Effects of Sucralfate vs Antacids on Gastric Pathogens

Results of a Double-blind Clinical Trial

Kimberly S. Ephgrave, MD; Rachel Kleiman-Wexler, PharmD; Michael Pfaller, MD; Brenda M. Booth, PhD; David Reed, PhD; Lisa Werkmeister, RN; Sharon Young

Background: Unblinded studies suggested that sucralfate prophylaxis for stress ulcers is associated with a lower rate of nosocomial pneumonia than acid-reducing approaches. We performed a randomized, double-blind, double-sham clinical trial comparing the exact microbial effects of each treatment.

Methods: One hundred forty patients entered this study before major elective surgery, allowing baseline cultures of gastric and pulmonary secretions to be obtained intraoperatively. Postoperatively, the patients were treated with standard doses of either sucralfate or antacids, plus a sham of the other drug. Cultures were repeated twice daily for 3 days. Molecular epidemiological typing was used to track the appearance of specific microbes and their transmission from site to site, and clinical end points were compared. The number of patients chosen was for sufficient statistical power to detect differences in the microbial measures, as detecting differences in clinical measures would have required increasing the sample size by an order of magnitude.

Results: Gastric pH was affected by the form of stress ulcer prophylaxis throughout the study, and this pH effect affected the number of new gastric organisms appearing in the 2 different groups. Colonization of the airway with new gastric organisms occurred more frequently in the antacid than in the sucralfate group, and colonization of the airway with organisms of gastric origin was associated with occurrence of postoperative pneumonia.

Conclusions: Both sucralfate and antacids offered safe and effective stress ulcer prophylaxis in this double-blind clinical trial of postoperative patients in an intensive care unit. In association with the drug’s effects on gastric pH, more new pathogens appeared in the gastric contents of antacid-treated than sucralfate-treated patients.

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STRESS ULCER prophylaxis with agents that affect gastric acidity became standard therapy for physiologically stressed patients after controlled clinical trials demonstrated a reduction in the incidence of gastrointestinal tract bleeding when gastric pH is maintained above 4.0.1-3 Prevention of upper gastrointestinal tract bleeding during stress also has been accomplished with the surface-active agent sucralfate, with an efficacy similar to that of acid reduction, in unblinded clinical trials.4-6

Gastric contents serve as a reservoir for growth of microorganisms when the pH rises above 3.5,7 and thus standard stress ulcer prophylaxis may contribute to postoperative pneumonia. Subclinical aspiration of the gastric contents occurs in 70% of seriously ill patients,8 and gastric microorganisms are recoverable in the pulmonary tree in seriously ill9-11 and postoperative12 patients.

Because of the effectiveness of acid-reducing stress ulcer prophylaxis, nosocomial pneumonia is now more frequent than is stress bleeding.13 Several unblinded clinical trials suggested recently that sucralfate decreases the nosocomial pneumonia rate associated with acid-reducing stress ulcer prophylaxis.14-16

As illustrated in Figure 1, our central hypothesis was that the type of stress ulcer prophylaxis would affect intragastric pH, and that gastric pH would affect appearance of new gastric microorganisms. We further hypothesized that the number of new gastric microorganisms would affect the incidence of seeding the pulmonary tree with gastric organisms, and finally that the incidence of seeding the pulmonary tree with gastric organisms would affect the rate of postoperative pneumonia.

PRESTUDY COMPARISONS OF THE PATIENT GROUPS

The patients who were randomly assigned to receive antacid or sucralfate stress ulcer prophylaxis were similar in most risk factors for postoperative complications.
PATIENTS AND METHODS

