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## Gastric Residual Volume and Aspiration in Critically Ill Patients Receiving Gastric Feedings

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### Abstract

**Background**—The helpfulness of bedside assessment of gastric residual volume in the prediction of aspiration has been questioned, as has the volume that signals increased risk of aspiration.

**Objective**—To describe the association between gastric residual volumes and aspiration of gastric contents.

**Methods**—In a prospective study of 206 critically ill patients receiving gastric tube feedings for 3 consecutive days, gastric residual volumes were measured with 60-mL syringes every 4 hours. Measured volumes were categorized into 3 overlapping groups: at least 150 mL, at least 200 mL, and at least 250 mL. Patients were categorized as frequent aspirators if 40% or more of their tracheal secretions were positive for pepsin and as infrequent aspirators if less than 40% of their secretions were positive for pepsin. Gastric residual volumes were compared between the 2 aspiration groups.

**Results**—Approximately 39% of the 206 patients had 1 or more gastric residual volumes of at least 150 mL, 27% had 1 or more volumes of at least 200 mL, and 17% had 1 or more volumes of at least 250 mL. Large-bore tubes identified most of the high volumes. Eighty-nine patients were frequent aspirators. Volumes less than 150 mL were common in both aspiration groups. However, the frequent aspirators had a significantly greater frequency of 2 or more volumes of at least 200 mL and 1 or more volumes of at least 250 mL.

**Conclusions**—No consistent relationship was found between aspiration and gastric residual volumes. Although aspiration occurs without high gastric residual volumes, it occurs significantly more often when volumes are high.

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A closed-book, multiple-choice examination following this article tests your understanding of the following objectives:

1. Describe the association between gastric residual volumes (GRVs) and aspiration of gastric contents.
2. Recognize that measurement error is a significant problem in assessing GRVs.
3. Understand that aspiration risk is significantly increased when GRVs are high.

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Measurement of gastric residual volume (GRV) is often recommended to determine tolerance to gastric tube feedings.<sup>1–7</sup> An underlying assumption is that high GRVs increase the risk for gastroesophageal reflux and associated aspiration. However, the extent to which bedside assessment of GRVs can help predict aspiration risk has been questioned,<sup>8</sup> as has the amount of GRV that signals increased risk of aspiration.<sup>9–13</sup> Values as low as 50 mL and higher than 500 mL have been reported.<sup>14–19</sup>

**Objective**

The objective of this prospective study was to describe the association between GRV and aspiration of gastric contents in a group of critically ill patients receiving gastric tube feedings.

**Methods****Setting and Subjects**

The study was conducted at Saint Louis University Hospital in St Louis, Missouri. Table 1 specifies demographic information for the 206 patients, and Table 2 has a description of their treatment conditions. The work was done in accordance with the appropriate institutional review body and carried out within the ethical standards set forth in the Helsinki Declaration of 1975. Written informed consent was obtained from the patients or their legal guardians. Because of reports<sup>1,6–19</sup> that high GRVs are more likely to occur during the first few days of tube feedings, attempts were made to enroll patients on the day that feedings began.

To be included in the study, patients must have been admitted to 1 of 5 intensive care units (ICUs) at Saint Louis University Hospital, be receiving continuous gastric tube feedings, have a tracheal intubation, be at least 18 years old, and provide informed consent (or have a legal guardian provide informed consent). Patients were excluded from the study if tube feedings were discontinued or tracheal extubation occurred before completion of the 3-day study.

**Data Collection**

Table 3 is a summary of measurements made during the 3-day study period. All data were collected by registered nurse research assistants who were present in the involved ICUs from 8 AM through midnight, 7 days per week, for 24 months. Each patient participated in the study for 3 consecutive days. Most (n = 155) patients were admitted to the study within 24 hours of the start of gastric feeding; the remaining 51 patients had been fed a mean of 3.8 (SD, 2.3) days before entry into the study (range, 2–10 days).

## Measurements

**Pepsin Assay to Assess for Aspiration**—An immunoassay was used to detect pepsin in the suctioned tracheal secretions. The procedure for the assay has been described previously<sup>20</sup>; in an animal model, the assay had a sensitivity of 93% and a specificity of 100%. Within an hour after collection, each secretion was cryopreserved for later analysis. The assay can detect pepsin in a concentration as low as 1 µg/mL. Gels were read by the same biochemist, who did not know the patients' clinical statuses; results were recorded as positive or negative. Pepsin-positive tracheal secretions served as a proxy for the aspiration of gastric contents.

