Pulmonary formulas.** Most standard formulas provide most nonprotein calories as carbohydrates. Carbohydrates are metabolized with a higher respiratory quotient than lipids. New formulations are available that provide a majority of calories as fat (55\%) and maintain the respiratory quotient below 1.0 so that less CO\textsubscript{2} is produced per unit of oxygen consumed.\textsuperscript{179} This may be beneficial in the intubated patient with lung disease who may be difficult to either oxygenate appropriately or wean from the ventilator. Chronic obstructive pulmonary disease outpatients fed a low-carbohydrate, high-fat diet have a lower PaCO\textsubscript{2} and an increased vital capacity when compared with similar patients fed a standard enteral diet.\textsuperscript{180}

For most patients with pulmonary disease, meeting caloric needs with a standard polymeric formulation is recommended. The most important issue is to provide adequate nutritional support and avoid overfeeding, which produces a substantially greater increase in CO\textsubscript{2} production because the respiratory quotient for converting carbohydrates to fat exceeds 1.0. In patients with CO\textsubscript{2} retention and pulmonary failure, the ratio of carbohydrate to fat calories within an enteral formulation may have some impact.

**Renal failure formulas.** Patients with renal failure may benefit from a formula that minimizes blood urea nitrogen formation, slows the rate of renal failure progression, and meets nutritional needs. This would be especially important for those patients with marginal renal function who are attempting to avoid dialysis therapy or patients who are not dialyzed on a regular basis. Enteral nutrition products designed for patients with renal failure are low in protein, phosphorus, magnesium, potassium, and sodium. Special formulations are available that contain primarily the essential amino acids. The premise is to use urea for the production of required nonessential amino acids, ultimately reducing urea waste. Although there is no evidence of improvement in survival with this type of formulation, decline of renal function is less rapid in patients given a similar parenteral product.\textsuperscript{181} In patients with acute renal failure, other medical complications often preclude the use of the gastrointestinal tract, necessitating the use of parenteral nutrition. Certain types of enteral products may be appropriate based on the level of renal impairment. In patients with glomerular filtration rates below 25 mL/min but not on dialysis, low-protein diets providing 0.28 g protein · kg\textsuperscript{-1} · day\textsuperscript{-1} with essential amino acid supplementation may be beneficial.\textsuperscript{182}

**Hepatic failure formulas.** In patients with decompensated cirrhosis and hepatic encephalopathy, serum levels of branched-chain amino acids (leucine, isoleucine, and valine) are decreased and serum levels of aromatic amino acids (phenylalanine, tyrosine, and tryptophan) and methionine are elevated. The use of a branched-chain amino acid–fortified, low aromatic amino acid enteral formulation may be useful in patients with hepatic encephalopathy. This premise is based on the belief that branched-chain amino acids inhibit aromatic amino acids from crossing the blood-brain barrier and acting as false neurotransmitters. A review of multiple trials using branched-chain amino acids in encephalopathic patients with chronic liver disease noted that branched-chain amino acids are no better in reducing encephalopathy than conventional therapy with neomycin or lactulose.\textsuperscript{183} However, a prospective, randomized trial in encephalopathic patients reported a reduced severity of encephalopathy and improved nitrogen balance.
in those fed a branched-chain amino acid–supplemented, protein-restricted diet compared with casein-fed controls. In addition, improved inpatient mortality was observed in severely malnourished patients with cirrhosis receiving continuous enteral nutrition supplemented with branched-chain amino acids compared with patients consuming a standard low-sodium hospital diet. In another study, no improvement in nutritional parameters or degree of encephalopathy was found among branched-chain amino acid–supplemented patients with acute alcoholic hepatitis.

Trauma formulas. It has also been suggested that high percentages of branched-chain amino acids are necessary for severely stressed or traumatized patients to enhance nitrogen balance. These patients show significant proteolysis and hydrolysis of skeletal muscle branched-chain amino acids for energy. The patient enters a period of negative nitrogen balance that may not be corrected by standard amino acid formulations. However, whereas some clinical trials show improvement in nitrogen balance with the use of branched-chain amino acids in the stressed patient, other trials do not show benefit.