STUDY DESIGN

Patient Entry

One hundred forty patients at the Veterans Affairs Medical Center, Iowa City, Iowa, who were scheduled for major elective surgical procedures requiring postoperative nasogastric intubation were asked to participate in this study, which was approved for human subjects by the appropriate committees of the University of Iowa College of Medicine and the Iowa City Veterans Affairs Medical Center. Patients were entered into the study between June 1, 1990, and April 30, 1992. Patients were contacted before their elective surgical procedures, and less than 10% of the patients asked to participate refused to do so. Patients who declined entry into the study were not monitored further. The 140 patients who were initially entered and randomly assigned were all monitored for clinical outcomes, even if microbial data could not be obtained or the patients withdrew from the study. A biostatistician (B.M.B.) calculated that an 80% likelihood of detection of a 50% improvement in the expected postoperative pneumonia rate of 15% to 20% would require entry of more than 300 patients into each arm of the study. With pilot work showing that more than 50% of patients in the surgical intensive care unit harbored pathogens in their gastric contents, we determined that approximately 70 patients in each arm would give an 80% likelihood of detecting an effect by the stress ulcer prophylactic agent on the gastric microbial flora. Entry into the study occurred preoperatively, so that baseline cultures of gastric and respiratory fluid samples could be obtained intraoperatively, before the initiation of stress ulcer prophylaxis in the intensive care unit. The microorganisms cultured from patients in this study were definitively identified by means of plasmid analysis, bacteriocin typing, and restriction endonuclease analysis, in addition to standard speciation techniques.17-19 Serial sampling and analysis with these microbial identification techniques allowed us to determine when a specific gastric microorganism was subsequently detected in the pulmonary tree (and vice versa), and whether this intrapatient transmission resulted in temporary seedling or long-term colonization.

Randomization and Blinding

Randomization was performed in blocks of 20 patients before the study began, to ensure that both treatment groups would be evenly represented throughout the 2 years of patient accrual. In keeping with the double-blind design, the treatment group assignment of each patient was known only to the pharmacy service until all the clinical and microbial data collection was complete.

Study Drugs

Both of the sham agents, as well as the active antacid solution, were developed by the Pharmaceutical Service, University of Iowa College of Pharmacy. The sham agents were designed to be similar in color and viscosity to the active agents, and free of acid-neutralizing properties. The active sucralfate suspension was provided by the manufacturer, Marion Laboratories (Hoechst Marion Roussel Inc, Kansas City, Mo). The manufacturer had no other financial or scientific involvement with this study.

Administration of Study Drugs

The patients were randomly assigned to receive either sucralfate suspension (1 g in 10 mL every 6 hours) or double-strength antacids (15 mL every 2 hours while in the intensive care unit, every 4 hours after transfer to the surgical ward) as their active agents for stress ulcer prophylaxis. A sham of the other agent was given in the same volume and on the same schedule as would have been appropriate for the active agent. Gastric pH was monitored hourly while the patient was in the intensive care unit and administration of the antacid (or sham antacid) was repeated after 1 hour if pH persisted below 4.0. The pH of the gastric fluid samples was tested on a pH meter (model SA 520, Orion Research Inc, Beverly, Mass).

Clinical End Points

Risk factors were clinically assessed preoperatively, and Acute Physiology and Chronic Health Evaluation II scores20 were calculated postoperatively by an investigator not involved with the clinical care of any patient (Table 1). Daily assessment for gastrointestinal tract bleeding, infections, and other postoperative complications was continued until discharge from the hospital or death for all 140 patients. Upper gastrointestinal tract bleeding was defined as the appearance of grossly bloody fluid in the nasogastric aspirate that failed to clear with a 100-mL saline lavage. Pneumonia was diagnosed by consensus of 2 investigators not involved with the clinical care (M.P. and L.W.) by means of the following criteria: a new or progressive infiltrate on chest roentgenogram, plus 3 of the following: (1) purulent sputum with more than 25 white blood cells per high-power field, (2) isolation of respiratory pathogens from an adequate sputum sample, (3) peripheral leukocytosis (>10.0×10^9/L), and (4) temperature higher than 38.3°C. Wound infections were defined whenever antibiotics were used for the purpose of treating cellulitis, when wounds were opened for suspected infections, and when purulent drainage occurred. Urinary tract infection was diagnosed with growth of more than 100,000 colonies of a single organism in a urine sample.

(Table 1), but they differed in the percentage of patients with a history of treatment for chronic obstructive pulmonary disease. Ironically, this was the only preoperative trait that was significantly associated with postoperative pneumonia in our previously published univariate analysis of pneumonia risk factors for all 140 patients.12 The univariate analysis of risk factors for postoperative pneumonia was performed as a post hoc offshoot of the present prospective, double-blind study, and did not address the present study’s central hypothesis regarding the effects of sucralfate vs antacid stress ulcer prophylaxis on gastric microbial flora.
Withdrawal From the Study

Seventeen patients did not have sufficient specimens to be included in the analysis of the later microbial events in the chain of our hypotheses. These included 5 patients (3.9%) who were removed from the study by their primary clinicians because they disallowed any oral or nasogastric medications postoperatively, 3 patients (2.1%) who removed themselves from the study because they tired of trying to produce daily sputum samples, and 9 additional patients (6%) who never produced adequate sputum samples, although they continued to cooperate with attempts. The analyses of drug effects on microbial appearance and transmission were thus limited to the 123 patients from whom we collected adequate microbial data.