**Gastric Residual Volume**—As shown in Table 2, 44.2% (n = 91) of the patients enrolled in the study had 10F polyurethane tubes; the rest had either polyvinyl chloride sump tubes (n = 99) or gastrostomy tubes (n = 16). Formula flow was turned off and the tube was flushed with 30 mL of air to force the tube's ports away from the mucosal folds. A 60-mL syringe was used to withdraw as much fluid as possible from the stomach. If 60 mL was withdrawn into the syringe, the fluid was emptied into a calibrated container, and the procedure was repeated until no more fluid could be withdrawn. Any amount less than 200 mL was reinstalled into the feeding tube. The tube was then flushed with 30 mL of water before being reconnected to the feeding pump. The GRV measurements were made in whatever position the patient was in at the time; no attempt was made to control this variable.

**Glasgow Coma Scale**—The Glasgow Coma Scale (GCS) is used to assess level of consciousness by evaluating eye opening, motor response, and verbal response. Because all patients were intubated, the best verbal response was estimated as appears able to converse, ability to converse is in question, or generally unresponsive. Possible scores ranged from 3 (worst) to 15 (best).

**Sedation Score**—The level of sedation was assessed by using the Vancouver Interaction and Calmness Scale.<sup>21</sup> This scale was specifically developed for use with adult, critically ill patients receiving mechanical ventilation and consists of two 5-item subscales for quantifying interaction along a continuum from 5 to 30 points. Possible total scores ranged between 10 (worst) to 60 (best).

**Acute Physiology and Chronic Health Evaluation II**—The score on the Acute Physiology and Chronic Health Evaluation (APACHE) II was calculated for each patient when the patient was admitted to the ICU. Parameters used to calculate the score included body temperature; mean arterial pressure; heart rate; respiratory rate; oxygenation; serum levels of sodium, potassium, and creatinine; hematocrit; white blood cell count; GCS score; chronic health points; and age. Possible scores were from 0 (best) to 71 (worst).

**Vomiting and Use of Medications**—The registered nurses who were the research assistants reviewed patients' medical records to determine if vomiting had occurred and to see if specific medications (stress ulcer prophylaxis, prokinetics, opioids, and dopamine) had been administered. These data were recorded at 4-hour intervals on the data collection forms for comparison with other clinical data.

## Data Analysis

Descriptive statistics (frequencies, percentages, and means and standard deviations) were used to report the data. A 1-way analysis of variance was used to compare variation in the percentage of aspiration according to changes in GRVs (categorized in 50-mL intervals from 0 to >250 mL). A  $\chi^2$  test was used to evaluate the association between dichotomized variables. A backward logistic regression was used to compare the relationship between aspiration and GRVs in context with other risk factors for aspiration.<sup>22</sup>

## Results

As indicated in Table 1, most patients were recruited from the trauma/surgery ICU; the next most frequently represented ICUs were general medicine and neurosurgery/neuromedicine. A higher percentage of men than women (61.2% vs 38.8%) participated in the project, primarily because the study site is a level I trauma center. A total of 86 patients (41.7%) had head injuries or cranial neurosurgical conditions. The mean GCS score was 7.1 (SD, 3.0); almost three-fourths (72.3%) of the patients had a mean GCS score less than 9. Further, the score on the Vancouver Interaction and Calmness Scale (mean, 35.9; SD, 4.8) indicated that the patients were heavily sedated; 71.2% had a mean score of 35 or less. Only a small percentage (6.8%) of the patients vomited during the 3-day study period. Although all 206 patients were receiving gastric feedings at the start of data collection, 14 patients (6.8%) had their tubes moved to the small bowel shortly before the end of the data collection period. In 12 of these patients, the tubes were repositioned to the small bowel because of persistent high GRVs or hypoactive bowel sounds; in the remaining 2, large-bore nasogastric tubes were replaced with small-bore nasointestinal tubes.

### Frequency of Aspiration

A total of 3203 tracheal secretions were assayed for pepsin. The mean percentage of tracheal secretions positive for pepsin in the entire sample was 36.2% (SD, 24.7%; range, 0%–100%). Most (92.7%) of the 206 patients had at least 1 tracheal secretion positive for pepsin during the 3-day study period. Because of this result, all patients had to be categorized according to the frequency of aspiration. Patients whose secretions were positive for pepsin in 40% or more of the observations were classified as frequent aspirators; patients with pepsin detected in less than 40% of observations were classified as infrequent aspirators. The median percentage of pepsin-positive tracheal secretions among the 89 frequent aspirators was 53.8%, as opposed to 19.2% among the 117 infrequent aspirators (Figure 1).

