Patterns and Routes of Tracheobronchial Colonization in Mechanically Ventilated Patients*

The Role of Nutritional Status in Colonization of the Lower Airway by Pseudomonas Species

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Tracheobronchial colonization by Gram-negative bacteria is common in mechanically ventilated patients. Pseudomonas sp are commonly isolated from the lower airways. We hypothesized that Pseudomonas sp would preferentially colonize the lower airway and would be more common in patients with poor nutritional status. We serially collected 75 pairs of upper and lower respiratory tract cultures from 14 patients treated with mechanical ventilation for at least one week, examined patterns of airway colonization and routes of bacterial entry for Pseudomonas sp and other enteric Gram-negative bacteria (EGNB), and related these findings to host-associated factors, including nutritional status. Pseudomonas sp were the most common species isolated from the lower airway, found in nine of 14 patients and in 41.3 percent of all cultures. In contrast to other EGNB, Pseudomonas sp were found significantly (p<0.05) more often in the tracheobronchial tree (31 of 75 cultures) than in the oropharynx (18 of 75 cultures). Primary colonization of the lower airway by Pseudomonas sp was found in four patients, while other EGNB never followed this pattern when subjects were studied with cultures taken every third day. A host-related factor related to lower airway colonization by Pseudomonas species was poor nutritional status, assessed by a multifactorial index (p<0.01). We conclude that in mechanically ventilated patients, Pseudomonas sp colonize the lower airway in a different pattern and by a different route from those of other EGNB. The findings that Pseudomonas sp preferentially colonize the tracheobronchial tree may be important for the design of strategies to prevent airway colonization. The recognition that poor nutritional status, a potentially modifiable host-related factor, favors lower airway growth of Pseudomonas sp suggests one direction for future infection-control efforts. (Chest 1989; 95:155-61)

EGNB = enteric Gram-negative bacteria; PNI = prognostic nutritional index; TSF = triceps skinfold thickness; ST = serum transferrin; LS = lymphocyte score.

Patients treated with endotracheal intubation and mechanical ventilation have enhanced in-hospital morbidity when they develop nosocomial pneumonia, a complication with an incidence of 10 to 70 percent, paralleling the severity of a given patient's illness.1,4 Gram-negative colonization of the respiratory tract is a frequent harbinger of pneumonia, and among patients ill enough to require the use of respiratory assistance devices, one particular group of bacteria, Pseudomonas sp, have become common and harmful infectious agents.3,5,6 Current hypotheses suggest that Gram-negative bacteria reach the lungs of mechanically ventilated patients by aspiration from a colonized oropharynx.6,7 However, a study of tracheostomized patients has shown that the upper and lower airways can become colonized independently of each other, the lower respiratory tract becoming colonized as a primary event without initial colonization of the oropharynx, particularly when Pseudomonas sp were present.9 Other data in mechanically ventilated patients suggest a similar dichotomy between upper and lower airway colonization patterns. Schwartz et al8 reported that while Enterobacteriaceae enter the trachea following initial oropharyngeal colonization, non-Enterobacteriaceae, such as Pseudomonas sp, rarely were found at another site before tracheobronchial colonization in mechanically ventilated patients. Pingleton et al8 also showed that primary tracheal colonization by Gram-negative bacteria can occur in mechanically ventilated patients and that the stomach can serve as a reservoir for these organisms.

