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Relationship Between Feeding Tube Site and Respiratory Outcomes

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Abstract

Background—It is unclear if placing feeding tubes postpylorically to prevent respiratory complications is worth the extra effort. This study sought to determine the extent to which aspiration and pneumonia are associated with feeding site (controlling for the effects of severity of illness, degree of head-of-bed elevation, level of sedation, and use of gastric suction).

Methods—A retrospective analysis was performed on a large data set gathered prospectively to evaluate aspiration in critically ill, mechanically ventilated patients. Feeding site was designated by attending physicians and confirmed by radiography. Each patient participated in the study for 3 consecutive days, with pneumonia assessed by the simplified Clinical Pulmonary Infection Score on the fourth day. Tracheal secretions were assayed for pepsin in a research laboratory; the presence of pepsin served as a proxy for aspiration. A total of 428 patients were included in the regression analyses performed to address the research objectives.

Results—As compared with the stomach, the percentage of aspiration was 11.6% lower when feeding tubes were in the first portion of the duodenum, 13.2% lower when in the second/third portions of the duodenum, and 18.0% lower when in the fourth portion of the duodenum and beyond (all significant at $P < .001$). Pneumonia occurred less often when feedings were introduced at or beyond the second portion of the duodenum ($P = .020$).

Conclusions—The findings support feeding critically ill patients with numerous risk factors for aspiration in the mid-duodenum and beyond to reduce the risk of aspiration and associated pneumonia.

Keywords

enteral nutrition; feeding site; critical care; aspiration; pneumonia

Introduction

The relationship between feeding site and respiratory outcomes (aspiration and pneumonia) in patients receiving tube feedings is unclear. Although patients can aspirate oropharyngeal secretions or gastric contents, the latter has received more attention in tube-fed patients. Studies comparing the aspiration of gastric contents across feeding sites in critically ill patients have yielded conflicting results.[1–3] In part, this may be due to small sample sizes

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and difficulty in measuring aspiration. For example, previously used bedside aspiration detection methods such as observing for dye-stained enteral formula or glucose in tracheal secretions have proved inaccurate.[4–9] More reliable methods such as testing tracheal secretions for radiolabeled enteral formula or laboratory assays for pepsin or colored beads are cumbersome and impractical for long-term studies.[2,10,11]

As with aspiration, a reliable measurement of pneumonia is difficult without the use of sophisticated tests. Nonetheless, a number of investigators have attempted to examine the relationship between feeding site and pneumonia.[1,12–15] Meta-analyses of these studies have presented conflicting views.[16–18] Reasons for discrepancies may include small sample sizes, differing criteria for the definition of pneumonia, differing small bowel feeding sites, and a multitude of other clinical variables.[17]

Both aspiration and pneumonia are likely influenced by coexisting clinical variables (such as severity of illness, level of sedation, and degree of head-of-bed [HOB] elevation).[10,19–23] As such, it is important to control for the effect of these variables when attempting to determine the relationship between feeding tube site and adverse respiratory outcomes.

There is no clear evidence that a postpyloric feeding site is superior to a gastric site in minimizing aspiration of gastric contents or pneumonia in critically ill patients. However, it is premature to conclude that a postpyloric feeding site has no merit.[24] Several published guidelines favor distal small bowel feedings in critically ill patients who are at high risk for aspiration, especially if unit personnel are skilled in small bowel tube insertions.[25,26] Also, postpyloric feedings are clearly favored over gastric feedings when gastric emptying is impaired.[18] Unfortunately, it is difficult to detect impaired gastric emptying by routine clinical observations.

In summary, given the paucity of research-based data, additional information is needed to help clinicians determine the benefit of small bowel feedings as opposed to gastric feedings in preventing poor respiratory outcomes (aspiration and pneumonia), especially because placement of small bowel feeding tubes requires more time, effort, and cost.

Objectives

In a group of critically ill, mechanically ventilated tube-fed patients, the objectives of the study were to determine the following:

1. The extent to which aspiration is associated with feeding tube site, controlling for severity of illness, level of sedation, degree of HOB elevation, and use of gastric suction.
2. The extent to which pneumonia is associated with: (a) feeding tube site and (b) aspiration, controlling for severity of illness, level of sedation, and degree of HOB elevation.

