The Lopez enteral feeding valve (ICU Medical, San Clemente, California) is a 3-way stopcock valve made of polycarbonate and polypropylene (Figure 1). This device is used to create a closed, feeding tube system when inserted between a percutaneous enteral gastrostomy or nasogastric feeding tube (which enters the stomach) and the enteral feeding tubing (which is connected to a container of enteral nutrition). Use of the 3-way stopcock creates a closed system and eliminates the need to disconnect the tubing to check gastric residual volumes and to administer water flushes and medications. The opportunity for reflux of gastric contents during tubing changes is also eliminated with a closed system. Use of a Lopez valve provides several potential benefits to nurses, patients, and facilities (see Table).

The Lopez valve is classified by the Food and Drug Administration as a class III medical device; therefore, it can be used nonsterile for enteral feedings (although a sterile product is available). The Food and Drug Administration does not require manufacturers to provide recommendations for frequency of changing. A Lopez valve can be used...
indefinitely (personal communication, Peter Hoffman, ICU Medical product specialist), although the tubing, container of nutritional formula, and flush syringes are usually replaced every 24 hours, per facility policy.

**Biofilm**

Many medical devices can become the focus of a patient’s infection, which can be difficult to treat because the causative bacteria exist in biofilms. A biofilm is a community of microbial cells that are irreversibly attached to a substratum and interfaced with each other. Production of a biofilm is a 2-stage process: first, the bacteria attach to the surface of a device, and then cell-to-cell adhesion and pluristratification occur. A 3-dimensional, extracellular polymer matrix, produced by the bacteria, embeds the bacteria in place. Formation of biofilms is partially controlled by quorum sensing, an interbacterial communication mechanism of densely populated cells. Antibiotic resistance is facilitated by biofilms because efficient transfer of virulence and resistance genes takes place in these densely populated groups of cells. Another hypothesis for this resistance is an extracellular signal, or alarmone, released from killed bacteria that may prime surrounding recipients into a state of resistance by the premature death of the peripheral cells. Overall, antimicrobial resistance is multifactorial and varies from microbe to microbe.

Prevention and control of biofilms on medical devices require consideration of the unique and tenacious nature of biofilms. Multiple intervention strategies include preventing initial colonization of the device, minimizing attachment of bacterial cells to the device, penetrating the biofilm matrix to kill the bacterial cells, and removing the device from the patient. Eventually, removal of the medical device may be necessary because a biofilm can cause acute or chronic infectious disease. The ability of biofilms to resist disinfectants and antibiotics makes them a public health problem. Biofilms are an important cause of nosocomial infections, because once established, the bacteria harbored inside are less exposed to a patient’s immune response and are less susceptible to antibiotics.

Biofilms can form on many medical devices used in the critical care unit. Included among these devices are urethral catheters, central vascular catheters, endotracheal tubes, ventilator circuits, ventricular assist devices, dialysis catheters, artificial hearts, orthopedic implants, stainless steel, and enteral feeding tubes.
Dautle et al studied silicon gastrostomy devices previously used for feeding (9-47 months) and found that all of them had biofilms. The biofilms were cultured, and the bacteria were identified. Dautle et al identified 24 species of bacteria, including *Pseudomonas aeruginosa*, in the used gastrostomy devices.

*Pseudomonas aeruginosa* is a gram-negative, aerobic rod and a known producer of biofilms. It has been associated with silicon gastrostomy devices, and a variety of clinically significant infections have been associated with it. Lennox L broth is routinely used for other work on biofilms. The Lopez device is used at room temperature, so an incubation temperature of 25ºC was chosen for this study. The initial culture time was randomly chosen to be 14 days, to ensure the establishment of a biofilm.

Lopez valves were submersed in liquid nitrogen and fractured by applying blunt force to expose the inner surfaces for scanning electron microscopy. Cultures of *P aeruginosa* of approximately 10^9 colony-forming units per milliliter were added to the Lopez fragments in 24-well, sterile culture plates (Becton Dickinson and Co, Franklin Lakes, New Jersey). The plates were incubated at 25ºC for 14 days. The cultured fragments were fixed in 2.5% glutaraldehyde in 0.1 M Millonig's buffer at pH 7.35 for 2 days at room temperature. The specimens were washed in the same buffer and treated with 2% osmium tetroxide in Millonig's buffered solution.

**Methods**

*Pseudomonas aeruginosa* was chosen for this study for several reasons. This organism is a known biofilm producer, it has been associated with silicon gastrostomy devices, and a variety of clinically significant infections have been associated with it. Lennox L broth is routinely used for other work on biofilms. The Lopez device is used at room temperature, so an incubation temperature of 25ºC was chosen for this study. The initial culture time was randomly chosen to be 14 days, to ensure the establishment of a biofilm.

