Enteral Feeding Tube Design and Differential Bacterial Overgrowth: An In Vitro Comparison

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Abstract

Background: Neonatal Intensive Care (NICU) patients often require nutritional support via enteral feeding tubes (EFTs). Various designs are available on the market. Parts such as caps, inlet hubs, and distal ends vary from product to product. It is possible that certain EFT designs may increase the risk for nosocomial infection by promoting bacterial overgrowth.

Objectives: To compare in vitro bacterial overgrowth of design components of commercially available 8 French EFTs, including the proximal hub (H), cap (C), and distal end (DE) outlet.

Design/Methods: EFT caps (plunger (PC), recessed (RC) and threaded (TC)); hubs (single or double port); and distal ends (open (OE) or pouch (POE)) were assessed. Four polyurethane (PE) and 1 silicone (S) EFT were selected. EFTs were inoculated with a 2:1 mixture of ready-feed 24 kcal/oz. premixed formula and human saliva, placed in a 75% humidified isotope at 34°C, and removed at 3, 24 or 72 hours. EFTs were sterilized, sectioned; caps, hubs and distal ends were placed in PBS and cultured using standard microbiological procedures. Bacterial colony forming units (CFUs) were determined for each specimen and standardized for maximum growth by time and component, creating a “0-100” scale for two-tailed t-test comparisons.

Results: Maximal growth was detected for specimens at 3 hours. A significant difference existed between PC and RC caps at 3 and 24 hours; this difference disappeared by 72 hours. Despite a significant amount of growth in the DEs, there was no difference between design types. Hubs also had abundant bacterial growth at 3 and 24 hours but no differences between designs (single port with recessed or plunger cap, Y-shaped design or threaded hub) were detected. EFTs made of PE and S had similar growth burdens.

Introduction

Neonates admitted to the neonatal intensive care unit typically have varying degrees of feeding difficulties requiring gavage feeding assistance. A very high percentage of these neonates admitted to the NICU require enteral feeding tubes (EFTs). EFTs are an essential component in the care for sick neonates in the neonatal intensive care unit (NICU). Sick neonates depend on such nutrition for growth and development. Without EFTs, many infants would suffer from malnutrition and its complications.

The introduction of enteral feeding is not only essential for nutrition but also for the maturation of the gastrointestinal tract (GIT). The GIT is an important organ for digestion, absorption, immunity and endocrine functions. In a healthy term infant, the GIT is sterile at birth and subsequently colonized by millions of microorganisms. These organisms play a commensal role in humans benefiting the host not only nutritionally, but also in processes of angiogenesis, and mucosal immunity. Sick neonates are inherently vulnerable and these feeding delays often add to their vulnerability. Many babies in the NICU are born via cesarean section and do not pass through the vaginal canal, further delaying and altering the “normal” bacterial colonization of their intestinal mucosa, thus delaying and altering GIT absorption of essential nutrients and the GIT’s role in immunity. Once they are introduced to the NICU environment and are exposed to many abnormal environmental factors, such as antibiotics, altered colonization of others in the NICU and the insertion of foreign bodies such as central lines and EFTs, their GIT’s adaptation to the extra uterine environment is further altered. Many believe that this alteration plays a crucial role not only in neonatal diseases and complications but also in long-term health of these neonates. The exact role this alteration in GIT maturation and colonization plays in the development of various neonatal diseases is unclear. It is very clear, however, that being premature and or ill in the neonatal period predisposes babies to sepsis, growth restrictions, and necrotizing enterocolitis (NEC). Enteral feedings (breast milk or formula) have been identified as a source of nosocomial infections. It has been documented that enteral delivery systems such as bags, tubing and EFTs themselves are susceptible to bacterial growth; however, there are no studies linking bacterial colonization of enteral feeding systems to actual patient disease or infection. It is well known that foreign bodies such as central lines increase the risk of blood stream infections in neonate, but this has not been replicated for enteral feeding systems. Bacterial translocation in the GIT, though, which occurs frequently in newborns, may be further amplified by delayed GIT colonization and buildup of bacteria on EFTs and subsequently leave babies more susceptible to bacterial sepsis and NEC. Anderton in 1984 demonstrated that adhesion of microorganisms to the interior walls EFTs occurs very readily after...
8 hours of perfusion with a milk-based feed experimentally contaminated with Staphylococcus aureus. The EFTs that were studied had such irregularities of their internal surface that microorganisms became trapped, potentially allowing a large and harmful amount of bacteria to be introduced into a patient’s intestine. This theory was again tested in 2009 by Hurrell et al. This group demonstrated that biofilm formation on EFTs by pathogens such as Salmonella can form in as little as 24 hours, possibly inoculating subsequent feedings through the same EFT.6

EFTs are composed of various materials ranging from polyurethane to silicone and come in a variety of designs. There are three main components of each EFT design in which they vary: the hub (H) to which a cap (C) is attached and the distal end (DE) which sits in the stomach. Hubs either consist of single or double ports. The caps to the hubs are manufactured in three different varieties: plunger (PC), recessed (RC) and threaded cap (TC). Finally, the distal end which drains the feed into the patient’s stomach is either open (OE) or manufactured with a pouch design (POE) with side ports for feeding drainage.