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While prior investigations have established risk factors for both upper and lower airway colonization, few such studies have been done in critically ill patients treated with mechanical ventilation. In addition, all Gram-negative bacteria have usually been grouped together, and therefore the unique behavior of, and predisposing factors for, colonization by certain organisms, such as Pseudomonas sp, have not been identified. We undertook the current study to examine whether there was a "tropism," or preference, of Pseudomonas sp for the lower airway rather than the upper airway of mechanically ventilated patients. Based on data collected in tracheostomized patients, we expected that if such a tropism existed, it would express itself as frequent and primary lower airway colonization by Pseudomonas sp. The presence of an endotracheal tube, similar to a tracheostomy, might permit such a pattern to emerge, because bacteria would have equal access to both the upper and lower respiratory tracts. Certain organisms might have a preference for the lower airway, because bacterial adherence is thought to be a pathogenic mechanism of airway colonization, and in vitro studies have shown that tracheal cells can inherently bind more Pseudomonas bacteria than can oropharyngeal cells. Specifically, patients' nutritional status has been shown to affect this preferential binding of Pseudomonas sp to the tracheal cells of tracheostomized patients. Malnourished patients had a higher degree of tracheal cell adherence and more frequent Pseudomonas sp colonization of the lower airway than better nourished patients.

In the current study, we prospectively collected paired cultures from the upper and lower respiratory tracts of mechanically ventilated patients to observe patterns of colonization and routes of entry of specific organisms into the lower airway. We examined whether Pseudomonas sp colonize the lower airway as a primary event, and whether colonization patterns with these organisms differ from patterns seen with other Gram-negative bacteria. We also related these colonization patterns to specific risk factors, including a prospective evaluation of patient nutritional status.

**Materials and Methods**

**Patients**

Patients admitted to the medical intensive care unit at Winthrop-University Hospital were eligible for this study if they required endotracheal intubation and mechanical ventilation for the treatment of respiratory, neuromuscular, or cardiovascular disease. To be included in the study, patients had to give informed consent and to remain on mechanical ventilation for a minimum of one week. Individuals were excluded if, at the time of endotracheal intubation, they had a diagnosis of an acute pneumonia as defined by results of history, physical examination, and chest roentgenogram. Patients were followed up by one of the investigators until death or discharge from the intensive care unit.

Fourteen subjects satisfied all inclusion criteria. Four other subjects were enrolled but later excluded because they received ventilation for less than one week. The duration of mechanical ventilation ranged from seven to 55 days (mean ± SD, 23 ± 14 days). The causes of respiratory failure were chronic obstructive pulmonary disease in five patients (two with chronic bronchitis); adult respiratory distress syndrome in two patients; neuromuscular disease in five patients; and cardiac disease (postcardiac arrest) in two patients. Nine subjects were smokers, and five were nonsmokers. The group had a mean age of 63 years (range of 31 to 80 years) and consisted of six men and eight women. Corticosteroids were given to eight subjects during the course of their illness; antibiotics were administered to 13 subjects; antacids or H2-blocking agents were received by 11 subjects; and all individuals in the study group had a nasogastric tube placed (of varying sizes in individual patients) and received enteral nutrition. All subjects were receiving supplemental oxygen (mean FIO2 = 0.4) on enrollment.

**Cultures**

Patients had respiratory tract cultures collected simultaneously from the oropharynx and tracheobronchial tree, and each such sampling comprised a "set" of respiratory tract cultures. A minimum of three culture sets were obtained serially from each patient, every third day during the course of mechanical ventilation. The first set of cultures was obtained within three days of instituting mechanical ventilation. A total of 75 paired sets of upper and lower respiratory tract cultures were collected from the 14 patients during the study, for a mean of 5.3 paired culture sets per patient. Cultures were not taken from patients requiring long-term mechanical ventilation after four weeks. Oropharyngeal cultures were obtained by rubbing the buccal mucosa bilaterally with a sterile cotton swab, which was then placed into modified Stuart's bacterial transport medium (Marion Scientific). Tracheobronchial cultures were collected by sterile suctioning of sputum directly from the trachea by inserting a suction catheter through the endotracheal tube. Cultures were immediately transported to the microbiology clinical laboratory and inoculated within 30 minutes of collection onto blood agar, MacConkey's medium, and into thioglycolate broth. They were incubated in ambient oxygen concentrations at 35°C and all enteric Gram-negative bacteria were identified qualitatively but not quantitatively by the API-20 E System (Analytab Products, Inc). If no bacterial growth was seen after 24 hours on the plates, the thioglycolate broth was subcultured onto plates to increase the sensitivity for detecting any degree of bacterial growth present in the sample. Data analysis was restricted to gram-negative enteric organisms.