Methods

Design

To address the objectives, we performed a retrospective analysis on a large data set gathered prospectively as part of an ongoing series of studies evaluating aspiration of gastric contents in critically ill, mechanically ventilated patients.[10,27] Data on aspiration and pneumonia were collected in 5 adult intensive care units (ICUs) at the same university-based medical center over 2 time periods (2002–2004 and 2007–2008). The first component of the study was descriptive, to determine risk factors for aspiration; the second component evaluated an

intervention to reduce aspiration by encouraging HOB elevation and small bowel tube placements when deemed appropriate. Attending physicians designated the desired feeding tube site for each patient. Radiographic confirmation was obtained at the time of initial tube insertion, and feeding tube site was monitored regularly throughout the study period. Each patient participated in the study for 3 consecutive days, with pneumonia assessed on the fourth day. Aspiration was assessed by an immunoassay for pepsin.[28] The simplified Clinical Pulmonary Infection Score (CPIS) was selected to screen for suspected pneumonia.[29] Data from 474 eligible patients were available for the study. Inclusion criteria were: age ≥18 years, admission to 1 of the 5 ICUs at the study site, continuous tube feedings, and mechanical ventilation. Exclusion criteria were: pneumonia present before tube feeding started and use of a gastrostomy or jejunostomy tube. Of the 474 patients, 42 were excluded from the analysis because the position of their tube was changed during the study period (29 patients' tubes spontaneously displaced from the small bowel back into the stomach, and 13 patients' tubes were intentionally diverted from the stomach to the small bowel). An additional 4 were eliminated because of incomplete data for the control clinical variables. Thus, the final sample for statistical comparisons was 428 patients. Demographic data are presented in Table 1.

Setting

The study site is a university-based level I trauma center. As shown in Table 1, patients were recruited from 3 services within the participating ICUs: trauma/surgery, neuromedicine/neurosurgery, and general medicine.

Data Collection

Permission to conduct the study was granted by the appropriate institutional review board, and informed consents were obtained from the patients' legal guardians. Registered nurse research assistants were present daily from 8 AM through midnight to collect data.

Measurement of Independent Variable—Radiologists specified the location of the distal end of the feeding tubes within the gastrointestinal (GI) tract immediately following initial insertion. Feeding tube sites were categorized as follows for statistical comparisons:

- Stomach
- First portion of duodenum (D1)
- Second or third portion of duodenum (D2–D3)
- Fourth portion of duodenum or proximal jejunum (D4–jejunum)

Research assistants monitored the feeding tube site at 4-hour intervals thereafter for evidence of tube displacement. These assessments included confirmation of the length of feeding tube measured at the insertion site (nose or mouth), as well as the volume, appearance, and pH of the feeding tube aspirates. Additional radiographs obtained during the study period for treatment purposes were reviewed to determine if the feeding tubes had remained in their original designated locations.

Measurement of Respiratory Outcome Variables—Methods for determining aspiration and pneumonia were described in previous publications and are summarized below.[10,27]

Aspiration—Pepsin-positive tracheal secretions served as a proxy for the aspiration of gastric contents. Tracheal secretions obtained during routine suctioning by bedside nurses were assayed for pepsin in a research laboratory by an immunoassay that used rooster

polyclonal antibodies to purified human pepsin. In an animal model, the immunoassay was found to have a sensitivity of 93% and a specificity of 100%; a single aspiration event could be detected up to 6 hours after its occurrence.[28] Gels were read by a biochemist blinded to the patients' clinical status, and results were reported as "pepsin positive" or "absent." The assay can detect pepsin in a concentration as low as 1 mcg/mL. For each patient, the extent of aspiration was computed as the percentage of tracheal secretions that were pepsin positive. The number of suctioned samples of tracheal secretions collected from each patient ranged from 4 to 28, with 86% of patients having between 11 and 28 samples collected and tested.

Pneumonia—The simplified CPIS (as described by Luna et al[29]) was used to assess for probable pneumonia. Components of the instrument include body temperature, blood leukocytes, oxygenation (Pao_2/Fio_2 ratio), quantity and appearance of tracheal secretions, and chest radiography. Possible scores ranged from 0 to 10, with 10 being worst. A score of 6 or higher was used as a proxy for pneumonia, provided an infiltrate was present. The simplified CPIS was feasible for daily use because it does not require cultures of tracheobronchial secretions. The score was calculated on tube-feeding days 1, 2, 3, and 4. The day 4 pneumonia score was used as the outcome variable in the analysis, with a score of 6 or higher coded 1 (positive for pneumonia) and a score of 5 or lower coded 0 (no pneumonia). Infiltrates were identified from radiographic reports. The oxygenation Pao_2/Fio_2 ratio was calculated from the first blood gas of the day. Estimates of the volume and appearance of tracheal secretions were made by the bedside nurses at the time of routine suctioning. Chart reviews were performed to obtain data regarding blood leukocytes and body temperature. The same research assistant, blinded to the pepsin immunoassay results, calculated all CPIS scores during the 2002–2004 phase of the study; a different research assistant calculated all CPIS scores during the 2007–2008 phase of the study.

