
History of Tube Feeding

An Overview of Tube Feeding: From Ancient Times to the Future

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ABSTRACT: The history of enteral feeding goes back about 3500 years to the ancient Greeks and Egyptians, who infused nutrient solutions into the rectum to treat various bowel disorders. Over the centuries, experimentation and research have contributed to a greater understanding of nutrient requirements; methods to more accurately access the gastrointestinal tract; development of new materials to use in equipment, tubes, and containers; and the digestion, absorption, and use of macro- and micronutrients. It is notable that while advances were made in one area, progress was being made in another. For example, while enteral access and feeding techniques were being developed, essential amino acids were identified. When new information came together, rapid changes opened up the applications for enteral feeding in new directions, sometimes in unexpected ways such as diets designed for the space program, leading to the use of elemental diets as a therapeutic modality.

Although we accept enteral feeding by tube as part of our standard armamentarium of methods to restore or preserve nutrition health in chronically or critically ill patients, feeding by tube has had an uneven history over thousands of years. The earliest recorded description of feeding nutrients by tube was found in papyrus from 3500 years ago.¹ Ancient Egyptians and Greeks used enemas to infuse nutrients to preserve health, protect an inflamed bowel surface, or treat diarrhea.^{2,3} Infused solutions were made from wine, milk, whey, and wheat or barley broths. Eventually, eggs and brandy were added to this mix. Rectal feeding was the artificial feeding method of choice for thousands of years due to the

difficulty of accessing the upper gastrointestinal (GI) tract.¹

Feeding into the upper GI tract was reported in the 12th century but is generally attributed to Capi-vaccus in 1598.^{1,4} He used a hollow tube with a bladder filled with a nutrient solution attached to the end, inserted into the esophagus. In the 17th century, advances were made in delivery systems that contributed to the ability of physicians to provide enteral feeding into the upper GI tract. A flexible leather tube for esophageal feeding was developed by Von Helmont³, and Boerhave suggested it could be used for nasogastric feeding.^{1,3} In the 18th century, John Hunter used a hollow catheter and syringe to deliver blended food into the stomach of a patient.^{4,5}

Hunter evidently got interested in methods to deliver enteral feeding with more efficiency and subsequently designed an orogastric probe made of whalebone encased in eel skin to deliver nutrients.¹ He suggested that the liquid formula contain jellies, eggs with milk, water with sugar beaten in, or wine. Rubber tubing was not used for feeding access until the early 19th century.⁴

Using gastrostomy access for feeding or giving medications was first suggested by Egeberg in 1837, but the earliest gastrostomies were done by Sédillot in 1845.⁶ The procedure developed by Sédillot was associated with many complications, so most physicians chose to use the nasogastric route. References to nasogastric feeding exist throughout the medical literature for centuries, generally describing milk- or cream-based solutions to provide nutrition.⁴ Others reported use of solutions made of milk, eggs, and beef tea^{3,7}; thick custards and mashed potatoes^{3,8}; and predigested milk (treated with acid or enzymes) with brandy or whiskey.^{3,9} Tube materials were somewhat limited to hard hollow tubes attached to softer, more pliable conduits, allowing the flow of nutrient solutions into the GI tract. These solutions were administered using gravity to effect solution flow.

Twentieth-Century Developments

In 1910, Einhorn was experimenting with feeding directly into the small bowel, either the duodenum

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or the proximal jejunum, using a nasally introduced weighted tube.⁴ Andresen¹⁰ attempted jejunal feeding while his patients were still in the operating room; although he had some success, his concepts were not widely recognized or adopted for many years. Contemporaneously, Loewi and Abderhalden were trying to feed dogs and maintain nitrogen balance using protein hydrolysates.¹¹ Hydrolysates were not considered safe for human use, but the recognition that protein could be predigested and absorbed was a precursor to the later development of protein hydrolysate-based formulas.

It is notable that advances in feeding techniques were being made at the same time that new solutions for feeding were being developed.¹¹ Ravdin, Abbott, Lawson, Cuthbertson, and others^{11,12} were looking for safer, more effective methods to feed nutrient solutions into the jejunum. Rose was exploring amino acid requirements and essentiality in rats and subsequently in humans.¹³ Rose's identification of essential amino acids proved timely, as it subsequently contributed to advances in both enteral and parenteral feedings.

