Impact of Not Measuring Residual Gastric Volume in Mechanically Ventilated Patients Receiving Early Enteral Feeding: A Prospective Before-After Study

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Impact of Not Measuring Residual Gastric Volume in Mechanically Ventilated Patients Receiving Early Enteral Feeding: A Prospective Before–After Study

Fanny Poulard¹; Jerome Dimet, PharmD²; Laurent Martin-Lefevre, MD¹; Frederic Bontemps, MD¹; Maud Fiancette, MD¹; Eva Clementi, MD¹; Christine Lebert, MD³; Benoit Renard, MD¹; and Jean Reignier, MD, PhD¹,⁴

Background: Monitoring of residual gastric volume (RGV) to prevent aspiration is standard practice in mechanically ventilated patients receiving early enteral nutrition (EN). No data are available to support a correlation between RGV and adverse event rates. We evaluated whether not measuring RGV affected EN delivery, vomiting, or risk of nosocomial pneumonia. Methods: Two hundred and five eligible patients with nasogastric feeding within 48 hours after intubation were included in a 7-day prospective before–after study. Continuous 24-hour nutrition was started at 25 mL/h then increased by 25 mL/h every 6 hours, to 85 mL/h. In both groups, intolerance was treated with erythromycin (250 mg IV/6 h) and a delivery rate decrease to the previously well-tolerated rate. RGV monitoring was used during the first study period (n = 102), but not during the subsequent intervention period (n = 103). Intolerance was defined as RGV >250 mL/6 h or vomiting in the standard-practice group and as vomiting in the intervention group. Results: Groups were similar for baseline characteristics. Median daily volume of enteral feeding was higher in the intervention group (1489; interquartile range [IQR], 1349–1647) than in the controls (1381; IQR, 1151–1591; P = .002). Intolerance occurred in 47 (46.1%) controls and 27 (26.2%) intervention patients (P = .004). The vomiting rate did not differ between controls and intervention group patients (24.5% vs 26.2%, respectively; P = .34), and neither was a difference found for ventilator-associated pneumonia (19.6% vs 18.4%; P = .86). Conclusion: Early EN without RGV monitoring in mechanically ventilated patients improves the delivery of enteral feeding and may not increase vomiting or ventilator-associated pneumonia. (JPEN J Parenter Enteral Nutr. 2010; 34:125-130)

Keywords: residual gastric volume; gastric emptying; esophageal reflux; vomiting; nosocomial pneumonia; enteral nutrition; mechanical ventilation
We hypothesized that RGV monitoring led to inappropriate interruptions in enteral feeding, with a risk of underfeeding, while failing to decrease the risk of vomiting and VAP. The lack of a sound rationale for RGV monitoring led us to discontinue this practice, which was previously included in our standard protocol for enteral feeding. When RGV was not monitored, enteral feeding was discontinued only if vomiting occurred. To assess the effects of not measuring RGV on enteral feeding delivery, vomiting, and VAP, we designed a prospective before–after study.

**Materials and Methods**

**Setting and Patients**

This prospective before–after study was performed from July 2004 to July 2006 in the 15-bed adult medical-surgical intensive care unit (ICU) of the District Hospital Center in La Roche-sur-Yon, France. A working group including ICU nurses and physicians studied means of improving enteral feeding delivery in patients receiving endotracheal mechanical ventilation. To this end, patient characteristics, enteral feeding variables, and patient outcomes recorded daily at the bedside were entered prospectively into a database. The working group wrote a protocol for enteral feeding based on published recommendations and a literature review. RGV monitoring was included in the initial protocol then removed in 2005. To assess the effects of this change, we conducted a before–after study. All eligible patients treated between July 2004 and June 2005 were compared to all eligible patients treated between July 2005 and June 2006. No other treatments that might have influenced our results were introduced during either period.