**Nutritional Evaluations**

Each subject had a nutritional assessment by a clinical dietitian on entry into the study and again after 14 days, if the patient was still receiving mechanical ventilation at that time. For each individual we generated a prognostic nutritional index (PNI) according to previously published methods. This index is a multifactorial assessment of nutrition that incorporates measurements of triceps skinfold thickness, serum albumin, serum transferrin, and total lymphocyte count according to the following formula:

\[
\text{PNI} = 158 - 16.6(\text{SA}) - 0.78(\text{TSF}) - 0.2(\text{ST}) - 5.8(\text{LS})
\]

where SA is serum albumin measured in g/dl; TSF is triceps skinfold thickness in mm; ST is serum transferrin in mg/dl; and lymphocyte score (LS) is measured on a scale from 0 to 2, in which 0 = less than 1,000 total lymphocytes, 1 = 1,000 to 2,000 total lymphocytes, and 2 = greater than 2,000 total lymphocytes. Repeated measurements of the PNI were made for seven subjects receiving nutritional support (either enteral feeding or parenteral nutrition), and an average value was calculated to give an estimate of their overall average nutritional condition during the study. The seven other patients with shorter periods of intubation had only one measurement of the PNI made.
Data Analysis

Culture results were correlated with clinical parameters and nutritional assessments. Patients with EGNB isolated qualitatively in any concentration from a mucosal culture were said to have colonization if there was no radiographic evidence of pneumonia. Colonization by Pseudomonas sp was distinguished from colonization by other EGNB and analyzed separately. In reviewing serial paired sets of respiratory cultures, it was sometimes possible to follow the pattern of spread of a particular EGNB which could appear first at one respiratory tract site and then at the other. While a given organism often appeared at both respiratory tract sites simultaneously, in ten instances involving six subjects, an organism's site of initial colonization could be identified, and these patterns were evaluated.

Respiratory assistance devices were changed according to standard hospital policy, and no surveillance cultures were taken from these devices. Ventilator tubing and cascade humidifiers were changed every 24 hours. All airway suctioning was done by the intensive care unit's nursing staff with sterile technique and new sterile equipment for each suction treatment.

Data were stored and analyzed using the Statview software package (Brainpower). Paired data were analyzed by a paired t-test or Spearman rank correlation. Clinical correlates of airway colonization were analyzed by χ² analysis.

RESULTS

Frequency of Colonization at the Two Respiratory Tract Sites

A total of 75 sets of paired cultures were collected simultaneously and serially from both the buccal mucosa and tracheobronchial tree of the 14 subjects. Enteric Gram-negative bacteria (EGNB) were present in the initial lower respiratory tract culture in three of the 14 subjects. EGNB were found at least once in the tracheobronchial cultures of 11 subjects, while three subjects were never colonized during the study. In nine of these 11 colonized individuals, Pseudomonas sp were present, while two subjects had other EGNB but never Pseudomonas sp. Of the nine subjects harboring Pseudomonas sp, four had these organisms exclusively, while five had them in conjunction with other EGNB.

Among the 75 pairs of serially collected cultures, Pseudomonas sp were isolated significantly (p≤0.05) more often from the tracheal site than from the buccal site (Fig 1). These organisms were found in 31 of 75 tracheal cultures but in only 18 of 75 buccal cultures. In no individual were these bacteria ever isolated more often from the buccal site than from the tracheal site. An opposite pattern emerged for colonization by other EGNB (Fig 1). Excluding Pseudomonas sp, other EGNB were found significantly (p≤0.05, by paired t-test and Spearman rank correlation) more often at the buccal site than at the tracheal site. These organisms were isolated from 34 of 75 buccal cultures, but from only 23 of 75 tracheal cultures and in no individual ever more often from the tracheal site than from the buccal site.