MICROBIOLOGICAL TECHNIQUES

Culture and Identification

All specimens were cultured for routine aerobic bacteria and fungi according to standard methods. Specimens were plated onto blood agar, MacConkey agar, and chocolate agar and incubated aerobically at 35°C. Gastric specimens were plated quantitatively by spreading a 10-µL aliquot evenly over the surface of each plate. All plates were incubated for 7 days and examined daily for evidence of growth. Colony counts were performed on the plates inoculated with gastric specimens, and the number of colony-forming units of each organism per milliliter of fluid was determined.

Bacterial and fungal isolates were selected for further identification and characterization on the basis of relative quantification, colony morphological characteristics, and gram-stain characteristics. For purposes of this study, only isolates of Enterobacteriaceae, *Pseudomonas* species, *Acinetobacter* species, *Staphylococcus aureus*, *Enterococcus* species, and *Candida* species were selected for definitive identification. All bacterial isolates were identified according to species with an automated microbiology indentification and susceptibility testing system (Vitek, Vitek Systems Inc, Hazelwood, Mo) and supplemented with conventional biochemical testing as necessary. Isolates of *Candida* species were identified to species with the API 20C yeast identifications system (API, Plainview, NY) plus conventional methods. Bacterial isolates were tested for in vitro susceptibility to antimicrobial agents with the Vitek system or a standard microdilution system (National Committee for Clinical Laboratory Standards).

Molecular Epidemiological Typing

The isolates were characterized further by 2 molecular epidemiological typing methods. Isolates of Enterobacteriaceae, *Pseudomonas* species, *S. aureus*, and *Enterococcus* species were typed by restriction endonuclease analysis of plasmid DNA (restriction endonuclease analysis of plasmid subtyping) and restriction endonuclease analysis of chromosomal DNA with pulsed field gel electrophoresis (genomic DNA subtyping), as described previously.\(^1\)\(^2\) Individual strains or subtypes within a given species were identified by comparing the DNA restriction fragment profiles of the organisms for similarities or differences. Serial isolates of the same species obtained from an individual patient were considered to be the same strain when the DNA restriction fragment profiles were identical.

DATA ANALYSIS

The data analysis consisted of 4 phases. First, the antacid and sucralfate groups were compared on baseline and intraoperative characteristics to determine whether the groups differed significantly before the initiation of treatment. Then, the central hypotheses were tested. Because it was hypothesized that a series of contingencies linked the type of stress ulcer treatment to postoperative morbidity, each hypothesized step was examined separately: the relationship of treatment to gastric pH, gastric pH to new gastric pathogens, new gastric pathogens to colonization of the pulmonary tree, and colonization of the pulmonary tree to postoperative pneumonia. In these analyses, variables involving the growth or transmission of pathogens (eg, new organisms appearing in the sputum on day 3) were time lagged in relation to other variables (eg, gastric pH on day 2).

In addition, we examined the relationship of treatment to outcomes at each step. If the hypothesized chain of effects held, treatment should correlate with the development of new gastric pathogens, and potentially with colonization of the pulmonary tree by new gastric pathogens (although the more remote the relationship, the more likely it would be that error and the influences of other significant factors would attenuate the remote relationship). Finally, the treatment groups were compared on clinical outcome measures, which were not expected to vary.

Because the analysis involved a mixture of categorical and continuous variables, a mixture of statistical procedures was used. Where the dependent variable was continuous and the independent variable was categorical, Student *t* tests were used. Continuous variables with a markedly skewed distribution were subjected to transformations to approximate a normal distribution before use in *t* tests. Where both independent and dependent variables were categorical, *χ*² tests of independence were used. Finally, where the dependent variable was categorical and the independent variable was continuous, analysis of variance or logistic regression was used. This mixture of procedures ensured that the most statistically powerful procedure available was used in each situation. All data are presented as group means (±SEM) unless otherwise noted.