### Frequency of High GRVs

A total of 3286 GRVs were measured (mean, 37.1 mL; SD, 36.6 mL). In an attempt to evaluate cutoff points for high GRVs commonly referred to in the literature,<sup>4,23–25</sup> we categorized high GRVs into 3 overlapping groups: at least 150 mL, at least 200 mL, and at least 250 mL. The frequency with which these GRV categories were identified is shown in Figure 2. Overall, 72.8% of the GRVs of at least 150 mL, 74.5% of the GRVs of at least 200 mL, and 80% of the GRVs of at least 250 mL were in patients with large-bore tubes; the rest of the high GRVs were in patients with small-bore tubes.

Patients admitted to the study within 24 hours of the start of gastric feeding were more likely to have at least 1 high GRV in the subsequent 3-day period. For example, 69 of the 81 patients with 1 or more GRVs of at least 150 mL were enrolled within 24 hours of the start of feeding ( $P = .008$ ).

### Relationship Between Aspiration and Gastric Residual Volume

Figure 3 depicts the percentage of secretions indicating aspiration associated with a continuum of GRVs (categorized in 50-mL intervals from 0 to >250 mL). The percentage of secretions indicating aspiration that occurred when GRVs were between 0 and 50 mL was relatively high (33.7%). However, the percentage of aspiration increased as GRVs increased ( $F = 7.7$ ,  $P < .001$ ).

Chi-square tests were done to determine the relationship between the high GRV categories and the 2 aspiration groups. The frequent and infrequent aspirators did not differ significantly in the following categories: 1 or more GRVs of at least 150 mL ( $\chi^2 = 0.3$ ,  $P = .56$ ) and 1 or more

GRVs of at least 200 mL ( $\chi^2 = 2.8, P = .10$ ; Figure 4). However, the aspiration groups differed significantly in the following GRV categories: 2 or more GRVs of at least 150 mL ( $\chi^2 = 4.6, P = .03$ ), 2 or more GRVs of at least 200 mL ( $\chi^2 = 4.9, P = .03$ ), 1 or more GRVs of at least 250 mL ( $\chi^2 = 4.9, P = .03$ ), and 2 or more GRVs of at least 250 mL ( $\chi^2 = 7.1, P = .008$ ).

Because of the patients' high acuity level, we evaluated the association between the various GRV categories and aspiration in context with other risk factors for aspiration. To predict the aspiration group, each of the GRV categories (1 or more GRVs  $\geq 150$  mL, 2 or more GRVs  $\geq 150$  mL, 1 or more GRVs  $\geq 200$  mL, 2 or more GRVs  $\geq 200$  mL, 1 or more GRVs  $\geq 250$  mL, and 2 or more GRVs  $\geq 250$  mL) were entered separately into a backward logistic regression equation with the following variables: a mean GCS score less than 9, heavy sedation (defined as a mean Vancouver Interaction and Calmness Score  $\leq 35$ ), vomiting, a mean head-of-bed elevation  $< 30^\circ$ , and severity of illness (APACHE II score). Only the categories of 2 or more GRVs of at least 200 mL, 1 or more GRVs of at least 250 mL, and 2 or more GRVs of at least 250 mL remained in the model at a  $P$  value less than .05 (Table 4). In the logistic regression analysis, the risk associated with having 2 or more GRVs of at least 200 mL was 2.3 (95% confidence interval [CI], 1.1–5.1), the risk associated with having 1 or more GRVs of at least 250 mL was 2.2 (95% CI, 1.0–4.6), and the risk associated with having 2 or more GRVs of at least 250 mL was 5.4 (95% CI, 1.1–26.4). Additional variables that were significant in 1 or more of the analyses were a mean GCS score less than 9 and a mean head-of-bed elevation less than  $30^\circ$  (Table 4).

## Discussion

### Frequency of Aspiration

The high rate of aspiration in the study most likely reflects the high acuity level of the patients and the sensitive assay used to detect aspiration. Other investigators<sup>8</sup> have reported similar findings in critically ill, tube-fed patients when a sensitive laboratory method was used to detect aspiration.

### Frequency of High GRVs

Our ability to identify 1 or more GRVs of at least 150 mL in 81 of the 206 patients (39.3%) was most likely related to the use of large-bore tubes in 55.8% of the patients. In a similar study, Elpern et al<sup>25</sup> were able to identify 1 or more GRVs of at least 150 mL in 28.2% of 39 patients (more than three-fourths of whom had 18F multiport tubes). Although the percentage of high GRVs in patients with small-bore tubes in our study was relatively low, we most likely achieved a higher success rate than would have occurred if we had not used the air insufflation technique during the procedure.<sup>26</sup>

Two major factors affect the ability to withdraw fluid blindly from a feeding tube via a syringe. First, more fluid can generally be withdrawn from large-bore tubes with multiple ports than from small-bore feeding tubes with only 1 or 2 ports. In a study<sup>27</sup> in which 645 concurrent measurements of GRV were made in 62 critically ill patients with 2 types of gastric tubes (10F polyurethane tubes and 14F–18F sump tubes), high volumes were detected 2 to 3 times more often in patients with large-bore sump tubes. Second, the tubes' ports must be resting in a pool of gastric fluid. For example, Taylor et al<sup>28</sup> reported that a single blind aspiration of GRV in 10 supine obese adults removed only 53% of the total gastric contents. In comparison, Cook-Sather et al<sup>29</sup> were successful in removing 98% of the gastric contents from 17 fasting pediatric patients by using large-diameter (16F–18F) multiport tubes during 3 passes (once while the patients were supine, then again when they were in alternate side-lying positions).