During the 1930s, advances in enterally fed formulas were made when protein hydrolysate formulations were fed to surgical patients.¹³ Stengel and Ravdin¹⁴ used a casein hydrolysate solution (skim milk treated with acid, pepsin, sodium chloride, sodium bicarbonate, dextrose, and some vitamins) to feed patients into their jejunum. Identification of many of the water-soluble vitamins, their chemistry, and their physiologic role was made during this decade too.

By the 1940s, more applications of enteral feedings were explored. An infant formula made from protein hydrolysate, corn oil, dextrimaltose, vitamins, and minerals was intended for babies with allergies, diarrhea, or other GI dysfunction. In 1943, Mulholland and colleagues¹⁵ conducted a study comparing enteral and parenteral feeding by measuring nitrogen balance, weight gain, and serum protein levels. Enteral feeding was significantly more successful in achieving positive nitrogen balance, weight gain, and restoration of normal serum values than was parenteral feeding.

Rose published the results of his studies on human amino acid requirements in 1949,¹⁶ leading to a greater knowledge of protein needs in adults. The issues of protein needs in surgical patients captured the attention of medical care providers. Bowles and Zollinger⁴ evaluated the efficacy of placing a jejunostomy feeding tube at the time of surgery. Usher¹⁷ and Fallis and Barron¹⁸ reported using tubes made from polyethylene, and Barron et al¹⁹ developed the first enteral feeding pump. In an effort to improve tolerance of tube feedings, formulations were made from blended foods mixed from infant foods and other ingredients cooked in the hospital kitchen. This method was an attempt to mimic a normal diet in a liquid form to pass through a feeding tube. This approach was used at Henry

Ford Hospital in Detroit and other hospitals throughout the United States.²⁰ These solutions are generally well tolerated but are difficult to keep contaminant-free and are labor intensive for hospital kitchen staff.

By the 1960s, with the availability of amino acid solutions, studies examined whether these solutions could support nitrogen balance in healthy adult subjects without side effects.²¹ The events that actually added to the interest in these diets were the development of "space diets" for the fast-moving aerospace program. It was important to find transportable diets that would maintain nitrogen balance and have minimal fecal output. The "elemental" diets (based on essential amino acids, glucose, vitamins, and minerals) had many positive attributes for space travel: (1) they had a high nutrient density in transportable powder form; (2) they were highly soluble and were easily reconstituted; (3) they had low fecal residue; (4) they were flexible so that they could be adjusted to meet individual nutrition demands; (5) they were completely digestible; and (6) they were stable for long-term storage.^{22,23}

Despite the benefits, the astronauts rejected the elemental diets due to their strong and bitter taste. However, in a local hospital, patients with bowel fistulas who were fed the diet by tube were managed successfully.^{24,25} This episode contributed to the application of these diets for use in other patients with GI diseases. Advances in tubes and delivery systems were developed rapidly but soon were overshadowed by breakthroughs in successful parenteral feeding.²⁶

The absorption of protein as amino acids and small polypeptides, various carbohydrate compounds including disaccharides and small oligosaccharides, and lipids, including medium-chain triglycerides, has been studied during the past 30 years. Research addressing the digestion, absorption, and use of enteral nutrients contributed to a greater understanding of gut physiology and the impact of feeding *via* tube. Some significant work was conducted during the 1980s. Several studies explored the impact of early postoperative feeding with enteral solutions.²⁷⁻²⁹

Being in the shadow of parenteral nutrition (PN) support, enteral feeding was moved forward by the evidence of fewer complications, lower costs, and safer access. Enteral feeding formulas have been developed for many different specific diseases, including hepatic, renal, and pulmonary diseases; diabetes; thermal injuries; and transplantation. See the article in this issue by Campbell³⁰ for a further discussion of enteral formula development.

The function of the GI tract under conditions of stress and disease and its responses to various substrate solutions have been further elucidated with studies in recent years.³¹ Modular formulas, allowing modification of existing products, or the construction of new formulations, have become available. Formulas with added fiber have contrib-

uted to improved GI function and better tolerance of some solutions. Addition of other nutrients believed to have immune-enhancing actions has also proven to be a significant advance in feeding formulations. New tubes that serve multiple functions, pumps, and other devices have been developed to make enteral feeding easier and safer.³²

In subsequent papers in this journal, the development of formulas,³⁰ devices, and access for successful enteral feeding will be discussed in greater detail. On the road from Hippocrates and the ancient Greeks and Egyptians, and their approach to feeding infusions, to the state of enteral feeding in the early 21st century, we have come far but we still have room for improvement and development. We can only speculate on what the future will hold, but likely investigations will lead to more sophisticated and successful treatment with enteral nutrition for patients in our care.

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