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**Purpose**

The purpose of this research study was to determine if a bacterial biofilm would form on Lopez enteral feeding valves when the valves were cultured with *P aeruginosa* in Lennox L broth (LB, Sigma-Aldrich, St Louis, Missouri) at 25ºC for 14 days. This study was done to develop a protocol for future studies that will include several objectives: to determine the time necessary for biofilm to form when feeding formula is used as a culture medium, to identify microorganisms present in the biofilm on Lopez valves that patients have used, and to determine if the bacteria can be cultured from the biofilm (which would support the idea that the bacteria could be a source of nosocomial infection).

**Table** Potential benefits of the Lopez enteral feeding valve to nurses, patients, and facilities

<table>
<thead>
<tr>
<th>To nurses</th>
<th>Time saved during administration of water flushes and medication</th>
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<tr>
<td></td>
<td>Time saved because reflux of water or enteral supplements can necessitate changes in the PEG dressing, the patient's gown, and/or linen</td>
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<tr>
<td></td>
<td>Protection from exposure to bodily fluids that may carry pathogens, such as human immunodeficiency virus and hepatitis C virus</td>
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<td></td>
<td>Ease of gastric sampling, such as checking residual volumes</td>
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<table>
<thead>
<tr>
<th>To patients</th>
<th>Shortened patient care time</th>
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<tbody>
<tr>
<td></td>
<td>Less manipulation of the patient than if changes in the patient's gown and/or linen were needed</td>
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<td></td>
<td>Decreased potential for infection because the feeding tube system remains closed</td>
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<td></td>
<td>Easier to keep the PEG site and dressing dry with less reflux of gastric contents</td>
</tr>
<tr>
<td></td>
<td>Decreased potential for skin breakdown and/or infection because the PEG site and dressing may remain drier and without exposure to acidic gastric contents when a closed system is used</td>
</tr>
</tbody>
</table>

| To facilities | Possible filtering of medications that have been inadequately crushed because the lumen of the 3-way valve is smaller than the lumen of the PEG tube, so the valve would clog instead |
|              | Exchange of a clogged Lopez valve easier and less expensive (about $6.50) than exchange or unclogging of a plugged PEG tube |

Abbreviation: PEG, percutaneous enteral gastrostomy.
buffer. After another wash with buffer, the specimens were dehydrated in a graded ethanol series and critical-point dried in an AutoSamdri 810 (Tousimis, Rockville, Maryland) with liquid carbon dioxide used as the transitional fluid. The dried specimens were attached to aluminum specimen mounts by using silver paint. Specimens were then coated with gold in a Balzers SCD 030 sputter coater (BAL-TEC RMC, Tucson, Arizona) and photographed with a JEOL JSM-6300 scanning electron microscope (JEOL USA, Peabody, Massachusetts) with an accelerating voltage of 15 keV.

Results

Biofilms of *P. aeruginosa* had formed on the Lopez valve fragments after 14 days of incubation at 25°C. Figure 2 is the scanning electron microscope field photographed at 12 000X magnification.

Implications for Critical Care Nursing Research and Practice

We established that *P. aeruginosa* can create a biofilm on Lopez valves during a 14-day culture in Lennox L broth at 25°C. Although our results are of interest, more research must be done and verified before specific practice recommendations can be made. Future experimentation may determine if a biofilm develops when a common enteral feeding formula, rather than Lennox L broth, is used. If a biofilm does develop on Lopez valves under these conditions, it is important to determine if bacteria can be isolated and cultured from the biofilm. Lopez valves that patients have used could be cultured to identify the bacterial species present and/or the presence of biofilms by using the technique described.

Conclusion

Biofilms have been associated with acute or chronic infectious diseases and are resistant to disinfectants and antibiotics. Critical care nurses might consider changing Lopez valves at intervals of 14 days or less and perhaps at each tubing change (or per facility policy).

Additionally, critical care nurses may contemplate other opportunities to promote infection control, because biofilms can develop on numerous medical devices. Overall, few evidence-based guidelines are available for nursing practice regarding these devices. Staff education about the production of biofilms may help promote adherence to facility policies on changes of medical devices.

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In Vitro Formation of Biofilms on Lopez Enteral Feeding Valves: Implications for Critical Care Patients and Nurses
Tracy Solseng, Heather Vinson, Penelope Gibbs and Beverly Greenwald

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