As indicated earlier, 69 of the 81 patients (85.2%) identified as having 1 or more GRVs of at least 150 mL were fed within the first 24 hours of admission to the study. This finding supports the view that high GRVs tend to be more prevalent during the first few days of tube feeding.<sup>19</sup>

### Relationship Between Aspiration and High GRVs

We found no consistent relationship between aspiration and GRVs; that is, as reported by other investigators,<sup>8</sup> aspiration occurred relatively often when GRVs were consistently low. However, we found that the frequency of aspiration increased significantly as GRVs increased (perhaps indicating a greater level of gastroesophageal reflux; Figure 3). Xin et al<sup>30</sup> found a significant positive correlation (0.932) between gastroesophageal reflux and GRVs measured by blind aspiration in 19 critically ill patients.

Although high GRVs may simply coincide with other risk factors for poor outcomes,<sup>31</sup> our findings suggest that high GRVs have an independent effect on risk for aspiration when entwined with other known risk factors. Additional risk factors (a mean GCS score <9 and a mean head-of-bed elevation <30°) were significant in some of the analyses (Table 4). It is not surprising that a low level of consciousness increased the risk for aspiration, because low levels of consciousness interfere with patients' ability to protect the airway from regurgitated gastric contents.<sup>32–35</sup> Other investigators<sup>36</sup> have shown that a low head-of-bed elevation predisposes to aspiration.

### Strengths and Limitations of the Study

A total of 206 critically ill patients participated in the study for a total of 618 patient days, allowing us to measure 3286 GRVs and to collect 3203 tracheal specimens for pepsin analysis. Registered nurses serving as research assistants collected all of the data; thus, the data collection methods were consistent. In addition, the assay used to detect aspiration was specific for the aspiration of gastric contents (the type of aspiration that is of greatest concern in tube-fed patients). However, because this study was descriptive, we had no control over the types of tubes used or other treatment conditions. Further, the highly sensitive pepsin assay could be viewed as a limitation, because small-volume aspirations could be detected. We attempted to deal with this limitation by separating the subjects into 2 distinct groups; as described earlier, we defined frequent aspirators as patients whose tracheal secretions were positive for pepsin in at least 40% of the observations.

### Conclusions

No consistent relationship exists between aspiration and GRVs. In our sample of 206 patients, aspiration occurred fairly often when GRVs were consistently low; however, it occurred significantly more often when GRVs were high. Measurement error is a major problem when attempting to detect high GRVs; we were able to detect proportionately more high GRVs in patients with large-bore tubes than in patients with small-bore tubes. Aspiration risk associated with GRVs probably should be evaluated in context with other risk factors (eg, level of consciousness, position of the head of the bed, sedation, vomiting, severity of illness). In a logistic regression analysis that included these factors, GRV categories identified as significant were having 2 or more GRVs of at least 200 mL, having 1 or more GRVs of at least 250 mL, and especially having 2 or more GRVs of at least 250 mL.

The descriptive nature of our study does not allow us to project significant GRV cutoff points for other adult populations. However, our findings tend to coincide with opinions expressed by several expert panels. For example, in the guidelines for enteral feeding in adult hospital patients, Stroud et al<sup>37</sup> recommended that patients with questionable gastrointestinal motility



have GRV measurements every 4 hours and that the feeding policy be reviewed if the volume exceeds 200 mL. The consensus statement<sup>38</sup> of the North American Summit on Aspiration in the Critically Ill Patient indicated that residual volumes of 200 to 500 mL should prompt careful bedside evaluation and initiation of an algorithmic approach to reduce risk. Also, the statement indicated that although GRVs less than 200 mL appear to be well tolerated, evaluation of risk should be ongoing.

Our findings suggest that it is prudent to measure GRVs at 4-hour intervals in critically ill patients in an effort to determine which patients are at greatest risk for aspiration. Our findings also suggest that to increase the probability of detecting high GRVs, it may be wise to use large-bore multiport tubes during the first few days of tube feedings when high GRVs are most likely to occur. Although only about one-fifth to one-fourth of the high GRVs detected in our study were in patients with small-bore tubes, this number is of sufficient clinical concern to warrant measurement of GRVs in patients with small-bore tubes.