Measurement of Control Variables—Four control variables were used: severity of illness, level of sedation, degree of HOB elevation, and use of gastric suction. Severity of illness was measured at study entry using the Acute Physiology and Chronic Health Evaluation (APACHE) II,[30] with a potential range from 0 (best) to 71 (worst). Level of sedation was measured every 4 hours using the Vancouver Interaction and Calmness Scale (VICS),[31] with a potential range from 10 (most sedated) to 60 (least sedated). An average score over the 3 days was calculated for each patient. HOB elevation was assessed hourly (between 8 am and midnight) by reviewing output from the beds' electronic readouts in degrees. An average score over the 3 days was calculated for each patient. Use of gastric suction was coded 1 if it was ever used during the 3 days and 0 if it was never used. For patients fed in the stomach, gastric suction was not applicable and thus was coded 0.

Data Analysis

To examine the extent to which aspiration was associated with feeding tube site, we performed a sequential multiple regression analysis with 2 steps through SPSS linear regression (version 17; SPSS, Inc, Chicago, IL).

In the first step, 3 feeding tube site dummy variables were entered as predictors for aspiration, with stomach as the reference category: (a) the duodenum D1 = 1 vs stomach = 0, (b) the duodenum D2 or D3 = 1 vs stomach = 0, and (c) the duodenum D4 or the proximal jejunum = 1 vs stomach = 0. The feeding tube sites D1, D2–D3, and D4–jejunum were coded 0 for the 2 dummy variables other than their own. In the second step, the 4 control variables—severity of illness, level of sedation, degree of HOB elevation, and use of gastric suction—were entered as predictors for aspiration. The main outcome of interest was in the relationship of feeding tube site to aspiration, as reflected by its raw regression weight B,

controlling for the other predictors, and the percentage of variance in aspiration explained by feeding tube site. Of secondary interest was the extent to which the control variables predicted aspiration and the additional percentage of variance explained by the control variables.

Using externally studentized residuals and the DFFITS and DFBETAS measures of influence, 9 outliers were identified.[32] Deletion of the 9 outliers from the analysis only slightly strengthened the results for the control variables and affected none of the key conclusions; thus, findings are reported for the entire sample.

To examine the association of feeding tube site and aspiration with pneumonia, we performed sequential logistic regression with 3 steps through SPSS binary logistic regression (version 17; SPSS Inc). In the first step, the 3 dummy variables for feeding tube site were entered to evaluate the influence on pneumonia of each successive feeding tube site beyond the stomach. In the second step, 3 control variables (severity of illness, level of sedation, degree of HOB elevation) were entered to determine if their inclusion improved the prediction of pneumonia. In the third step, the extent of aspiration (percent pepsin) was entered to determine its additional contribution to predicting pneumonia. Main interest was in the odds ratios (ORs) for individual predictors at each step, controlling for other predictors, and improvement at each step with the addition of predictors. To make interpretation of ORs more clinically relevant, degree of HOB elevation was divided by 10 such that 0 = 0 degrees, 1 = 10 degrees, 2 = 20 degrees, and so on. Similarly, percent pepsin was divided by 10 such that 0 = 0%, 1 = 10%, 2 = 20%, and so on.

Results

Descriptive data are provided in Table 2. Appendix Tables A and B report full results from the regression analyses described in the Data Analysis section. Summaries of these findings are presented in Tables 3–6.

Objective 1—Aspiration

Table 2 shows the incidence of aspiration and pneumonia, as well as the mean values of the clinical variables (APACHE II, level of sedation, degree of HOB elevation, and incidence of gastric suction) for each feeding site. Table 2 also shows a progressive decrease in the percentage of tracheal samples that were positive for pepsin (indicating aspiration) as the site of the tube tip descends the GI tract. There was no significant difference in the mean APACHE II score, level of sedation, or degree of HOB elevation between the various feeding tube sites. Gastric suction was used at least once in 28.4% to 46.9% of patients when the feeding tube site was distal to the stomach.

As shown in Table 3, the percentage of pepsin-positive tracheal secretions was 13.6% lower in patients with feeding tubes in D1 than in those patients where the tube was in the stomach ($P < .001$), 17.4% lower in patients with feeding tubes in D2–D3 than in the stomach ($P < .001$), and 26.8% lower in patients with feeding tubes in D4–jejunum than in the stomach ($P < .001$).