Duration of Study Drug Treatment

The treatment groups were similar in the number of doses of the study medications they received daily, and in the number of days the study medications were continued postoperatively. One hundred twenty-two patients received 3 or more days of stress ulcer prophylaxis with the study drugs, while only 25 received 7 or more days. Many patients were treated with intravenous *H*₂-receptor blockers after 3 days postoperatively, which was when the study drugs were generally discontinued.
All of the patients received intravenous antibiotics perioperatively as prophylaxis for wound infections. Oral antibiotic and mechanical bowel preparation was given to 50 (35%) of the patients, with a similar percentage in each treatment group. The treatment groups also were similar in the distribution of types of the surgical procedures (Table 2, \( P = .27 \) by \( \chi^2 \)) and in the lengths of the surgical procedures. Additionally, the treatment groups did not differ in the percentage of patients who received intragastric tube feeding (antacid group, 21%; sucralfate, 20%; \( P = .8 \)). Intragastric tube feedings did not affect the appearance of new gastric organisms, as 7% of tube-fed vs 12% of non–tube-fed patients developed new gastric organisms on days 3 and 4 postoperatively (\( P = .45 \), \( \chi^2 = 0.56 \)).

**TESTS OF THE CENTRAL HYPOTHESES**

**pH Effects of Study Drugs**

The first major element in our hypothesis, that sucralfate and antacid therapy would differ in their effects on gastric pH, was confirmed (Figure 2); gastric pH differences between groups occurred for each of the first 3 days postoperatively. The proportion of gastric pH measurements below 3.5 on study days 2 through 4 (postoperative days 1 through 3) also differed in the 2 treatment groups (Figure 3), ranging from 2% to 12% in the antacid group in comparison with 18% to 38% in the sucralfate group. However, the mean pH for both groups was above 3.5 (in the range thought to allow the growth of microorganisms) for all study days.

**Effects of Gastric Acidity on Microbial Appearance and Pneumonia**

The second element in our hypothesis, that average gastric pH for a day would be related to the appearance of new gastric pathogens on the following days, was also confirmed. By logistic regression, average gastric pH on day 2 was related to the number of new organisms appearing on day 3 (\( P = .01 \)), and average gastric pH on day 3 was related to the number of new gastric organisms appearing on days 4 and 5 (\( P = .03 \)). In addition, gastric pH on days 2 through 4 (postoperative days 1 through 3) was statistically linked to postoperative pneumonia (mean pH, 4.9±0.1 for those without pneumonia vs 6.0±0.3 for those who developed pneumonia postoperatively; \( P < .01 \)).

**Effects of Study Drugs on Microbial Appearance**

We found that the treatment group affected appearance of new gastric pathogens, as had gastric pH. On the third study day (second postoperative day), new gastric organisms were detected in 35% of antacid-treated patients compared with 17% of sucralfate-treated patients (\( P = .04 \)). On subsequent days, 18% of antacid-treated patients developed new gastric organisms, compared with 3% of sucralfate-treated patients (\( P < .01 \)). Considering all new gastric organisms appearing on study days 3 through 5, twice as many were noted in the antacid group as in the sucralfate group (Table 3; \( P = .004 \)).

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**Table 1. Patient Characteristics**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Antacids (n=70)</th>
<th>Sucralfate (n=70)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>COPD,† No.</td>
<td>11</td>
<td>22</td>
<td>.03</td>
</tr>
<tr>
<td>Peptic ulcer disease, No.</td>
<td>6</td>
<td>8</td>
<td>.60</td>
</tr>
<tr>
<td>Diabetes, No.</td>
<td>8</td>
<td>11</td>
<td>.50</td>
</tr>
<tr>
<td>Alcohol, No.</td>
<td>40</td>
<td>36</td>
<td>.50</td>
</tr>
<tr>
<td>APACHE II score</td>
<td>9.1</td>
<td>8.6</td>
<td>.50</td>
</tr>
</tbody>
</table>

*COPD indicates chronic obstructive pulmonary disease; APACHE, Acute Physiology and Chronic Health Evaluation. †Significantly more patients with a clinical diagnosis of COPD preoperatively were randomly assigned to receive sucralfate; COPD was an independent risk factor for development of pneumonia.12