**Inclusion/Noninclusion Criteria**

Patients were eligible if they received EN via a nasogastric tube within 48 hours after the initiation of endotracheal mechanical ventilation. Noninclusion criteria were a history of esophageal or gastric surgery; bleeding from the esophagus, stomach, or bowel; administration of prokinetic agents within 48 hours before starting EN; EN via a jejunostomy or gastrostomy; acute pancreatitis; and pregnancy.

**Early EN**

The EN preparation (Isosource, Novartis, Revel, France) was administered via a 14-F silicone nasogastric tube inserted by the patient’s nurse. A chest radiograph obtained daily at the bedside was used to check that the tip of the tube was in the stomach. EN was initiated as soon as possible after the beginning of endotracheal mechanical ventilation. A peristaltic infusion pump injected the EN preparation into the tube at a continuous rate. Nutrition was delivered continuously over a 24-hour cycle, starting at 25 mL/h and increasing by 25 mL/h every 6 h, up to 85 mL/h. In the event of intolerance (RGV >250 mL or vomiting in the control group; vomiting in the intervention group), the delivery rate was decreased to the previously well-tolerated rate, and erythromycin (250 mg IV/6 h) was started. If no further evidence of intolerance occurred over the next 6 h, the rate was again increased by 25 mL/h, and erythromycin was stopped after 48 hours of well-tolerated enteral feeding at 85 mL/h. Patients were positioned in a semirecumbent position (45°) using an adjustable electrical bed equipped with an angle indicator (TotalCare, Hill-Rom, Batesville, IN).

**Control Phase**

Tolerance of EN was assessed by measuring the RGV and by recording vomiting episodes. RGV was measured at 6-hour intervals (6 am, noon, 6 pm, and midnight) by aspirating the nasogastric tube with a 50-mL syringe. The aspirate was returned to the patient, unless it exceeded 250 mL.

**Phase Without Monitoring of RGV**

Tolerance of EN was assessed by recording vomiting episodes. RGV was not measured.

**Data Collection**

The following characteristics were recorded daily during the 7-day study period: age, sex, McCabe score, weight, Simplified Acute Physiology Score (SAPS) II, diagnosis, Sequential Organ Failure Assessment (SOFA) score, vital signs, laboratory values, volume and rate of EN, RGV (in the control group only), and vomiting. Day 1 of the study was the first day of enteral feeding. Episodes of VAP were recorded until ICU discharge.

**Diagnosis of Ventilator-associated Pneumonia**

VAP was suspected in patients who had new and persistent or progressive infiltrates on the chest radiograph with at least 2 of the following criteria: peripheral leukocytosis (>10,000/mm³), or leukopenia (4,000/mm³), and body temperature ≥38.5°C or ≤35.5°C, and purulent tracheal aspirates. Patients with clinically suspected VAP underwent fiberoptic bronchoscopy with protected distal bronchial sampling. The diagnosis of VAP was confirmed when the quantitative culture of the protected distal bronchial sample was positive at ≥10⁵ cfu/mL.

**Ethics**

In this observational study, the protocols for EN were those used routinely in our unit. Therefore, according to French law on biomedical research, informed consent
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from the patients or relatives was not required. Our local ethics committee approved the study.

Statistical Analysis

Groups were compared using the Student t test for continuous data and the $\chi^2$-square test for categorical variables. Demographic data were expressed as mean ± SD. The Mann-Whitney test was used to compare the control and intervention groups regarding median EN volume and episodes of vomiting. The incidence of VAP (expressed as the ratio of the number of events over the number of patient-days with mechanical ventilation) was compared between the 2 groups using the $z$ test. $P$ values <.05 were considered significant.