Identity of the Colonizing Organisms at Each Respiratory Tract Site

The identity of EGNB colonizing each site is shown in Figure 2. In the tracheobronchial tree Pseudomonas species

![Figure 1. Frequency of colonization at two airway sites by identity of colonizing bacteria. Pseudomonas sp more often at the tracheobronchial site (hatched bars) than oropharyngeal site (open bars) in serially and simultaneously collected pairs of airway cultures (p≤0.05). Opposite pattern observed for other EGNB, oropharyngeal site colonized more often than tracheobronchial site (p≤0.05).](http://journal.publications.chestnet.org/pdaaccess.ashx?url=/data/journals/chest/21587/)

![Figure 2. Identity of Gram-negative organisms colonizing the oropharynx (open bars) and tracheobronchial tree (hatched bars) in 75 pairs of serially collected cultures. Pseudomonas sp were most common organisms at both sites, found more often in lower airway cultures than in upper airway cultures. All other Gram-negative isolates appeared more often in upper than lower airway cultures.](http://journal.publications.chestnet.org/pdaaccess.ashx?url=/data/journals/chest/21587/)
sp were the most commonly isolated bacteria, found in 41.3 percent of all cultures, and found more often in tracheal cultures than in buccal cultures. In contrast, all the other species of EGNB shown in Figure 2 were isolated more often from buccal than from tracheal cultures. Although Pseudomonas sp were also the most frequently isolated EGNB from the buccal site (24 percent of all cultures), the next most frequent organisms were Enterobacter aerogenes (18.6 percent of all cultures) and Klebsiella pneumoniae (13.3 percent of all cultures).

Relationship of Host Factors to Colonization Patterns

Because Pseudomonas sp were the most common colonizing organism in the tracheobronchial cultures, we examined the relationship of host factors to colonization of the lower respiratory tract by this organism. Nutritional status was the most important factor to affect lower airway colonization by Pseudomonas sp. In the eight patients with the better nutritional status (PNI less than 67) 11 of 44 cultures showed Pseudomonas sp. The six patients who were less well nourished (PNI greater than 67) had Pseudomonas sp in significantly (p≤0.01) more cultures (20 of 31). Of the eight patients with a PNI less than 67, only four were ever colonized by Pseudomonas species, while five of the six with a PNI above 67 had these organisms in their tracheobronchial tree. These observations (Fig 3) indicate that when percentage of total, serially collected, cultures is used as an indicator, lower airway colonization by Pseudomonas sp was more common in the poorly nourished than in the better nourished patients receiving mechanical ventilation. During the course of this study, we did not observe a reduction in the PNI of any of the seven subjects who received nutritional support and had serial nutritional assessments. However, no active nutritional intervention protocols were followed, and patients received nutritional support under routine hospital guidelines.

The use of corticosteroid therapy did not appear to be a factor promoting lower respiratory tract colonization by Pseudomonas sp. Patients receiving steroid therapy had significantly (p=0.01) fewer tracheal cultures containing Pseudomonas sp than patients not receiving this therapy. The eight steroid-treated patients had nine of 42 tracheal cultures with Pseudomonas sp (with only four of the eight ever having these organisms), while the six patients not receiving steroids had 22 of 33 cultures with Pseudomonas (five of the six having these organisms). On the other hand, other EGNB were more commonly found in steroid-treated subjects (15 of 39 cultures) than in non-steroid-treated subjects (eight of 36 cultures), but this finding did not reach significance (p=0.10).

Since all subjects had been treated with a nasogastric tube and 13 had received antibiotics, these interventions could not be evaluated as factors leading to colonization. The 11 patients who received either antacids or H2-blocking drugs had a total of 53 tracheal cultures, of which 24 contained Pseudomonas sp. This was in contrast to seven of 22 cultures with Pseudomonas sp in the three patients who did not receive this therapy. The observation that patients receiving therapy to raise gastric pH had colonization in the tracheobronchial tree by Pseudomonas sp more often than patients who did not receive this therapy did not achieve significance by χ² analysis (p=0.20).