There are no studies investigating EFT design, the issue of bacterial colonization and its possible clinical significance/ramifications. This topic is intriguing in neonates, especially, due to their vulnerability to infection and predilection to NEC. This study was an in vitro design examining the potential of bacterial contamination/colonization of the three EFTs’ components of various manufactured commercially available designs.

Materials and Methods

Five EFTs (all 8 French catheters) were chosen based on their designs. Four polyurethane (PE) EFTs were tested and one silicone (S) EFT. The PE tubes included: Corpak Y-hub EFT with both types of caps on the hub and a closed distal end (POE); two NeoMed EFTs: one made of S the other PE. Both NeoMed EFTs had plunger caps and open distal ends. The third PE EFT was manufactured by Vygon; it had a threaded recessed cap (TC) and POE type distal segment. The final EFT was a product of Kendall. This final tube was made of PE, had a recessed cap and a pouch type distal segment (Table 1 and Figure 1).

![Figure 1. Schematic demonstrating plunger and recessed caps, open versus closed distal end, and Y-type hub.](image)

<table>
<thead>
<tr>
<th>EFT</th>
<th>Substance</th>
<th>Cap</th>
<th>Hub</th>
<th>Distal End</th>
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<tbody>
<tr>
<td>Corpak</td>
<td>PE</td>
<td>Recessed/Plunger</td>
<td>Y-type</td>
<td>Open</td>
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<tr>
<td>NeoMed</td>
<td>PE</td>
<td>Plunger</td>
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<td>Open</td>
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<tr>
<td>Kendall</td>
<td>PE</td>
<td>Recessed</td>
<td>Single</td>
<td>Pouch</td>
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Table 1. Design Summary of five EFTs studied.

Each feeding tube was inoculated with a mixture of sterile ready-feed Special Care 24 formula (Abbott Nutrition) and human saliva (ratio 2:1) to simulate a patient’s mouth. The tubes were then placed in a 75% humidified isolette at 34° C to simulate a premature infant’s environment. Nine tubes of each variety were inoculated simultaneously using the same saliva source.

Three of each of the tubes were removed sterilely from the isolette at 3, 24 and 72 hours respectively. At each time point, the three tubes were cut with sterile blades. The caps, hubs and distal ends were placed in PBS solution separately. Cultures were then performed by standard microbiological procedures (BCS Laboratory, Gainesville, FL) to assess amount of bacterial growth at each time point. The 72 hour cultures did not include the distal tip because this was felt to be clinically irrelevant since EFTs are flushed regularly when in place. Results were reported in colony forming units (CFU). This is a measure of viable cells (Figure 2).

Another set of feeding tubes were inoculated and incubated in a similar manner as described above. These tubes were removed from the isolette at 3 hours and sectioned sterilely. They were processed by the University of Florida, Interdisciplinary Center for Biotechnology Research, Electron microscopy and Bio-Imaging Core. Electron Microscopy (EM) and Transmission Electron Microscopy (TEM) were performed to obtain detailed photographs of the surface of the plunger and recessed caps (Figure 3).

Statistical Analysis: The CFU for each EFT at each time point were analyzed. CFU were standardized using maximum growth for both time point and location on the EFT (hub, cap or distal end). For a given time point and site, the maximum CFU was used to create a scale of 0-100 for the culture results. Two-tailed t-test was performed to analyze these results. P values were calculated from means and standard deviations. A p-value of less than 0.05 was considered statistically significant.

Results

CFU were analyzed by time point and location. The most overall growth occurred in the first 3 hours of incubation, especially at the hub and distal end. The amount of bacterial growth then decreases at 24 hours and again further subsides by 72 hours overall (Figure 2).
When each EFT part was analyzed separately, differences in design appeared to play a role in bacterial growth in the caps (recessed versus plunger) only, but only in the first 24 hours. The growth observed in the recessed hub was significantly more at both the 3 hour and 24 hour time point (p values .04 and .001 respectively). The difference disappears by the 72 hour time point (Figure 4).

Though there was a significant amount of growth in the distal end of the EFTs, the design of the distal end did not alter the amount of growth at any time point. At both 3 and 24 hours, the growth was similar in both the open-ended and closed-ended EFTs (Figure 5).

Following the same trend as the distal ends, the hubs had abundant bacterial growth at 3 and 24 hours. The design of the hub, whether it was a single port with recessed or plunger cap, Y-shaped design or threaded hub, did not appear to influence the bacterial growth (Figure 6). Of note, there was also no difference in bacterial growth when comparing silicone versus polyurethane EFTs.