## Acknowledgements

The authors dedicate this article to the memory of Dr Ray E. Clouse, who died shortly after the manuscript was completed. Dr Clouse was a quintessential physician and colleague as well as a beloved friend.

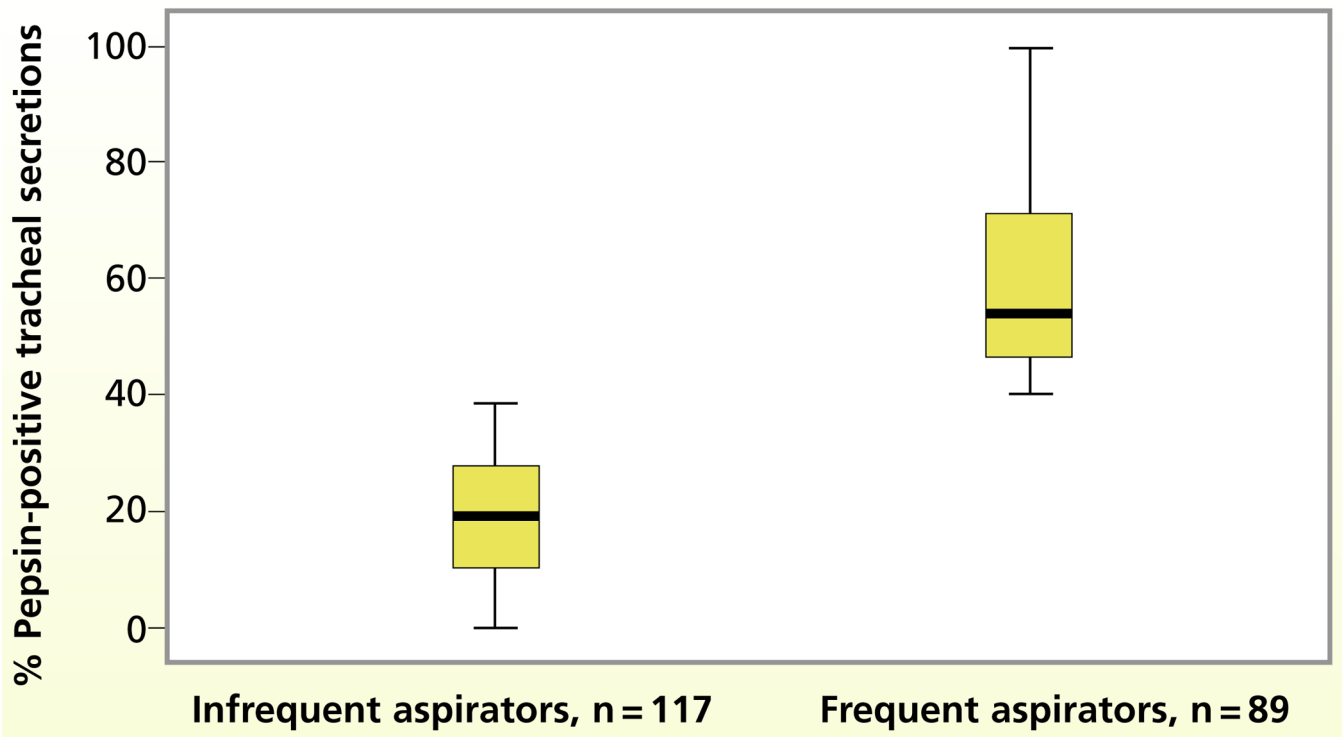
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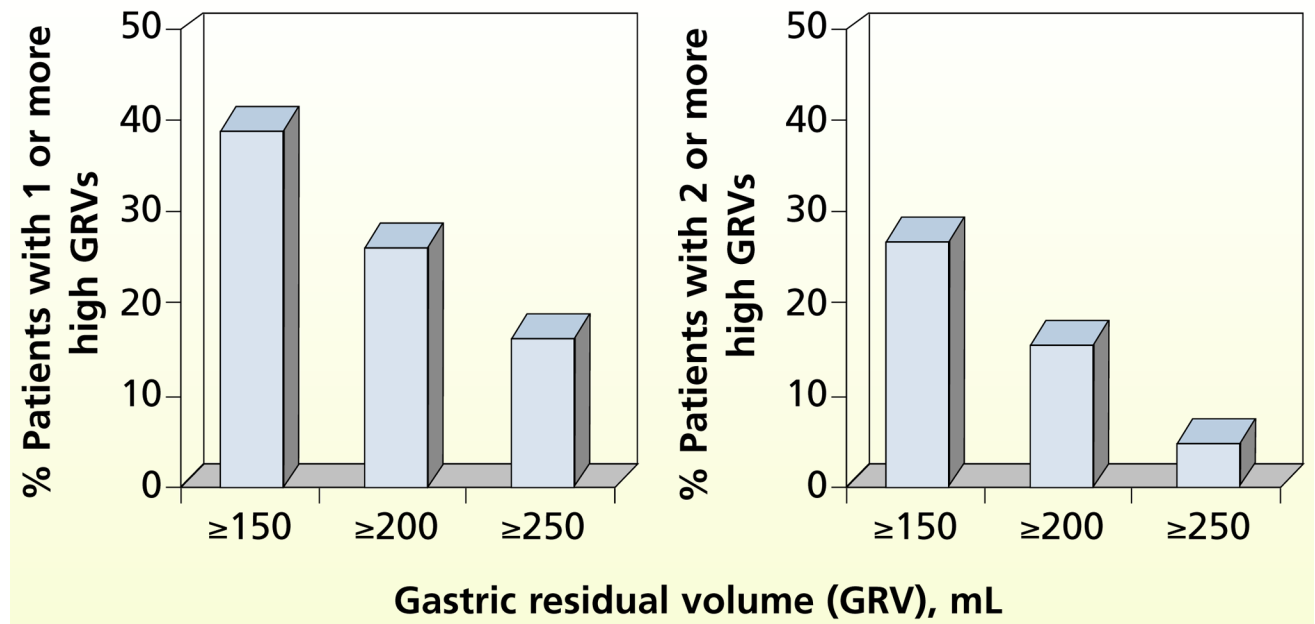
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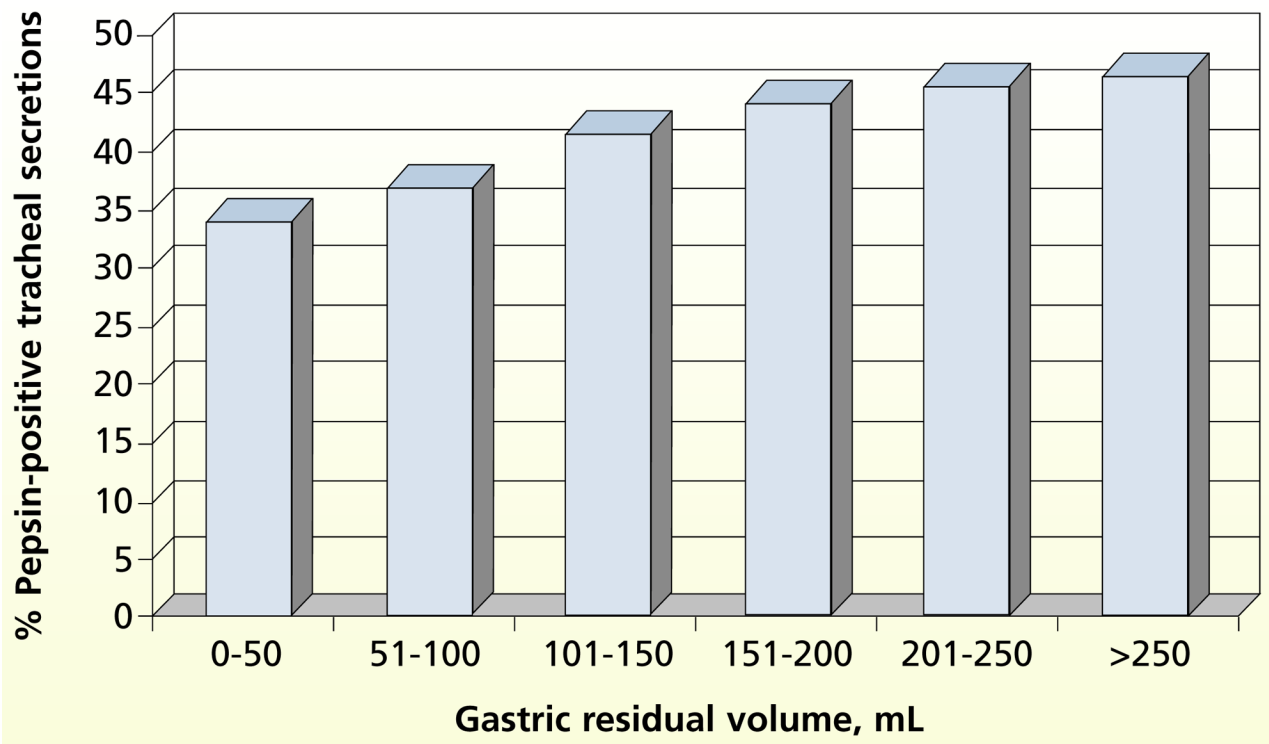
