Background Contamination of equipment, colonization of the oropharynx, and microaspiration of secretions are causative factors for ventilator-associated pneumonia. Suctioning and airway management practices may influence the development of ventilator-associated pneumonia.

Objectives To identify pathogens associated with ventilator-associated pneumonia in oral and endotracheal aspirates and to evaluate bacterial growth on oral and endotracheal suctioning equipment.

Methods Specimens were collected from 20 subjects who were orally intubated for at least 24 hours and required mechanical ventilation. At baseline, oral and sputum specimens were obtained for culturing, and suctioning equipment was changed. Specimens from the mouth, sputum, and equipment for culturing were obtained at 24 hours (n=18) and 48 hours (n=10).

Results After 24 hours, all subjects had potential pathogens in the mouth, and 67% had sputum cultures positive for pathogens. Suctioning devices were colonized with many of the same pathogens that were present in the mouth. Nearly all (94%) of tonsil suction devices were colonized within 24 hours. Most potential pathogens were gram-positive bacteria. Gram-negative bacteria and antibiotic-resistant organisms were also present in several samples.

Conclusions The presence of pathogens in oral and sputum specimens in most patients supports the notion that microaspiration of secretions occurs. Colonization is a risk factor for ventilator-associated pneumonia. The equipment used for oral and endotracheal suctioning becomes colonized with potential pathogens within 24 hours. It is not known if reusable oral suction equipment contributes to colonization; however, because many bacteria are exogenous to patients' normal flora, equipment may be a source of cross-contamination. (American Journal of Critical Care. 2002;11:141-149)

Pneumonia is the second leading cause of nosocomial infection in the United States. According to the Centers for Disease Control and Prevention (CDC), median rates of ventilator-associated pneumonia (VAP) are 4.2 to 16.3 cases per 1000 ventilator days in adult critical care units. Rates for VAP are highest in trauma, burn, and neurosurgical units. The estimated occurrence of VAP in critical care units is 10% to 65%, with mortality rates of 20% to 70%. When VAP occurs, the likelihood of death increases 3- to 4-fold. In recent studies, VAP increased hospital length of stay by 16 to 17 days and increased costs by almost $30,000 per case.

Assessment of potential risk factors for VAP is important so that strategies to reduce risk can be implemented. The CDC groups risk factors for nosocomial pneumonia into 5 categories: host factors, surgery, medications, invasive devices, and respiratory equipment. Harris et al proposed that 3 factors contribute to VAP in trauma patients: host, treatment-
related, and infection control-related factors. These factors lead to either inhalation or aspiration of pathogens into the respiratory tract.

Research on the potential role of airway management in the pathogenesis of VAP is limited. Airway management includes maintenance of the artificial airway (use of an endotracheal tube or tracheostomy), suctioning of the artificial airway and the mouth, and related care such as oral hygiene. Because most instances of VAP are due to aspiration of bacteria from the oropharynx,1,6,10-12 airway management practices may influence development of VAP. The purpose of our study was to identify potential pathogens in oral and endotracheal aspirates and on suctioning equipment that may contribute to VAP.

The 3 research questions were as follows:
1. What potential pathogens for VAP are cultured from oropharyngeal and endotracheal aspirates of intubated patients?
2. What potential pathogens are cultured from oral suction devices (ie, Yankauer suctioning tube), the internal lumen of the common connection section of the suction tubing, and the distal connection of the in-line suction catheter?
3. How/where is the tonsil suction device stored?

Background and Significance

Aspiration of secretions into the lower part of the respiratory tract is a risk factor for pneumonia.1,6,10-12 Many potential pathogens endogenous to the normal oral flora, such as Staphylococcus aureus and various species of Streptococcus, may be introduced into the lower part of the respiratory tract during intubation.7,11 Once a patient is intubated, microaspiration of secretions from above the cuff of the endotracheal tube may occur. Oral secretions can be colonized with endogenous and/or exogenous pathogens. Exogenous pathogens, such as gram-negative bacteria and antibiotic-resistant organisms, can be introduced into a patient’s mouth secondary to lack of handwashing and through devices such as oral suctioning equipment.1 Some organisms, such as Pseudomonas, can be transmitted either endogenously or exogenously.