Also shown in Table 3, after adjusting for the 4 confounding clinical variables (severity of illness, level of sedation, degree of HOB elevation, and use of gastric suction), the benefits of placing the site of infusion lower in the small bowel for reducing pepsin-positive tracheal secretions compared with the stomach remained significant ($P < .001$) but were somewhat smaller. Compared with patients with feeding tubes in the stomach, the percentage of pepsin-positive tracheal secretions was 11.6% lower for patients with feeding tubes in D1,

13.2% lower for those with tubes in D2–D3, and 18.0% lower in patients with the tube in D4–jejunum.

As shown in Table 4, of the 4 controlled clinical variables, degree of HOB elevation and use of gastric suction were significant predictors of aspiration after controlling for the other 6 predictors in the model. Each 10-degree increase in HOB elevation was associated with a 3.8% reduction in the percentage of pepsin-positive secretions. In small bowel–fed patients in whom gastric suction was used at least once, the percentage of pepsin-positive tracheal secretions was 7.1% lower than in patients for whom gastric suction was off.

Objective 2—Pneumonia

Table 2 shows that although there was no significant difference in pneumonia between tube sites in D1 vs the stomach, the incidence of pneumonia was significantly lower in D2–D3 and D4–jejunum compared with the stomach ($P < .01$).

As reported in Table 5, patients with a feeding tube in D2–D3 or in D4–jejunum had a significantly lower incidence of pneumonia (defined as a simplified CPIS ≥6) than did patients fed in the stomach. The odds of developing pneumonia decreased by more than 50% for patients fed in D2–D3 (OR = 0.48; 95% confidence interval [CI]: 0.28–0.83; $P = .008$) and nearly 80% for patients fed in D4–jejunum (OR = 0.21; 95% CI: 0.08–0.58; $P = .002$) compared with patients fed in the stomach. Patients fed in D1 did not have a significantly lower rate of pneumonia compared with patients fed in the stomach (OR = 0.78; 95% CI: 0.48–1.25; $P = .301$).

As also reported in Table 5, after adjusting for severity of illness, level of sedation, and degree of HOB elevation, the 2 feeding tube sites D2–D3 and D4–jejunum remained significant predictors of decreased pneumonia but with slightly reduced ORs of 0.52 for D2–D3 (95% CI: 0.30–0.90; $P = .020$) and 0.30 for D4–jejunum (95% CI: 0.11–0.83; $P = .021$). After adjusting for the variable of aspiration (measured by percent pepsin), the feeding tube sites D2–D3 and D4–jejunum were no longer significant.

As shown in Appendix Table B, the control variables of level of sedation (OR = 0.91; 95% CI: 0.85–0.97; $P = .003$) and degree of HOB elevation (OR = 0.75; 95% CI: 0.63–0.88; $P < .001$) were significant predictors of pneumonia, but severity of illness (APACHE II) was not. Patients who were less sedated (OR = 0.91; 95% CI: 0.85–0.97; $P < .01$) and who had higher HOB elevation (OR = 0.82; 95% CI: 0.68–0.98; $P = .03$) had lower odds of developing pneumonia. As reported in Table 6, the odds of developing pneumonia were decreased by 9% for each 1-unit increase (less sedation) on the VICS and decreased by 18% for each 10-degree increase in HOB elevation. The control variable of severity of illness was not a significant predictor of pneumonia.

Aspiration itself was a strong predictor of pneumonia (OR = 1.44; 95% CI: 1.30–1.60; $P < .01$). As the percentage of pepsin-positive tracheal secretions increased by 10%, the odds of developing pneumonia increased by 40%. The controlled clinical variables of sedation and HOB elevation remained significant predictors of pneumonia.

Discussion

We found that aspiration was significantly reduced when feeding tubes were in the small bowel (especially in the D4–jejunum sites); furthermore, the relationship remained significant even when controlling for severity of illness, level of sedation, and HOB elevation. Thus, our findings support the concept that diverting the level of infusion of formula within the GI tract reduces the risk of aspiration. Heyland et al[2] reported similar

findings from a study in which they added technetium 99m (Tc99m) sulfur colloid to 33 critically ill patients' enteral feedings during 3 separate 6-hour periods. Tracheal secretions collected during these periods were tested for radioactivity; an episode of microaspiration was said to have occurred if an increase in radioactivity more than 100 counts/min/g was found. The percentage of positive aspiration was noted to decline as the feeding tube was advanced lower in the GI tract (5.8% in the stomach, n = 21; 4.1% in D1, n = 8; 1.8% in D2, n = 3; and 0% in D4, n = 1). Overall, gastric-fed patients tended to have a higher percentage of microaspiration than did those fed in the small bowel (7.5% vs 3.9%, $P = .22$). A trend toward higher microaspiration (1.9 vs 1.4 counts/g, $P = .09$) was reported when the logarithmic mean of the radioactivity count was compared across groups. In contrast, also using the Tc99m detection method, Esparza et al[3] found no significant difference in aspiration in 27 patients fed in the stomach and 24 patients fed transpylorically (7% vs 13%, respectively). No information was provided in the latter study about the degree of aspiration encountered in patients fed in different portions of the small bowel.