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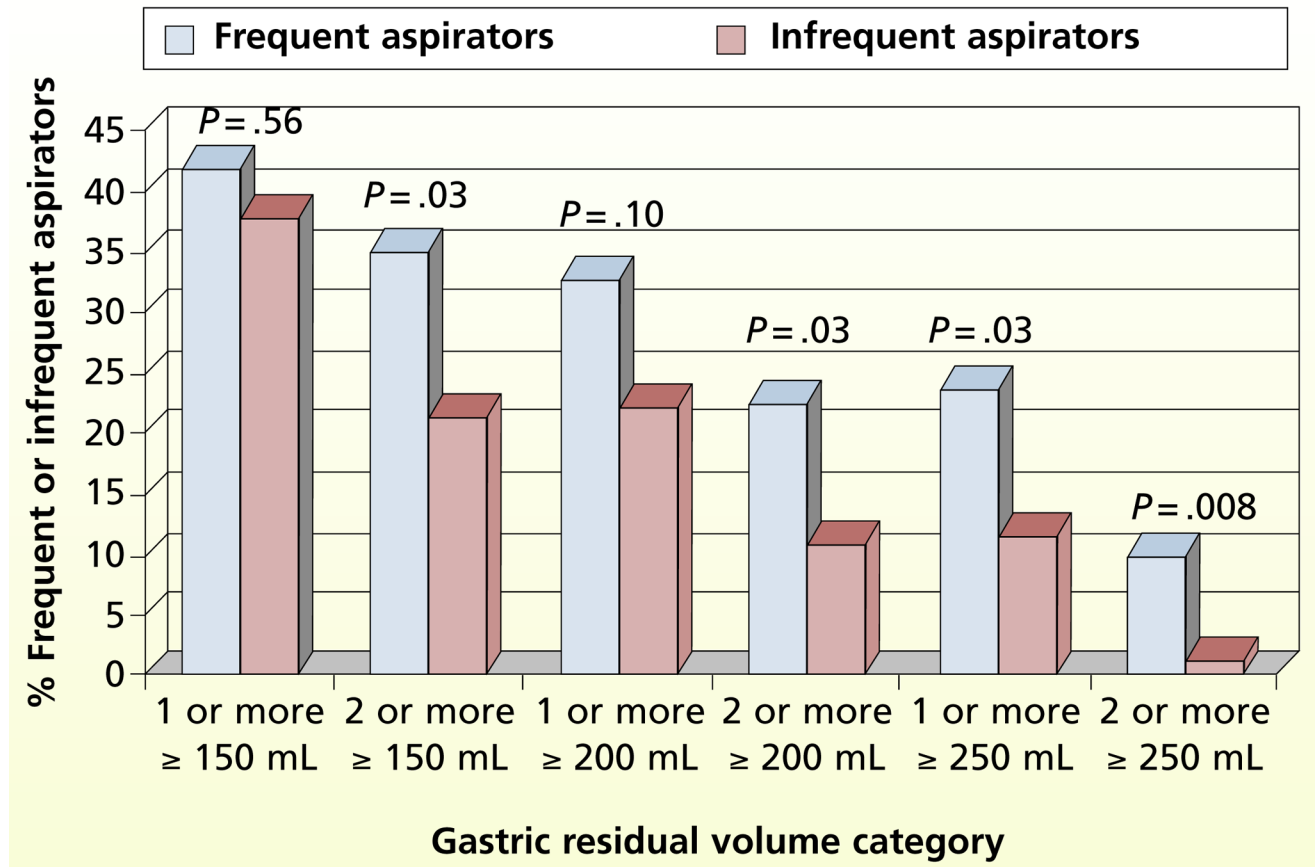
**Figure 1.** Median, upper and lower quartiles, and range of percentages of pepsin-positive tracheal secretions in the frequent and infrequent aspiration groups.