Results

Of the 205 eligible patients who met our inclusion criteria during the study period, 102 underwent RGV measurement (control group, July 2004–June 2005) and 103 did not (intervention group, July 2005–June 2006). The main patient characteristics are reported in Table 1. Age, sex, McCabe score, weight, SAPS II, SOFA score, admission diagnosis, and risk factors for enteral feeding intolerance did not differ between the 2 groups. Neither were differences found regarding mean duration of mechanical ventilation (13 ± 9 vs 14 ± 12 days, respectively; $P = .65$), mean length of stay in the ICU (18 ± 14 vs 17 ± 15 days; $P = .59$), mean length of stay in hospital (27 ± 22 vs 27 ± 22 days; $P = .98$), ICU mortality (24.5% vs 35%; $P = .13$), or hospital mortality (35.3% vs 42.7%; $P = .32$).

Enteral Feeding

Total duration of EN was 619 days in the control group and 611 days in the intervention group (median duration per patient [interquartile range (IQR)], 7 [5–7] vs 7 [5–7], respectively; $P = .5$). When all days with enteral feeding were pooled, median volume of enteral feeding per day was higher in the intervention group (1489; IQR, 1349–1647) than in the control group (1381; IQR, 1151–1591; $P = .002$). Median daily EN volumes were greater in the intervention group than in the control group on days 1 and 2 of the 7-day study period, but did not differ between groups on days 3–7 (Table 2). Intolerance to enteral feeding was recorded in 47 (46.1%) control and 27 (26.2%) intervention patients ($P = .004$). The mean cumulative erythromycin dose over the 7-day study period was higher in the control group (1593 ± 1775 mg) than in the intervention group (888 ± 1515 mg) ($P < .05$). However, rates of vomiting did not differ between the 2 groups (Table 3).

Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Control Group (n = 102)</th>
<th>Intervention Group (n = 103)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>62 ± 16</td>
<td>63 ± 15</td>
<td>.67</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>66/36</td>
<td>73/30</td>
<td>.37</td>
</tr>
<tr>
<td>McCabe, n (%)</td>
<td></td>
<td></td>
<td>.94</td>
</tr>
<tr>
<td>(0) No fatal underlying</td>
<td>52 (51)</td>
<td>50 (48.5)</td>
<td></td>
</tr>
<tr>
<td>(1) Death expected within 5</td>
<td>39 (38.2)</td>
<td>41 (39.8)</td>
<td></td>
</tr>
<tr>
<td>(2) Death expected within 1 y</td>
<td>11 (10.8)</td>
<td>12 (11.7)</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75 ± 20</td>
<td>81 ± 22</td>
<td>.07</td>
</tr>
<tr>
<td>SAPS II</td>
<td>53 ± 15</td>
<td>51 ± 17</td>
<td>.25</td>
</tr>
<tr>
<td>SOFA at baseline</td>
<td>8 ± 3</td>
<td>7 ± 4</td>
<td>.06</td>
</tr>
<tr>
<td>SOFA, maximum value*</td>
<td>10 ± 3</td>
<td>10 ± 4</td>
<td>.74</td>
</tr>
<tr>
<td>Medical diagnosis at admission, n (%)</td>
<td>91 (89.2)</td>
<td>91 (89.3)</td>
<td>.99</td>
</tr>
<tr>
<td>Diagnosis at ICU admission, n (%)</td>
<td></td>
<td></td>
<td>.97</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>6 (5.9)</td>
<td>8 (7.8)</td>
<td></td>
</tr>
<tr>
<td>Acute heart failure</td>
<td>8 (7.8)</td>
<td>6 (5.8)</td>
<td></td>
</tr>
<tr>
<td>Acute central nervous failure</td>
<td>25 (24.5)</td>
<td>22 (21.4)</td>
<td></td>
</tr>
<tr>
<td>Acute respiratory failure</td>
<td>34 (33.3)</td>
<td>36 (35)</td>
<td></td>
</tr>
<tr>
<td>Sepsis</td>
<td>21 (20.6)</td>
<td>23 (22.3)</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>8 (7.8)</td>
<td>8 (7.8)</td>
<td></td>
</tr>
<tr>
<td>Risk factors for EN intolerance, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prone position</td>
<td>35 (34.3)</td>
<td>28 (27.2)</td>
<td>.23</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>7 (6.9)</td>
<td>11 (10.7)</td>
<td>.46</td>
</tr>
<tr>
<td>Sedative agents</td>
<td>63 (62.4)</td>
<td>62 (60.2)</td>
<td>.78</td>
</tr>
<tr>
<td>Dialysis</td>
<td>18 (17.6)</td>
<td>14 (13.6)</td>
<td>.45</td>
</tr>
</tbody>
</table>

Abbreviations: EN, enteral nutrition; ICU, intensive care unit; SAPS II, Simplified Acute Physiology Score; SOFA, Sequential Organ Failure Assessment.