In 2000, Kearns et al[1] reported no difference in aspiration rates among patients fed in the stomach (n = 23) and those fed in the small bowel (n = 21) when aspiration was defined as finding blue dye or glucose in tracheal secretions. Five (24%) of the small intestine tubes ended in D2, 6 (28%) ended in D3, and the remaining 10 (48%) were in or beyond D4. The overall OR for aspiration at all small intestine sites was 1.1. Results from this study are clouded by the lack of sensitivity and specificity of the methods used to detect aspiration.[4,6,7,9,11]

In a study of 74 critically ill children randomized to gastric or small bowel feedings, Meert et al[33] found no significant difference in the proportion of pepsin-positive tracheal aspirates according to feeding site. Although the study used a sensitive assay for aspiration, collection of tracheal samples was limited to a daily 3-hour window.

As indicated earlier, the study reported here used pepsin, produced in the stomach and then released in the gastric juice, as a physiologic marker for aspiration of gastric contents. A different physiologic marker was used in the Lien et al[34] study, where a pH monitoring probe placed in the distal esophagus was used to test for the presence of gastric acid refluxing up into the esophagus in a study that compared gastric with jejunal feedings. As the level of feedings was diverted from the stomach to the jejunum, gastroesophageal reflux (as measured by the pH monitor) decreased. The explanation of this physiologic response may be that feeding in the stomach increases gastric acid and decreases pressure in the lower esophageal sphincter. Of course, feeding in the small bowel can lead to duodenogastric reflux, and feeding in the stomach or small bowel can lead to gastroesophageal reflux. Diverting the infusion into the lower GI tract reduces the risk for regurgitation of gastric contents and possibly subsequent aspiration. The lower the level of feeding within the GI tract, the more likely it is that inhibitory factors will be invoked to offset stimulation of acid, bile, and pancreatic secretions.

Although we found that the mean percentage of aspiration was low in the 32 patients fed in the D4–jejunum sites, 4 of the 32 patients experienced relatively high percentages (30%–61%) of pepsin-positive tracheal secretions. Two of the 4 had no concurrent gastric tube present; thus, it is conceivable that they had undetected high gastric residual volumes (GRVs). Although there is no firm agreement on what constitutes a high GRV, 2 or more volumes of at least 200 mL and 1 or more volumes of at least 250 mL have been reported to occur more frequently in critically ill patients with documented frequent aspiration.[35]

There is evidence that jejunal feedings may stimulate the production of gastric and pancreatobiliary secretions and thus predispose people to gastroesophageal reflux.[34] In a

retrospective evaluation of gastric output in 51 trauma patients started on jejunal feedings, Chendrasekhar[36] found that gastric output almost doubled from the 24-hour prefeeding period to the 24-hour postfeeding period (301.9 ± 19.8 mL vs 587.8 ± 47.1 mL, respectively). For this reason, the investigators recommended that nasogastric residual volume checks be performed routinely in patients receiving jejunal feedings. If high GRVs are found during small bowel feedings, authors agree that it is prudent to apply gastric decompression.[37]

As indicated earlier, the study reported here used the simplified CPIS to screen for suspected pneumonia. The accuracy of the CPIS in detecting pneumonia has been questioned, especially when tracheobronchial cultures are not used.[38,39] We chose the simplified CPIS because of its feasibility in monitoring patients on a daily basis. In an earlier report, we found a high correlation ($r = .96$) between results from the simplified CPIS and pneumonia defined quantitatively by bronchoalveolar lavage in a small number of cases (n = 34).[10] Several other investigators have used various forms of the CPIS for clinical studies.[40–46]

Our study provides evidence that diverting the level of feeding within the GI tract protects against the development of pneumonia by reducing aspiration of gastric contents. Similar findings were reported by Hsu et al[47] in a recent randomized trial that compared duodenal vs gastric feeding in a group of 121 medical ICU patients. In that study, 8.5% (5/59) of the patients fed in the duodenum developed pneumonia, as compared with 24.2% (15/62) of the patients fed in the stomach ($P = .02$). In our study, the benefit of feeding at the level of D2 and beyond on the incidence of pneumonia occurred through a reduction in aspiration. That is, aspiration was a mediating variable between feeding tube site and pneumonia; a lower feeding tube site reduced aspiration, which in turn reduced pneumonia. A similar mechanism was likely in the Hsu et al[47] study in that the incidence of GRVs greater than 100 mL was about 3 times higher in patients with nasogastric feedings as opposed to those with nasoduodenal feedings.