A review by Kollef7 on the epidemiology and prevention of VAP emphasized the role of subglottic secretions in the development of VAP. As secretions pool above the cuff of the endotracheal tube, bacteria and secretions can gain access to the lower part of the respiratory tract by leaking around the cuff. Oral secretions may become the subglottic secretions that pool above the cuff and lead to microaspiration of secretions into the lower parts of the airway. Bonten et al14 reported that oropharyngeal colonization and duration of mechanical ventilation were the most important risk factors for VAP caused by enteric gram-negative bacteria and Pseudomonas. Other factors that may contribute to microaspiration include sedation, decreased level of consciousness, and use of nasoenteric tubes.10,15

Today, endotracheal suctioning is commonly performed with in-line (closed) suction catheters.16 Although research on in-line suctioning is limited, cited advantages include prevention of suction-induced hypoxemia, convenience, decreased exposure of healthcare staff to patients’ secretions, and cost-effectiveness when patients require frequent suctioning.17-21

Since the advent of in-line suctioning, the procedures for oral and endotracheal suctioning have changed. Historically, a single-use sterile catheter was used to suction secretions from the endotracheal tube. Once secretions were cleared from the endotracheal tube, the same catheter was used to suction secretions from the oropharynx, and then the catheter was discarded. The in-line catheter is designed only for suctioning secretions from an endotracheal tube or tracheostomy. Another device is needed to suction secretions from the oral cavity. Many caregivers use reusable equipment, such as a tonsil suction device (eg, Yankauer device), to suction the oral cavity. In addition, the suction connecting tubing and the suction canister are often used for both the in-line catheter and the tonsil suction device, requiring that the in-line suction catheter be disconnected from the suction tubing when oral suctioning is done. Rinsing of both in-line and oral suctioning devices is recommended after use; however, rinsing is not consistently done, and secretions often accumulate in the suction devices as well as in the connecting tubing.18,21 No standard for storing the tonsil suction device exists.

Studies on colonization of in-line suctioning equipment are limited. In-line suction catheters become colonized with bacteria as soon as the catheters are used on patients; however, the catheters have not been associated with an increased risk of pneumonia.24 In one study,7 use of in-line suctioning reduced the prevalence of VAP. Prolonged use of ventilator tubing and in-line suction devices has been recommended to reduce the prevalence of VAP; however, devices and equipment for management of oral secretions were not examined. Product literature26 for in-line suctioning equipment states that the tubing used for suctioning should not be used for both bronchial and oral suctioning; however, no data are published to substantiate that claim.
In-line suctioning practices may contribute to the pathogenesis of VAP. First, the mouth is not usually suctioned after each episode of endotracheal suctioning. Secretions then may pool in the oropharynx and contribute to microaspiration and VAP. Second, the reusable tonsil suction device may become colonized from bacteria exogenous to a patient's normal flora and contaminate the oropharynx. Third, using the same suction tubing for both oral and endotracheal suction devices may lead to contamination of the inline suction catheter at the common connection between the 2 devices. Figure 1 shows the proposed role of airway management in the pathogenesis of VAP.

Methods
A prospective descriptive design was used. A power analysis indicated that a sample size of 20 would allow us to detect a difference in presence of pathogens on equipment (0.0 proportion at baseline [sterile equipment] to 0.45 proportion at 24 hours after use), with a power of 74% at an α of .05 (1-tailed). The study was done in the intensive care units (medical, neurosurgical, or surgical-trauma) of a tertiary care facility in the Southeastern United States. Approval for the study protocol was obtained from the institutional review boards of both the hospital and the university. Informed consent was obtained from all subjects.

The inclusion criteria required that patients be at least 18 years old and be orally intubated for at least 24 hours before enrollment in the study. Exclusion criteria were documented presence of pneumonia or sinusitis at the time of possible enrollment in the study, reintubation at any time during the current hospitalization, diagnosis of human immunodeficiency virus infection or tuberculosis, and the presence of facial fractures.

Demographic information was obtained from patients' records by 2 of us (F. E. P. and M. L. S.). Interrater reliability was established by simultaneously collecting data on the first 2 subjects and then on one subject midway through data collection. Raters achieved 100% agreement on the items. The nursing and respiratory staff provided usual oral care and suctioning during the study period. Staff members were asked to record oral and endotracheal suctioning on the critical care flow sheet.

One investigator (M. L. S.) collected all samples that were sent for culture. The following procedures were used for collecting specimens:

1. Upon enrollment, baseline specimens of oral secretions and endotracheal aspirates were obtained by using aseptic technique. Secretions were obtained via sterile suctioning catheters and sputum traps. Endotracheal suctioning was done when the patient needed suctioning, and the patient was hyperoxegenated before the procedure. Instillation of isotonic sodium chloride solution was not used for collection of specimens.