**Figure 2.**  
Frequency of high gastric residual volumes (N = 206)



**Figure 3.** Mean percentage of pepsin-positive tracheal secretions according to gastric residual volume. Data are from 3286 aspirates from small- and large-bore tubes. By 1-way analysis of variance,  $P < .001$ .



**Figure 4.** Distribution of gastric residual volume categories in frequent and infrequent aspirators (univariate analysis,  $\chi^2$  analysis).

**Table 1**

## Demographic information

<b>Variable</b>	<b>Findings<sup>a</sup></b>
Total sample	206
Service from which enrolled	
Trauma/surgery	101 (49.0)
General medicine	46 (22.3)
Neuromedicine/neurosurgery	46 (22.3)
Cardiac services	13 (6.3)
Sex	
Male	126 (61.2)
Female	80 (38.8)
Age, mean (SD, range), y	51.9 (18.1, 18–88)
Acute Physiology and Chronic Health Evaluation score on admission, mean (SD, range)	23.3 (6.3, 10–40)

<sup>a</sup>Values are number (%) of patients unless otherwise indicated. Because of rounding, not all percentages total 100.



**Table 2**

## Description of treatment conditions

<b>Variable</b>	<b>Findings<sup>a</sup></b>
Gastric feeding site	206 (100)
Feeding tubes	
10F polyurethane nasogastric or orogastric tube	91 (44.2)
14F polyvinyl chloride nasogastric or orogastric sump tube	11 (5.3)
16F polyvinyl chloride nasogastric or orogastric sump tube	3 (1.5)
18F polyvinyl chloride nasogastric or orogastric sump tube	85 (41.3)
20F gastrostomy tube	16 (7.8)
Enteral formula administration	
No. of days feedings in use at entry into the study, mean (SD, range)	1.2 (1.9, 0–10)
Rate of formula administered, mean(SD, range), mL/h	54.3 (17.4, 10–90)
Mean backrest elevation	
≥30°	72 (35.0)
≥45°	2 (1.0)
Use of stress ulcer prophylaxis	
H <sub>2</sub> -receptor antagonist	144 (69.9)
Proton pump inhibitor	62 (30.1)
Use of prokinetics	107 (51.9)
Use of opioids	154 (74.8)
Use of dopamine	21 (10.2)

<sup>a</sup> Values are number (%) of patients unless otherwise indicated. Because of rounding, not all percentages total 100.

**Table 3**

## Summary of measurements

**Measurement**

Assay of sputum for pepsin

Residual volume from feeding tube

Level of consciousness

Level of sedation

Presence of vomiting

Use of medications (opioids, dopamine, prokinetics, stress ulcer prophylaxis)

Volume of formula administered

Acute Physiology and Chronic Health Evaluation II score

Angle of backrest elevation

**Frequency**

Samples collected at time of routine suctioning between 8 am and midnight for 3 consecutive days

Every 4 hours between 8 am and midnight for 3 consecutive days

At time of admission to intensive care unit

Hourly from 8 am through midnight

**Table 4**Prediction of aspiration group (frequent versus infrequent) according to multiple risk factors for aspiration<sup>a</sup>

<b>Analyses</b>	<b>Retained variables</b>	<b>Risk (95% CI)</b>	<b>P</b>
Analysis 1 1 or more GRVs $\geq$ 150 mL	Head of bed $<30^\circ$	1.9 (1.0–3.5)	.04 <sup>b</sup>
	GCS score $<9$	2.0 (1.0–3.8)	.04 <sup>b</sup>
Analysis 2 2 or more GRVs $\geq$ 150 mL	Head of bed $<30^\circ$	1.8 (0.9–3.3)	.08
	GCS score $<9$	2.0 (1.0–3.9)	.04 <sup>b</sup>
	2 or more GRVs $\geq$ 150 mL	1.8 (0.9–3.5)	.06
Analysis 3 1 or more GRVs $\geq$ 200 mL	Head of bed $<30^\circ$	1.9 (1.0–3.5)	.04 <sup>b</sup>
	GCS score $<9$	2.0 (1.0–3.8)	.04 <sup>b</sup>
Analysis 4 2 or more GRVs $\geq$ 200 mL	APACHE II score	1.1 (0.9–1.1)	.06
	GCS score $<9$	2.0 (1.0–3.9)	.04 <sup>b</sup>
	2 or more GRVs $\geq$ 200 mL	2.3 (1.1–5.1)	.03 <sup>b</sup>
Analysis 5 1 or more GRVs $\geq$ 250 mL	Head of bed $<30^\circ$	1.9 (1.0–3.5)	.048 <sup>b</sup>
	GCS score $<9$	1.9 (0.9–3.7)	.06
	1 or more GRVs $\geq$ 250 mL	2.2 (1.0–4.6)	.047 <sup>b</sup>
Analysis 6 2 or more GRVs $\geq$ 250 mL	Head of bed $<30^\circ$	1.9 (1.0–3.5)	.04 <sup>b</sup>
	GCS score $<9$	1.7 (0.9–3.5)	.10
	2 or more GRVs $\geq$ 250 mL	5.4 (1.1–26.4)	.04 <sup>b</sup>

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; CI, confidence interval; GCS, Glasgow Coma Scale; GRV, gastric residual volume.

<sup>a</sup>Variables in model include dichotomized mean elevation of head of bed, dichotomized mean score on GCS, dichotomized mean sedation score, presence or absence of vomiting, and the mean APACHE II score.

<sup>b</sup> $P < .05$ .