**Table 2. Type of Operation**

<table>
<thead>
<tr>
<th>Type of Operation</th>
<th>Antacids (n=70)</th>
<th>Sucralfate (n=70)</th>
<th>Total (N=140)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General abdominal</td>
<td>23</td>
<td>27</td>
<td>50</td>
</tr>
<tr>
<td>Abdominal aortic</td>
<td>14</td>
<td>18</td>
<td>32</td>
</tr>
<tr>
<td>Head and neck cancer</td>
<td>13</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Urological</td>
<td>10</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Neurological</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

\( P = .27 \) by \( \chi^2 \) test.
Appearance of New Gastric Organisms and Colonization of the Pulmonary Tree

For the third element in our hypothesis, which was the relationship between appearance of new gastric organisms and colonization of the pulmonary tree with gastric microorganisms, we defined colonization of the pulmonary tree as the appearance of a microorganism in the sputum that had previously been identified in the gastric contents of the same patient, followed by persistence of the gastric-originating organism in sputum samples for more than 24 hours. This phenomenon occurred in 28% of the patients. The phenomenon of colonization of the sputum with gastric microorganisms (the next element in our hypothesis) was more than twice as common in the patients who developed new gastric microorganisms than in those who did not (39% vs 17%; \( P = .03 \)).

Effect of Study Drugs on Pulmonary Colonization With New Gastric Organisms

Treatment group also affected this next link in the chain of events by which stress ulcer prophylaxis might influence postoperative pneumonia, the colonization of the pulmonary tree with new organisms of gastric origin. Twenty-five percent of the patients in the antacid group had colonization of the pulmonary tree with microorganisms that were first identified in the gastric contents during their course of stress ulcer prophylaxis, compared with 9% of the sucralfate-treated patients (\( P = .03 \)). At the time of the operative procedure, which was before initiation of study drugs, potential pathogens were already present in 40% of the patients’ gastric contents. As one would expect, the 2 treatment groups were nearly identical in the incidence of pulmonary colonization with microorganisms that were present in the gastric contents at the time of their surgical procedures (16% of antacid group vs 15% of sucralfate group; \( P = .9 \)).

Pulmonary Colonization With Gastric Organisms

Pulmonary colonization with organisms of gastric origin was a clinically important phenomenon because it was associated with the development of postoperative pneumonia (incidence of postoperative pneumonia was 40% in the colonized vs 12% in the noncolonized patients; \( P = .001 \)). The strong (\( P = .001 \)) link between pulmonary colonization with organisms of gastric origin and development of postoperative pneumonia was the final element in our hypothesis (Figure 1).

Comparisons of Clinical Outcomes

The clinical outcomes of the 2 groups are compared in Table 4 and Table 5, but no differences were noted other than a trend to increased endotracheal intubation time in the sucralfate group, which had the higher percentage of patients with preoperatively diagnosed pulmonary disease. Of the 26 patients who were diagnosed as having pneumonia at any time postoperatively, only 16 had it in a time frame when aspiration of organisms during the course of stress ulcer prophylaxis with study drugs might have been a factor. The 16-member subset eliminated 3 patients from the analysis who were diagnosed before the second postoperative day as having community-acquired organisms (Streptococcus pneumoniae or Haemophilus influenzae in all 3 patients), 6 patients who were diagnosed as having pneumonia more than 3 days after the study drugs had been discontinued and who had...
been treated with H₂-receptor blockade during that interval, and 1 patient who was withdrawn so early that no microbial data were collected. However, neither limiting the pneumonia analysis to those cases that might have been affected by the type of study drug nor controlling for chronic obstructive pulmonary disease disclosed any differences between the treatment groups’ incidence of postoperative pneumonia.

Although unrelated to treatment group, the presence of gastric organisms before any stress ulcer treatment was clinically important. Thus, the 47 patients with microorganisms growing in their gastric contents before initiation of study drugs had a pulmonary colonization rate of 49%, compared with a 16% rate in the 76 patients whose initial gastric cultures were sterile. Incidence between groups was physiologically important, as the 47 patients with stress ulcer prophylaxis compared with 4 days in similar patients receiving placebo.