Oxygen concentration at the time of intubation could not be related to colonization risk, in that patients with Pseudomonas sp in the tracheobronchial tree received a mean of 40 percent oxygen, while those without colonization received a mean of 41 percent oxygen.

Sequence of Colonization at Both Respiratory Tract Sites (Fig 4)

In many instances the same organism appeared at both cultured sites at the same time. However, in ten instances in six patients, the use of serial cultures allowed us to observe a sequence of colonization by a particular organism because one site became colonized before the other. We evaluated these findings with the understanding that since cultures were taken every third day, our interpretations would be limited. In four patients the tracheobronchial tree was colonized before the oropharynx, and in each of these instances Pseudomonas sp were the colonizing bacteria. In six instances colonization began first in the oropharynx, and then the organism moved to the tracheobronchial
tree and this pattern was seen only with non-Pseudo-
monas EGNB. The finding that Pseudomonas sp colonized the trachea initially while other EGNB colonized the oropharynx initially was significant (\(p \leq 0.01\)), but its interpretation is limited by our having collected samples every third day.

Among the six individuals who had initial orophar-
ryngeal colonization followed by tracheal colonization with non-Pseudomonas EGNB, four subsequently developed tracheal colonization by Pseudomonas sp, while two did not. These four subjects were more malnourished (PNI \(\geq 60\)) than the two subjects (PNI \(\leq 60\)) who did not subsequently become colonized by Pseudomonas sp, an observation that approached significance (\(p = 0.06\)). These data, shown in Figure 4, indicate that, in addition to malnutrition, prior transfer of non-Pseudomonas Gram-negative bacteria from the oropharynx to the trachea was a risk factor for subse-
quent colonization by Pseudomonas sp.

**Occurrence of Pneumonia**

During the course of follow-up, six patients develop-
ed hospital-acquired pneumonia, four of whom had preceding tracheobronchial colonization by Pseudo-
monas sp. The diagnosis of pneumonia was a clinical one, requiring a new pulmonary infiltrate with either fever or leukocytosis, and patients were treated for the organisms present in sputum cultures, which were Pseudomonas species in four cases. During the study, these patients were not colonized significantly more often (14 of 33 cultures) by Pseudomonas species in the trachea than the eight patients who did not develop pneumonia (17 of 42 cultures). The initial oxygen concentration used was no different in those who acquired pneumonia than in those who did not.

**DISCUSSION**

Respiratory tract colonization is common in hospi-
talized patients, with a frequency that parallels the degree of underlying illness in a given individual. Among critically ill patients treated with endotracheal intubation and mechanical ventilation, such colonization becomes more prominent as time in the intensive care unit increases and frequently culminates in the development of nosocomial pneumonia. In studies of critically ill patients, tracheobronchial colonization by enteric Gram-negative bacteria has been found in as few as 28 percent of intensive care unit patients or in as many as 100 percent of those with long-term intubation. When tracheobronchial colonization occurs in intubated patients, the source of bacteria has been suggested to be the environment, the orophar-
rynx, or the gastrointestinal tract. A specific rela-
tionship between mode of bacterial entry to the lower airway and host factors favoring colonization has not been previously examined.

In the current study we observed that 78 percent of 14 patients treated with endotracheal intubation and mechanical ventilation for at least one week were colonized by enteric Gram-negative bacteria. The frequency of colonization increased over time, only 22 percent of the subjects being colonized at the start of mechanical ventilation. The most common bacteria found in these individuals was Pseudomonas sp, which were cultured from the lower respiratory tract of 64 percent of the patients and were present in 41 percent of all tracheobronchial cultures.