Glucose intolerance. A low-carbohydrate, high-fat formulation is available for glucose-intolerant patients. Only 33% of total calories are provided as glucose, whereas fructose, a sugar with a low glycemic response, provides approximately one quarter of the carbohydrate calories. The inclusion of medium-chain fatty acids reduces osmolality. Compared with standard enteral formulations in type I diabetics, this formulation produces a significantly lower postprandial glyemic response. Concerns with fructose include its ability to cause an elevation in serum lipids compared with other carbohydrates and its incomplete gastrointestinal absorption leading to abdominal distention and cramping. The provision of higher fat formulas will need to be balanced with the need to control blood glucose levels in a population already predisposed to coronary artery disease and dyslipoproteinemias.

Fiber-containing formulas. Enteral formulations were originally designed to have a low fiber or residue content. Although dietary fiber recommendations have been reported for healthy individuals, no recommendations exist for various disease states or for the patient in a long-term care facility. Enteral formulations containing soy fiber have been used in the acute care setting to prevent diarrhea associated with tube feedings. However, as noted previously, their efficacy in this regard remains inconclusive. The major role for fiber in enteral formulas is likely the contribution of short-chain fatty acids, which are trophic for bowel mucosa. Because fiber has a potential protective effect for multiple disease states, including diverticulosis, colon cancer, diabetes, and heart disease, it may have a role for patients in long-term care facilities or patients who will require enteral formulations for a prolonged period of time.

Medium-chain triglyceride formulas. Medium-chain triglyceride–supplemented formulations have been proposed as alternatives to long-chain fatty acids in patients with fat malabsorption. Unlike long-chain fatty acids, which are hydrolyzed first in the intestinal lumen to monoglycerides and free fatty acids by bile salts and pancreatic lipase before absorption, medium-chain triglycerides are absorbed unchanged into the enterocyte. They are also independent of carnitine transport into the mitochondria. Medium-chain triglycerides can be an advantage to the patient who shows fat malabsorption secondary to intestinal mucosal damage, bile salt deficiency, or biliary tract dysfunction.

Modular Diets

Modular feedings consist of individual nutrient components that are mixed to create a specific enteral formulation or can be added to an existing one. They exist as separate nutrient units: fat, carbohydrate, or protein. Thus, a custom enteral solution can be devised or individual components added to a commercial formula to obtain higher levels of a particular nutrient.

Supplements

Patients who cannot meet all of their protein or calorie needs may be administered supplements. They may take the form of a liquid, shake, pudding, or solid food bar and may be taken with or between meals. The multitude of available products and conflicting information regarding product efficacy can often make appropriate aggressive nutritional support complicated.

Conclusions

1. Standard isotonic polymeric formulations can meet most patients' nutritional needs.
2. The use of elemental formulations should be reserved for patients with severe small bowel absorptive dysfunction.
3. Specialty formulations currently have a limited clinical role. More information is needed concerning their practicality and effectiveness.

What Is the Role of Nutrition Support Teams for Enteral Nutrition and the Tube-Fed Patient?

The ultimate decision concerning nutritional support rests with the patient's physician. The foundation
of this decision depends on an appropriate nutritional assessment. Use of a nutrition support team, a multidisciplinary team consisting of physicians, dietitians, nurses, and pharmacists with expertise in nutritional support, can be valuable in managing patients in a comprehensive, cost-effective manner. The team may be involved in patient care, education, and research. In a prospective, non-blinded study comparing team-managed and non–team-managed enteral nutrition support patients, Powers et al. showed that the team approach reduced complications compared with the nonteam patients and resulted in better attainment of nutritional goals. In addition, a review of the role of nutrition support teams showed that enough favorable evidence exists for cost-effectiveness to support establishing nutrition support teams. Even while debate still continues concerning the validity of aggressive nutritional support in reducing morbidity, mortality, and hospital stay, the use of a nutrition support team allows a comprehensive and orderly approach to aggressive nutritional therapy in a very complex patient population.

Conclusions

Nutrition support teams are a valuable adjunct in the management of tube-fed patients. For patients who require enteral nutrition, the use of a nutrition support team may significantly improve care and assist in the cost-effective therapy with the goal to decrease complications associated with tube feeding.

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