Colonization of the airway by gastric organisms⁵⁻¹¹ was associated with nosocomial pneumonia in previous studies of patients receiving ventilatory assistance, but as it was in the present study of postoperative patients. Colonized patients in the present study had a postoperative pneumonia rate of 40%, which was more than 3 times that of noncolonized patients. The interaction between stress ulcer prophylaxis and gastric microbial colonization of the airway has been an area of great concern recently, as the possibility exists that stress ulcer prophylaxis causes more harm than benefit. A recent meta-analysis of studies containing relevant data produced mixed results, because of the wide variations in methods and definitions of pneumonia in the original studies. The meta-analysis suggests that sucralfate results in a nosocomial pneumonia risk reduction of 45% compared with acid-reducing therapies. This reduction in the risk of nosocomial pneumonia associated with sucralfate compared with antacid stress ulcer prophylaxis is consistent with our present findings.

The study by Driks et al,¹⁴ which suggested that sucralfate stress ulcer prophylaxis was associated with a lower pneumonia rate than antacids, also suggested that the H₂-blocker cimetidine might be associated with a lower pneumonia rate than either antacids or sucralfate, perhaps by decreasing the volume of gastric secretions. However, this study was not blinded and the use of H₂-blockers and antacids was not controlled. Recently, 2 large blinded studies of cimetidine vs placebo have been published, but with opposite findings regarding the effects of cimetidine stress ulcer prophylaxis on pneumonia. In the single-institution study of 200 postoperative patients described by Cheadle et al,²³ only 3% of placebo-treated patients developed pneumonia, compared with 13% of those receiving H₂-blockade. Conversely, in the multicenter trial of 131 intensive care unit patients described by Martin et al,²⁴ cimetidine seemed protective, as 7% of placebo-treated patients developed pneumonia compared with none of those receiving cimetidine.

Directly addressing the issue of gastric microbial growth during stress ulcer prophylaxis with an H₂-receptor antagonist, Apte et al²⁵ found that gastric colonization occurred at a mean of 2 days in patients with tetanus who were receiving ventilatory assistance and stress ulcer prophylaxis compared with 4 days in similar patients receiving placebo (P<.05). Unfortunately, the low mean gastric pH of 2.1 in the placebo group was not sufficient to prevent gastric colonization with microorganisms, although it was delayed in comparison with treated patients (mean pH of 4.7). The occurrence of gastric colonization despite the low gastric pH is dif-

### Table 6. Gastric Bleeding

<table>
<thead>
<tr>
<th>Source, y</th>
<th>Antacids</th>
<th></th>
<th></th>
<th>Sucralfate</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Patients</td>
<td>% With Bleeding</td>
<td>No. of Patients</td>
<td>% With Bleeding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borrero et al,² 1986</td>
<td>25</td>
<td>0</td>
<td>25</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bresalier et al,³ 1987</td>
<td>36</td>
<td>17</td>
<td>38</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannon et al,⁴ 1987</td>
<td>19</td>
<td>37</td>
<td>19</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present report</td>
<td>70</td>
<td>4</td>
<td>70</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>150</td>
<td>11</td>
<td>152</td>
<td>9</td>
<td></td>
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</tr>
</tbody>
</table>
fferent from expectations based on in vitro studies, but it demonstrates an important limitation of attempts to affect nosocomial pneumonia by altering stress ulcer prophylaxis.

Recent prospective, unblinded comparisons of the effects of acid-reducing and sucralfate stress ulcer prophylaxis on nosocomial pneumonia produced mixed results,16,26–31 but none of these unblinded studies had sufficient numbers of patients for the statistical power needed to detect such a difference. No difference in nosocomial pneumonia rates were found in intubated trauma patients,26 mixed intensive care unit patients,27–29 or thermally injured patients.30 However, sucralfate was associated with a statistically significantly lower pneumonia rate than ranitidine stress ulcer prophylaxis in a randomized trial of 60 intensive care unit patients16 and a lower pneumonia rate than cimetidine prophylaxis in a prospective trial of 49 patients receiving ventilatory assistance.31

In conclusion, postoperative stress ulcer prophylaxis with sucralfate reduced acid suppression, appearance of new gastric pathogens, and transmission of these gastric organisms to the pulmonary tree, compared with antacid prophylaxis. However, gastric pathogens were present in 40% of patients during major surgery, which also increased their risk of postoperative pulmonary colonization with gastric pathogens. The sucralfate suspension provided safe and effective stress ulcer prophylaxis, which may be preferable to antacid therapy on the basis of its gastric and pulmonary microbial effects.

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Reprints: Kimberly S. Ephgrave, MD, Department of Surgery, University of Iowa Hospitals and Clinics, 200 Hawkins Dr, Iowa City, IA 52242-1009.

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