A meta-analysis by Heyland et al[2] showed a reduction in ventilator-associated pneumonia in patients fed in the small bowel; however, the meta-analysis was driven primarily by a study that randomized patients to different levels of allowed GRV and slow vs rapid increases in the rate of infusion.[48] When the latter study was excluded, the difference between gastric and postpyloric feeding with regard to pneumonia was no longer significant. Other investigators who performed meta-analyses regarding feeding tube site (gastric vs postpyloric) and pneumonia have concluded that there is no significant relationship between these conditions; however, a marker for aspiration was not included in their analysis.[18,49]

Three clinical variables evaluated in this study were shown to play an important role in both aspiration and pneumonia. Higher HOB elevation for patients in generally was associated with lower aspiration, and the use of gastric suction in patients fed in the small bowel was associated with lower aspiration. Both higher HOB elevation and lower sedation were associated with a lower incidence of pneumonia, even after controlling for aspiration of gastric contents. Other authors have suggested that aspiration of oropharyngeal secretions is an important factor in bacterial contamination of the upper respiratory tree.[50–54] Unfortunately, we did not have a marker for the aspiration of oropharyngeal secretions.

Strengths and Limitations

The use of a sensitive and specific assay for pepsin (a proxy for aspiration of gastric contents) allowed us to detect microaspirations of gastric contents in our population of critically ill patients. The large sample size (n = 428) provided a reasonable representation of gastric vs small bowel–fed patients. The presence of registered nurse data collectors for 16

hours each day during the patients' participation in the study was beneficial in obtaining reliable data.

A limitation of the project was the absence of randomization of patients to gastric vs small bowel feeding sites; as such, it is difficult to generalize our findings to other populations. A second limitation was the relatively small percentage of patients with feeding tubes at or beyond D4. Because we had no marker for the aspiration of oropharyngeal secretions, we were unable to assess the extent to which this phenomenon influenced pneumonia. We recognize that changes may have occurred in the clinical site during the 28-month lapse in data collection (because of the absence of funding during this period) to account for part of the variability in pneumonia scores. Finally, we would have preferred to use daily cultures of tracheobronchial secretions to improve our measure for pneumonia; however, this was not feasible for our long-term, prospective clinical study.

Conclusions

Our findings support feeding critically ill patients with numerous risk factors for aspiration in the mid-duodenum and beyond to reduce the incidence of aspiration of gastric contents and associated pneumonia. Diverting the level of feedings is one component of a multitiered strategy (including HOB elevation to at least 30 degrees when possible and using gastric suction during small bowel feedings) to decrease the risk of aspiration and ultimately to decrease the risk of pneumonia. As noted in our findings, the percentage of pepsin-positive tracheal secretions was significantly lower in small bowel–fed patients when gastric suction was used at least once, as compared with when it was not used at all during small bowel feedings.

Clinical Relevancy Statement

Research findings to support the assumption that aspiration is reduced in small bowel–fed patients are inconclusive; therefore, clinical practice continues to vary widely. Although the study reported here was not a randomized trial, it did control for the effects of other risk factors for aspiration and does provide support for feeding in the distal small bowel to reduce the risk for aspiration of gastric contents in a population of high-risk, critically ill patients.

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Appendix

Table A

Results of Sequential Multiple Regression for Predicting Aspiration (Percent Pepsin) From Feeding Tube Site and 4 Control Variables (n = 428)

	Aspiration Step 1: Feeding Tube Site Added			Aspiration Step 2: Control Variables Added		
Predictor	**B (SE)**	**β**	***P***	**B (SE)**	**β**	***P***
Constant	34.42 (1.61)			54.84 (10.43)		
Feeding tube site						
D1 vs stomach	−13.61 (2.81)	−0.23	<.001	−11.63 (2.90)	−0.20	<.001

	Aspiration Step 1: Feeding Tube Site Added			Aspiration Step 2: Control Variables Added		
Predictor	**B (SE)**	**β**	***P***	**B (SE)**	**β**	***P***
D2–D3 vs stomach	−17.44 (3.00)	−0.28	<.001	−13.24 (3.17)	−0.21	<.001
D4–jejunum vs stomach	−26.84 (4.42)	−0.28	<.001	−18.01 (4.73)	−0.19	<.001
Control variables						
APACHE II				0.12 (0.18)	0.03	.489
Sedation				−0.37 (0.25)	−0.07	.149
Mean degree HOB elevation				−0.38 (0.09)	−0.20	<.001
Gastric suction (1 = on, 0 = off)				−7.14 (3.29)	−0.11	.030
Overall model						
R^2 feeding tube site at step 1		.133	<.001		.133	<.001
R^2 control variables at step 2		—	—		.055	<.001
R^2 total		.133	<.001		.189	<.001
R^2 adjusted		.127			.175	