2. All suction devices were changed by using aseptic technique: the in-line suction catheter (Steri-Cath, Portex, Inc, Keene, NH), tonsil suction device (Argyle Yankauer Suction Tube, Sherwood Medical Co, St Louis, Mo), and the common suction tubing (Argyle Non-Conductive Connecting Tube, Sherwood Medical Co). Suction devices were marked to validate that the same devices were in place during the data collection period.

3. At 24 hours after enrollment, oral and endotracheal aspirates were collected. (Time is approximate because endotracheal suctioning was done as determined by assessment of each patient.) Specimens were also obtained from the suctioning equipment by using sterile swabs and were placed into culturettes. The following parts of the equipment were swabbed: the inner lumen of the tonsil suction device (Figure 2A), the inner lumen of the suction tubing at the common connection (to either the in-line suction catheter or the tonsil suction device; Figure 2B), and the inner lumen of the distal connection of the in-line suction catheter (where it connects to the suction tubing; Figure 2C). The suction tubing was disconnected from the in-line suction catheter to obtain specimens; however, this practice was common, because the same tubing was used for both in-line and oral suctioning.

4. At 48 hours, collection of specimens was repeated. All suctioning equipment was replaced at the end of the data collection period.

Specimens were taken to a microbiology research laboratory at the University of Central Florida for qualitative cultures and were processed within standard time frames for respiratory samples. The specimens were plated by a designated laboratory technician and were cultured on blood, chocolate, and MacConkey agar. After an incubation period of 48 hours, the culture plates were assessed for potential pathogens. A clinical microbiologist experienced in interpreting respiratory specimens from patients receiving mechanical ventilation interpreted all specimen samples.

Results
Description of the Sample
A total of 20 patients were enrolled in the study by using convenience sampling. Specimens and other
data were collected at 24 hours for 18 patients (1 patient died, and 1 was extubated). Because of attrition, specimens and other data were collected at 48 hours after enrollment for only 10 patients. Few differences in culture results were found between the 24- and 48-hour collection periods; therefore, data are reported for the 18 subjects at the 24-hour measurement.

The typical subject was a 49-year-old, white woman who had been intubated for 4 days at the time of enrollment (Table 1). Most patients had teeth (89%), had a nasoenteric tube in place (94%), and were receiving antibiotics (78%) and histamine antagonists (56%). Most patients (67%) did not have any oral care within 4 hours of collection of specimens. The majority of patients were receiving synchronized intermittent mandatory ventilation. Mean ventilator settings were tidal volume, 800 mL; fraction of inspired oxygen, 0.40; positive end-expiratory pressure, 6 cm H₂O; and pressure support, 13 cm H₂O. Mean oxygen saturation was 97%.

At the time of enrollment (baseline), 17 subjects (94%) had potential pathogens for VAP in oral secretions, and 11 (61%) had potential pathogens for VAP in sputum.

**Figure 1** Role of airway management in the pathogenesis of nosocomial pneumonia. Based on the model proposed by the Centers for Disease Control and Prevention.1
Potential Pathogens for VAP in the Oropharynx and Respiratory Tract

Potential pathogens for VAP were present in oral secretions in all patients and in sputum in 67%. The median number of potential pathogens was 2 kinds of organisms in the mouth, and 1 kind of organism in the sputum. Table 2 and Figure 3 summarize culture results according to source. Gram-positive bacteria were detected most often (78% of oral secretions and 50% of sputum cultures). Gram-negative bacteria were found in the mouth in nearly half (44%) of the subjects and in one third of the sputum cultures. Drug-resistant organisms, such as methicillin-resistant \( S \) \( aureus \), were found in samples from several patients.

Potential Pathogens for VAP on Suction Devices

After 24 hours of use, most suction equipment had potential pathogens for VAP: tonsil suction device, 94%; suction tubing, 83%; and distal connection of in-line suction catheter, 61%. The devices were colonized with many of the same pathogens cultured from the oral secretions and/or sputum. Gram-positive bacteria were the most common.