The pattern of airway colonization was different for Pseudomonas species than for other enteric Gram-negative bacteria (EGNB). We found, using serial and paired cultures of both the upper and lower respiratory tract, that these organisms were more commonly isolated from the tracheobronchial site than from the oropharyngeal site, while all other EGNB behaved oppositely (Fig 1 and 2). Overall, 41 percent of the serially collected tracheobronchial cultures contained Pseudomonas sp, while only 24 percent of the paired oropharyngeal cultures had these organisms. In con-
trast, non-Pseudomonas EGNB were isolated from only 30 percent of all tracheobronchial cultures but from 45 percent of all oropharyngeal cultures. Also, with serial paired samples, no patient had Pseudo-
monas sp isolated more often from the upper airway than from the lower airway, and no patient had other EGNB isolated more often from the tracheobronchial tree than from the oropharynx.

Not only did we find Pseudomonas species coloniz-
ing the respiratory tract in a pattern different from other EGNB, but also that the route of entry for these organisms into the tracheobronchial tree may have been distinctive. Within the limitations of collecting samples every third day, we were able to use serial paired cultures to identify which of the two respiratory tract sites was colonized first in four of the nine patients who harbored Pseudomonas sp in the tracheobronchial tree. In all of these individuals the lower airway became colonized before the oropharynx, indicating possible primary tracheobronchial colonization by these organisms. In six instances, other EGNB could be traced for their route of tracheobronchial entry, and in all of these the oropharynx was colonized first (Fig 4). In addition, four of the patients who had oropharyngeal to tracheal transfer of Gram-negative bacteria subsequently developed apparent primary lower airway colonization by Pseudomonas species. By collecting cultures only every third day, we might have missed other episodes of bacterial colonization of one site before another. Although less likely, a different sequence of events might have emerged with more frequent sampling. Thus, our findings must be confirmed by a similar study using daily cultures of both respiratory sites.

These data suggested that of all EGNB, Pseudomonas sp may have a unique tropism to colonize the lower airway rather than the oropharynx when both sites are equally accessible to bacterial entry, as is the case when an endotracheal tube is present. This tropism was expressed as more frequent tracheobronchial than oropharyngeal, colonization by Pseudomonas sp (Fig 1 and 2) and as primary lower airway growth of these organisms in some patients. Other EGNB did not express such a tropism, and tracheobronchial colonization with these bacteria occurred less often than oropharyngeal colonization and could occur after these organisms had first attached to the upper airway. The finding that Pseudomonas sp exhibited a different colonization pattern in the respiratory tract than other Gram-negative bacteria did reach statistical significance in our population of 14 subjects. However, these data could be strengthened by confirming them in more subjects in other critical care settings, stratified by underlying disease process. Nonetheless, these observations agree with our previous finding that Pseudomonas sp, in contrast to other EGNB, preferentially and persistently colonize the lower airway of patients with chronic tracheostomy. The explanation for this pattern of colonization is unknown, but may relate to the observation that tracheal cells can bind more Pseudomonas organisms than can buccal cells when bacterial adherence is measured in vitro with isolated human epithelial cells.

Our data are similar to other studies of mechanically ventilated patients. Schwartz et al found that all of 20 patients receiving prolonged orotracheal intubation were colonized by Gram-negative bacteria, while Pingleton et al found colonization in 89 percent of mechanically ventilated patients. Pseudomonas sp were the dominant tracheobronchial colonizer in several studies of critically ill patients. Johanson et al found these organisms in 26 percent of intensive care unit patients in the early 1970s, while Bryant et al found them in approximately 40 percent of surgical patients treated with mechanical ventilation in the same period. In mechanically ventilated brain-injured patients, P aeruginosa was the most common tracheobronchial organism, found in 52 percent of all study patients. More than half of all patients treated with long-term tracheostomy have Pseudomonas sp found in tracheobronchial cultures at some point, and often these organisms persist. Our finding that Pseudomonas sp can colonize the trachea as a primary event is similar to data reported by Schwartz et al in which 13 of 21 isolates of non-Enterobacteriaceae from mechanically ventilated patients were found in the trachea before the hypopharynx.