APACHE II, Acute Physiology and Chronic Health Evaluation II; D1 = first portion of duodenum; D2–D3 = second or third portion of duodenum; D4–jejunum = fourth portion of duodenum or proximal jejunum; HOB, head of bed; B, raw (unstandardized) regression coefficient; SE, standard error of B coefficient Gastric suction: 1 = on at any time during the 3-day study period, 0 = not used at any time during the study period; Sedation measured by the Vancouver Interaction and Calmness Scale.

Appendix

Table B

Odds Ratios From Logistic Regression for Predicting Pneumonia From Feeding Tube Site, 3 Control Variables, and Aspiration (n = 428)

	Pneumonia Step 1: Feeding Tube Site Added			Pneumonia Step 2: Control Variables Added			Pneumonia Step 3: Aspiration Added		
Predictor	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***
Feeding tube site									
D1 vs stomach	0.78	0.48–1.25	.301	0.73	0.44–1.21	.220	1.18	0.68–2.04	.548
D2–D3 vs stomach	0.48	0.28–0.83	.008	0.52	0.30–0.90	.020	0.87	0.47–1.60	.646
D4–jejunum vs stomach	0.21	0.08–0.58	.002	0.30	0.11–0.83	.021	0.62	0.21–1.87	.399
Control variables									
APACHE II				0.99	0.96–1.03	.711	0.99	0.95–1.02	.525
Sedation				0.91	0.85–0.97	.003	0.91	0.85–0.97	.006
HOB elevation (divided by 10)				0.75	0.63–0.88	<.001	0.82	0.68–0.98	.026
Aspiration									
% pepsin (divided by 10)							1.44	1.30–1.60	<.001
Overall model									
Comparison to previous step	Step 1 vs null model χ^2 (df = 3) = 16.58, P = .001			Step 2 vs step 1 χ^2 (df = 3) = 28.86, P < .001			Step 3 vs step 2 χ^2 (df = 1) = 55.50, P < .001		

	Pneumonia Step 1: Feeding Tube Site Added			Pneumonia Step 2: Control Variables Added			Pneumonia Step 3: Aspiration Added		
Predictor	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***
Cox and Snell R^2		.038			.101			.210	
Nagelkerke R^2		.051			.136			.285	
Hosmer and Lemeshow test		χ^2 (df = 2) = 0.00, P = 1.00			χ^2 (df = 8) = 9.60, P = .294			χ^2 (df = 8) = 5.48, P = .705	

APACHE II, Acute Physiology and Chronic Health Evaluation II; CI, confidence interval; HOB, head of bed; df, degrees of freedom, D1 = first portion of duodenum; D2–D3 = second or third portion of duodenum; D4–jejunum = fourth portion of duodenum or proximal jejunum OR, odds ratio; Sedation measured by the Vancouver Interaction and Calmness Scale.

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Table 1

Patient Demographics (n = 428)

Service, %	
Neuromedicine/neurosurgery	29.9
Trauma/surgery	42.5
General medicine	27.6
Age, y	
Range	18–95
Mean ± SD	51.8 ± 18.2
Gender, %	
Male	60.0
Female	40.0
Ethnicity, %	
White	76.2
African American	22.4
Other	1.4

SD, standard deviation.

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Table 2

Descriptive Data

		Outcome Variables		Control Variables			
		Aspiration	Pneumonia				
Feeding Tube Site	n	Percent Positive Pepsin, Mean ± SD	Percent Positive CPIS	APACHE II, Mean ± SD	Sedation (VICS), Mean ± SD	HOB (Degrees), Mean ± SD	Gastric Suction, % Used
Stomach	209	34.4 ± 27.0	46.4	22.5 ± 6.2	36.2 ± 4.7	26.2 ± 13.0	0.0
D1	102	20.8 ± 19.4[a]	40.2	21.1 ± 6.1	35.7 ± 3.3	26.1 ± 13.5	28.4
D2–D3	85	17.0 ± 19.5[a]	29.4[a]	21.5 ± 6.5	36.0 ± 4.4	30.5 ± 11.9	35.3
D4–jejunum	32	7.6 ± 16.3[a]	15.6[a]	20.2 ± 7.0	37.6 ± 6.6	38.6 ± 11.0	46.9
Total	428						

APACHE II, Acute Physiology and Chronic Health Evaluation II; CPIS, Clinical Pulmonary Infection Score (proxy for pneumonia); D1 = first portion of duodenum. D2–D3 = second and third portions of duodenum. D4–jejunum = fourth portion of duodenum and proximal jejunum; HOB, head-of-bed elevation; Percent positive pepsin (proxy for percentage of aspiration of gastric contents); SD, standard deviation; VICS, Vancouver Interaction and Calmness Scale.