Storage of the Tonsil Suction Device

During the study period, 47 observations of the location of the tonsil suction device were recorded. The most common (66%) location of the device was on a shelf near the patient’s bedside. Many of the tonsil

Table 1 Characteristics of the sample (N=18)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>Female</td>
<td>11</td>
<td>61</td>
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<tr>
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<td>White</td>
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<td>50</td>
</tr>
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<td>Black</td>
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</tr>
<tr>
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<td>17</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td>39</td>
</tr>
<tr>
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<td>7</td>
<td>39</td>
</tr>
<tr>
<td>Surgical, trauma</td>
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<td>22</td>
</tr>
<tr>
<td>Mouth care in previous 4 hours</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>Sputum color</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>28</td>
</tr>
<tr>
<td>Tan/brown</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>Yellow/green</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>Other</td>
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<td>6</td>
</tr>
<tr>
<td>Thick sputum</td>
<td>12</td>
<td>67</td>
</tr>
<tr>
<td>Days of intubation</td>
<td>1-14</td>
<td>4</td>
</tr>
<tr>
<td>Size of endotracheal tube, mm</td>
<td>6.5-9.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Score on Glasgow Coma Scale</td>
<td>3-13</td>
<td>8</td>
</tr>
<tr>
<td>Times endotracheal tube suctioned in previous 24 hours</td>
<td>3-16</td>
<td>8</td>
</tr>
<tr>
<td>Times mouth suctioned in previous 24 hours</td>
<td>1-9</td>
<td>3</td>
</tr>
</tbody>
</table>
suction devices were attached to the connection suction tubing and were hanging freely (21%). When this finding was noted, the in-line suction catheter was not connected to any suction, and the distal end was open, disrupting the “closed” system. The remaining oral suction devices (13%) were located in the patient’s bed. Most of the time (51%), the device was uncovered.

### Discussion

**Colonization of Mouth and Endotracheal Aspirates**

Potential pathogens for pneumonia were detected in both the mouth and endotracheal specimens. Many potential pathogens were found in the cultures of oral secretions, and most of the same organisms were found in the sputum cultures. Although the presence of a potential pathogen for pneumonia in a sputum culture is not definitive for a diagnosis of pneumonia, our findings support the notion that microaspiration of oral secretions occurs. Several of the organisms we detected are endogenous to the mouth, yet the bacteria are potentially pathogenic when aspirated into the lower part of the respiratory tract. Retrospective analysis of infection control data indicated that VAP was later diagnosed in 4 (22%) of the patients in our study; however, the VAP had not been diagnosed when the study began.

Early-onset VAP, which occurs between 48 to 72 hours after intubation, is usually the result of aspiration and is often due to *S aureus, Haemophilus influenzae*, or *Streptococcus pneumoniae*. Late-onset VAP is often caused by antibiotic-resistant organisms, including *Pseudomonas aeruginosa*, methicillin-resistant *S aureus*, *Acinetobacter* species, and *Enterobacter* species.\(^6\) The mean duration of intubation before enrollment in our study was 4 days. The varied duration of intubation at the time of data collection most likely resulted in the diversity of organisms detected in the mouth and sputum.

Other researchers have reported similar findings. The endotracheal tube is colonized rapidly (within 12-36 hours after intubation) by gram-positive bacteria from the mouth.\(^7,13\) Cardenosa Cendrero et al\(^12\) found an 89% prevalence of tracheal colonization. In their study,

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<table>
<thead>
<tr>
<th>Potential pathogen</th>
<th>Oral secretions</th>
<th>Sputum</th>
<th>Tonsil suction device</th>
<th>Suction tubing</th>
<th>Distal connection of in-line suction catheter</th>
</tr>
</thead>
<tbody>
<tr>
<td>All potential pathogens</td>
<td>100</td>
<td>67</td>
<td>94</td>
<td>83</td>
<td>61</td>
</tr>
<tr>
<td>Gram-positive bacteria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em>, not drug resistant</td>
<td>39</td>
<td>22</td>
<td>22</td>
<td>17</td>
<td>17</td>
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<tr>
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<td>22</td>
<td>39</td>
<td>33</td>
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<td>44</td>
<td>28</td>
<td>33</td>
<td>28</td>
<td>17</td>
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<tr>
<td>Gram-negative bacteria</td>
<td></td>
<td></td>
<td></td>
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<td>11</td>
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<tr>
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<td>11</td>
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<td>6</td>
<td>6</td>
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<tr>
<td><em>Pseudomonas</em></td>
<td>17</td>
<td>6</td>
<td>6</td>
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<tr>
<td><em>Proteus</em></td>
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<td>39</td>
<td>6</td>
<td>17</td>
<td>28</td>
<td>6</td>
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<tr>
<td>All varieties</td>
<td></td>
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</tbody>
</table>

**Figure 3** Potential pathogens for ventilator-associated pneumonia by type of organism.
gram-positive bacteria were noted within the first 24 hours of mechanical ventilation and were attributed to translocation of bacteria during intubation. Gram-negative bacteria, antibiotic-resistant organisms, and yeast were found later during the course of intubation. Trauma can increase the risk for Staphylococcus aureus colonization and ventilator-associated pneumonia (VAP) [25,27]. George et al. [28] found a high prevalence of tracheal colonization with S. aureus, *Streptococcus* species, *H. influenzae*, and *Pseudomonas*. They noted a 12.5% prevalence of colonization with gram-negative bacteria. Colonization with methicillin-resistant *S. aureus* occurred later in the course of intubation.