The finding that the route of bacterial entry into the lower respiratory tract can vary with the organism present in mechanically ventilated patients may have implications for preventing airway colonization and infection. Efforts directed at the oropharynx are likely to prevent the growth of non-Pseudomonas EGNB and thereby prevent upper airway colonization that may lead to secondary colonization caused by aspiration into the lung. Indirectly, these efforts might also limit tracheobronchial Pseudomonas colonization by preventing the prior colonization and injury of the lower airway by certain EGNB that seems to lead to favorable growth conditions for later colonization by Pseudomonas sp. However, the possibility that Pseudomonas sp can cause primary lower airway colonization and the tropism of these bacteria for the tracheobronchial tree indicate that efforts to prevent their colonization may have to be directed at the lower airway as well.

An additional route of bacterial entry into the lung has recently been described, that of gastric to tracheal transmission along a nasogastric tube. We did not perform gastric cultures, so we cannot directly comment on this pathway in our patients, but all of the study subjects had a nasogastric tube in place, so that this factor was common to all patients and could not be related to observed routes of bacterial spread. Although our data are compatible with a tropism of Pseudomonas sp for the lower airway, an alternative explanation also exists. Pseudomonas sp might have originated from the environment, been inoculated into the lower respiratory tract during endotracheal suctioning, and then moved retrograde into the oropharynx, while other EGNB started in the stomach.

Tracheobronchial Colonization in Mechanically Ventilated Patients (Niederman et al)
and moved into the oropharynx and then the trachea. We do not favor such an explanation, because suctioning was also applied to the oropharynx, and thus we would have expected to find Pseudomonas sp at this site as often as in the lower airway if the environment were a source for Pseudomonas sp and if there was no specific tracheobronchial tropism for their colonization.

We identified risk factors for tracheobronchial colonization by Pseudomonas sp. Prior transfer of other EGNB from the oropharynx to the trachea was a risk factor for tracheobronchial Pseudomonas sp colonization. The use of gastric acid-neutralizing therapy did not increase the likelihood of finding Pseudomonas sp in the lower airway, despite observations by others that neutralization of gastric acid can promote the growth of Gram-negative bacteria in the stomach and is a risk factor for nosocomial pneumonia.

The most important host factor to influence colonization patterns was patient nutritional status. Those with the highest prognostic nutritional index, ie, the most malnourished, had significantly higher rates of isolating Pseudomonas sp from the tracheobronchial tree than those with lower indices (Fig 3). We analyzed the data in Figure 3 by examining percentage of cultures with Pseudomonas sp in patients above and below a PNI value of 67 to see whether nutritional status was in any way serving as a risk factor for colonization. Although this value did not clearly separate colonized from noncolonized individuals, a significantly greater percentage of lower respiratory tract cultures contained Pseudomonas sp in patients with a PNI above 67 than in patients with a value below 67. While determination of PNI for any given patient may not necessarily be predictive of colonization status, in general, nutritional status may be a risk factor for airway colonization by Pseudomonas sp. Poor nutritional status also seemed to enhance the effect of prior transfer of other EGNB from oropharynx to trachea, thereby increasing the occurrence of subsequent lower airway growth of Pseudomonas sp (Fig 4). Malnutrition has multiple effects on pulmonary host defenses, but it may increase the occurrence of tracheobronchial colonization by leading to an increase in the tracheal cell-binding capacity for P aeruginosa.

Data in this study have shown that Pseudomonas sp commonly colonize the tracheobronchial tree of mechanically ventilated patients. This colonization occurred in a different pattern and by a different route from that seen with other EGNB. Risk factors for Pseudomonas sp colonization were examined, and we found that the most important was nutritional status. Since this factor can be modified, its recognition as a host-related factor favoring tracheobronchial colonization by Pseudomonas sp may be useful for the future development of programs to prevent colonization.

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