**Discussion**

EFTs, like many other medical devices, are an essential component in the care of a fragile neonate. Like other common indwelling foreign bodies, contamination with bacteria is highly likely. Central line catheters, for instance, are a well-known source of nosocomial infections in all hospitalized patients. Much less is known about EFTs and their role in disease processes, but they are still a possible source of bacteria. This is the first study investigating the potential for bacterial growth based on design of the feeding tube.

The EFT material and composition may play an important role in the extent of bacterial growth on the catheter itself, and then possibly lead to significant clinical consequences. Bacterial growth can build up over time and when a critical mass of growth has been achieved, it could be dislodged into the gastrointestinal system of compromised NICU patients. Many fragile neonates experience translocation of bacteria from the intestinal lumen into the blood stream. Bacterial translocation is defined as the passage of both viable and non-viable microbes and microbial products, such as endotoxin, from the lumen through the mucosa into the lymphatic system. This source of infection is well-studied in neonates and other compromised patients.7,8

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is required is a call from the doctor instructing the patient to re-hydrate, and the false labor symptoms subside. The doctor-patient interaction can take place over the phone without the need for stressful, unnecessary and costly hospital admissions and examination.

**In the cases where a premature birth is still possible, how does this technology aid the team as well as the expectant mother?**

FULLTERM focuses on managing premature births, and directly involves the patient in her care. The expectant mother is empowered, and she becomes part of the team. She helps the doctors see what is appearing. For doctors, being able to see these changes early is a tremendous advantage. So while FULLTERM does not directly prevent premature birth, it focuses on managing the patient to provide the best outcome for the preemie. When a doctor gets early warning of the patient’s cervical effacement and dilation with FULLTERM, he or she has enough time to call the patient to get her to a center with a NICU for the premature delivery, increasing the preemie’s chance of survival.

**What have the studies shown in relation to FULLTERM and its success rate?**

FULLTERM multi-center European clinical trials are slated for the third quarter of 2014 and are designed for European CE mark and FDA approvals. Two groups of patients will participate in the trials: a group who receives FULLTERM wireless pregnancy management (FULLTERM group), and a group who received standard care without the adjunctive outpatient service (control group). Study endpoints will focus on pregnancy and neonatal outcome: gestational age at delivery, less than 35 weeks at delivery, less than 32 weeks at delivery, birth weight, regular nursery days, level II nursery days, NICU days, total nursery days, neonatal mortality, and survivability.

**When will this product be available for use by perinatal professionals?**

FULLTERM is targeted for CE mark approval in the fourth quarter of 2014, and will be available in Europe upon CE mark approval. FDA approval is slated for the first quarter 2015, and will be available in the US after FDA approval.

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**National Perinatal Association** – Mission: To promote the health and well-being of mothers and infants enriching families, communities and our world. Website: www.nationalperinatal.org

**Keep ’Em Cookin’** – Keep ’Em Cookin’ is an educational organization that gives pregnant women the greatest opportunity to prevent preterm birth by providing them with current information on high-risk pregnancy and by offering them an online bed rest support group. Website: www.keepemcookin.com.

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**Enteral Feeding...continued from page 28**

The parts of the EFT that are outside the neonates (cap and hub) had the greatest potential for prolonged bacterial contamination. The cap and the hub had the most sustained growth through 72 hours. The distal end had the most growth initially, but it tapered off significantly by 72 hours (Table 6). Because, the distal portion is regularly flushed with feedings and sits in an acidic gastric environment, bacterial growth in this portion of the EFT is most likely the least clinically significant. Though a pouch type distal end would logically seem more likely to accumulate bacteria, the results only showed a trend of increased growth in the pouch-end compared to the open end at 3 hours (p=.07). This difference in growth disappeared at the 24 hour time point. In this study, the hub, or point of entrance of the EFT, had significant growth in all designs, but it appears the cap has the most influence on the amount of bacterial growth. The growth at 72 hours appears to diminish and this is most likely do to loss of substrate to support bacterial growth, since formula was not reintroduced into the catheters as it would be in real clinical scenarios.

Though more studies are needed to prove the association of bacterial contamination of EFTs and nosocomial infections or NEC, the potential seems great. If a recessed cap increases the risk of bacterial translocation, the design of EFTs should be directed towards preventing an increased risk to fragile infants. Or, instead of changing the design, the care for EFTs should mimic the care of central line catheters and include regular sterilization of the area where feeds are introduced many times per day.

The limitations to this study include the small numbers of catheters used for culture and the fact that the cultures were in vitro and not performed in actual patients. Also, though a single donor was used for the saliva, the EFT inoculation may have not been uniform. Further studies are needed to draw more conclusions.

**References**

2 Martin, Camilia and Walker, Allan. Innate and Mucosal Immunity in the Developing Gastrointestinal Tract: Relationship to Early and Later Disease. Chapter 70.