Oral hygiene may play a role in oral colonization. Munro and Grap [29] found that plaque increased during a 7-day period after intubation, and they proposed a link between plaque formation and VAP. They reported cases of VAP attributed to the presence of *S. aureus*, *Pseudomonas*, and *Acinetobacter* detected in cultures of oral specimens obtained before VAP developed. We did not use plaque scores as a measure of oral hygiene, an aspect that is a limitation of our study.

Only 33% of the patients in our study had received some type of oral care in the 4 hours preceding the specimen collection periods, a situation that may have contributed to our findings. Abele-Horn et al. [30] found that selective oropharyngeal decontamination significantly reduced the rate of colonization and infection in patients receiving mechanical ventilation for more than 4 days. Kollef [31] suggested that chlorhexidine gluconate rinses for selected patients might be beneficial in reducing bacteria in dental plaque, which may be a source of pathogens for development of VAP. Topically applied antibiotics or chlorhexidine gluconate rinses may aid in reducing bacteria in the mouth, potentially decreasing the risk for VAP.

New endotracheal tubes have been introduced to provide continuous aspiration of subglottic secretions and have been effective in reducing the occurrence of VAP [31-33]; however, oral suctioning may be just as important. In our study, up to 16 g of secretions were aspirated from patients’ mouths during specimen collection (mean, 5 g). Oral suctioning is not always done concurrently with endotracheal suctioning. A recent survey [34] of nurses and respiratory therapists indicated that just over half of respondents suctioned patients’ mouths after each episode of endotracheal suctioning.

### Colonization of Equipment

Oral and endotracheal suctioning equipment became colonized with potential pathogens within 24 hours of use. Organisms cultured from the equipment were the same as those found in oral secretions and sputum. We detected gram-positive bacteria on 50% or more of the devices and gram-negative pathogens on 22% to 28% of the devices. Not all devices became colonized. For example, gram-negative organisms were detected in 44% of the specimens of oral secretions but on only 28% of the tonsil suction devices. Most of the tonsil suction devices had visible mucus on both the interior and the exterior surfaces. Although evidence of rinsing of the tonsil suction device was not consistent, rinsing may account for fewer bacteria on the device. The CDC [35] recommends rinsing noncritical equipment, such as the tonsil suction device, with sterile water and then placing the equipment on a paper towel to air dry. Also, some bacteria may not grow outside the respiratory tract.

The presence of potential pathogens in the distal connection section of the in-line suction catheter may have occurred because inefficient or lack of rinsing of the catheter after use led to adherence to the inner lumen of secretions suctioned from the endotracheal tube. [36,37] Blackwood [38] reported that most caregivers did not think that the suction catheter was rinsed effectively after use. In-line suction catheters are supposed to be rinsed with sterile isotonic sodium chloride solution via an instillation port after use; this action would theoretically rinse most bacteria-laden secretions into the collection unit. However, self-reported data from nurses and respiratory therapists indicate that only 42% of staff always rinse the in-line suction catheter after use.

Another possible explanation for the presence of potential pathogens in the distal connection section is cross-contamination of bacteria from the common suction tubing that is used for both oral and endotracheal suctioning. We detected bacteria in the tubing for all but one patient. Possibly, some bacteria are introduced into the distal in-line suction connection during attachment and removal of the common suction tubing.

The role of equipment as a source of contamination and infection has been examined. The equipment studied included heat and moisture exchangers, ventilator circuitry, in-line nebulizers, endotracheal tubes, and suction catheters. [33,34,37] These studies indicated that prolonged use of equipment does not increase the risk for VAP and may actually reduce the risk. However, Weber et al. [39] reported that pathogens colonizing or infecting the respiratory tract of patients receiving mechanical ventilation were found on the exterior and port connection of manual resuscitation bags and were considered a potential source of infection. Therefore, equipment such as suction tubing used for both in-line suctioning and tonsil suction devices may later be a source of reinfection.
Oral suctioning equipment has not been explored as a potential source of pathogenic organisms even though such devices are used to suction a patient’s oral mucosa several times a day. In our study, tonsil suction devices, the in-line suction catheter, and suction tubing harbored potential pathogens for VAP.