[a] $P < .01$ compared with stomach.

Table 3

Relationship Between Feeding Site and Extent of Aspiration, Controlling for 4 Clinical Variables (n = 428)[a]

Feeding Tube Site	Aspiration, %[b]	Aspiration, %[c]
D1 vs stomach	13.6% less aspiration in D1	11.6% less aspiration in D1
D2–D3 vs stomach	17.4% less aspiration in D2–D3	13.2% less aspiration in D2–D3
D4–jejunum vs stomach	26.8% less aspiration in D4–jejunum	18.0% less aspiration in D4–jejunum

[a] Controlled clinical variables included severity of illness, level of sedation, degree of head-of-bed elevation, and use of gastric suction.

$P < .001$ for all values.

[b] Percentage of aspiration compared with stomach without effect of confounding clinical variables.

[c] Percentage of aspiration compared with stomach adjusted for effect of confounding clinical variables.

Table 4

Relationship Between Each of 4 Clinical Variables and Aspiration (Percent Pepsin-Positive Tracheal Secretions), Controlling for Tube Site and the Other 3 Clinical Variables (n = 428)

Clinical Variable	Relationship With Aspiration
APACHE II	*NS*
Sedation (Vancouver Interaction and Calmness Score)	*NS*
Mean elevation	Each 10-degree elevation was associated with a 3.8% decrease in aspiration, $P < .001$
Gastric suction (1 = on, 0 = off)	Gastric suction being on was associated with a 7.1% decrease in aspiration, $P = .03$

APACHE II, Acute Physiology and Chronic Health Evaluation II; HOB, head of bed; *NS*, not significant.

Table 5

Relationship Between Feeding Site and Incidence of Pneumonia, Controlling for 3 Clinical Variables and Aspiration (n = 428)

Feeding Tube Site	Feeding Tube Site Only[a]: Odds Ratio for Pneumonia (95% CI)	Feeding Tube Site Adjusted for 3 Clinical Variables[b]: Odds Ratio for Pneumonia (95% CI)	Feeding Tube Adjusted for 3 Clinical Variables and Aspiration (% Pepsin-Positive Tracheobronchial Secretions)[c]: Odds Ratio for Pneumonia (95% CI)
D1 vs stomach	0.78 (0.48–1.25), *P* = *NS*	0.73 (0.44–1.21), *P* = *NS*	1.18 (0.68–2.04), *P* = *NS*
D2–D3 vs stomach	0.48 (0.28–0.83), *P* = .008	0.52 (0.30–0.90), *P* = .020	0.87 (0.47–1.60), *P* = *NS*
D4–jejunum vs stomach	0.21 (0.08–0.58), *P* = .002	0.30 (0.11–0.83), *P* = .021	0.62 (0.21–1.87), *P* = *NS*

CI, confidence interval; *NS,* not significant.

[a] Feeding tube site only (no control for clinical variables or percentage of aspiration) shows a significant relationship with pneumonia for D2–D3 and D4–jejunum.

[b] After adjusting for 3 clinical variables (severity of illness, level of sedation, and degree of head-of-bed elevation), there continued to be a significant relationship between D2–D3 and D4–jejunum feeding site and pneumonia.

[c] After adjusting for the effect of aspiration (percentage of pepsin-positive tracheal secretions), added to the 3 clinical variables (severity of illness, level of sedation, and degree of head-of-bed elevation), the relationship between tube and pneumonia was no longer significant.

Table 6

Relationship Between 3 Clinical Variables and Pneumonia, After Controlling for Aspiration (n = 428)

Clinical Variable	Risk of Pneumonia
APACHE II	*NS*
Sedation (Vancouver Interaction and Calmness Scale)	Odds of developing pneumonia decreased by 9% for each 1-unit increase (less sedation), $P < .01$
Mean HOB elevation	Odds of developing pneumonia decreased by 18% for each 10-degree increase in HOB elevation), $P = .03$

APACHE II, Acute Physiology and Chronic Health Evaluation II; HOB, head of bed; *NS*, not significant.