### Storage of Tonsil Suction Device

The tonsil suction device was stored in a variety of places, depending on the clinician. Visible mucus was noted on many of the devices, and none of the devices was placed on a paper towel as recommended by the CDC. Devices that were found on shelves near patients’ bedsides were stored either uncovered or in the original package; such storage may contribute to bacterial growth because it provides a warm, moist environment. The tonsil suction device was connected to the suction tubing 21% of the time, leaving the in-line suction catheter without continuous suction and the distal end open. We do not know if this practice contributed to growth of pathogens in the in-line suction catheter, because continuous suction is not applied when the equipment is used in this way.

### Additional Findings

Pressures in the cuffs of the endotracheal tubes were measured at time of specimen collection and were compared with pressures recorded approximately 6 to 7 hours earlier. A total of 41 observations were made. In 30 instances (73%), the cuff pressure was less than that recorded in the morning. Mean cuff pressures were 21 cm H$_2$O in the morning and 17 cm H$_2$O in the afternoon. This difference was significant (paired t test, $P<.001$). In 8 observations (20%), the pressures were 10 to 12 cm H$_2$O less than the morning pressure. These findings are clinically important, because in one study, maintaining the cuff pressure at 20 cm H$_2$O or higher reduced the risk for VAP.

### Limitations

The study had several limitations. It was done at a single point during a patient’s intubation, and the duration of intubation at the time of enrollment in the study varied. Most subjects had potential pathogens for VAP present in oral secretions and sputum when the study began. We do not know when colonization occurred, because patterns of bacterial growth in secretions and devices during the course of intubation were not determined. Most patients were receiving antibiotics, which may have influenced findings.

The sample size was adequate to determine colonization of devices within 24 hours after use of the devices. However, only half of the subjects had data collected for the proposed study period of 48 hours, limiting additional analysis. The study was done at a single site and may be biased by local practices of suctioning by the nursing and respiratory care staff. Only qualitative cultures were done. Quantitative cultures would have yielded specific information about bacterial growth patterns.

### Implications

Strict adherence to infection control practices are advocated as one of the most effective ways clinicians can prevent occurrence of nosocomial infections. Critical care nurses and respiratory therapists responsible for patients receiving mechanical ventilation must observe infection-control practices to help minimize the occurrence of VAP. Critical care nurses should continue to investigate suctioning practices, to determine appropriate practice based on empirical data. Inadequate oral care may play an important role in the colonization of oropharyngeal secretions and the development of VAP. Mouth care has always been considered part of basic hygiene. Perhaps oral care should move to the forefront, and its impact on the overall health of critically ill patients should be examined.

Critical care practitioners should continue to question practices related to suctioning in intubated patients to determine ways to minimize the occurrence of VAP. Further studies are needed to clarify the role of suctioning equipment in the pathogenesis of VAP. Research is needed to establish clinical practice guidelines; however, research related to many aspects of suctioning and airway management is lacking.

Potential research questions include the following:

- Does the implementation of specific oral care guidelines decrease the prevalence of equipment contamination, tubing contamination, and VAP?
- Does use of a separate suction setup eliminate the contamination of the in-line catheter?
- Is there a difference between single-use disposable tonsil suction devices and reusable-disposable tonsil suction devices related to oropharyngeal colonization and VAP?
- Is there a relationship between the colonized suction equipment, oral secretions, and VAP?

### Conclusions

Our results indicate concurrent colonization of the mouth, sputum, and suctioning equipment with similar bacteria in patients receiving mechanical ventilation. All bacteria are potential risks for VAP in intubated patients. Tonsil suction devices can host a multitude of potential pathogens and have been overlooked as a potential contributor to the development of VAP. Suction tubing and in-line suction tubing, at the distal
end, harbor potential pathogens, and the colonization of these areas may also play a role in the etiology of VAP. It is not known whether the reusable oral suctioning equipment contributes to colonization of patients with organisms that can cause VAP; however, because these organisms are exogenous to normal oral flora, contamination of the devices might result in contamination of the oral secretions and sputum. Patients may be at risk of reinoculation of pathogenic organisms from respiratory suction equipment.

ACKNOWLEDGMENTS
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