*Maximum SOFA score value during the 7-day study period.
Table 2. Volume of Enteral Feeding (mL) Received Daily by the Patients in Each Groupa

<table>
<thead>
<tr>
<th></th>
<th>Control Group</th>
<th>Intervention Group</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 102)</td>
<td>(n = 103)</td>
<td></td>
</tr>
<tr>
<td>Day 1b</td>
<td>300 (159–300)</td>
<td>415 (175–450)</td>
<td>.012</td>
</tr>
<tr>
<td>Day 2</td>
<td>1431 (1156–1500)</td>
<td>1725 (1583–1800)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Day 3</td>
<td>1800 (1445–1920)</td>
<td>1800 (1800–1800)</td>
<td>.69</td>
</tr>
<tr>
<td>Day 4</td>
<td>1800 (1322–2040)</td>
<td>1800 (1800–1915)</td>
<td>.88</td>
</tr>
<tr>
<td>Day 5</td>
<td>1800 (1350–2040)</td>
<td>1800 (1706–2040)</td>
<td>.53</td>
</tr>
<tr>
<td>Day 6</td>
<td>1800 (1530–2040)</td>
<td>1800 (1800–2040)</td>
<td>.93</td>
</tr>
<tr>
<td>Day 7</td>
<td>1815 (1470–2040)</td>
<td>1800 (1748–2040)</td>
<td>.81</td>
</tr>
</tbody>
</table>

Values are presented as median (interquartile range).

bDay 1 of the study was the first day of enteral feeding.

In the 25 controls with vomiting, 76 vomiting episodes were recorded, of which only 2 were preceded by RGV volumes >250 mL; the last measured RGV volume was >200 mL in 4 episodes and >100 mL in 10 episodes.

Ventilator-associated Pneumonia

VAP occurred in 39 (19%) of the 205 study patients. The number of patients with VAP was not different between the control and intervention groups (Table 3). The incidence of VAP did not differ (20.9 episodes vs 16.9 episodes/1000 patient-days of intubation in the control and intervention groups, respectively; P = .9).

Overall, 12 (30.8%) of the 39 patients with VAP had vomiting, compared to 40 (24.1%) of the 166 patients without VAP (P = .42). In the control group, 7 (35%) patients with VAP had RGV values >250 mL, compared to 25 (30.5%) patients without VAP (P = .79).

Discussion

This prospective before–after study showed that compared to patients with RGV monitoring, patients without RGV monitoring during early enteral feeding received larger feeding volumes without experiencing increases in the rates of vomiting and VAP.

Early enteral feeding has been recommended in critically ill patients treated with endotracheal mechanical ventilation because of documented positive effects on gut mucosa integrity, immune function, infection rates, glycemic control, and survival.1,2,17 In our ICU, we use early enteral feeding whenever possible in patients receiving endotracheal mechanical ventilation. Here, we studied patients who were receiving mechanical ventilation at the acute phase of their illness and who were given EN within 48 hours after intubation. A complication of enteral feeding is vomiting followed by aspiration and VAP. Many critically ill patients experience poor tolerance of early EN because of impaired gastric motility with delayed gastric emptying. The resulting high RGV increases the risk of gastroesophageal reflux.3-6,18,19 Gastroesophageal reflux with marked inhibition of esophageal motility is common in critically ill patients receiving endotracheal mechanical ventilation and may increase the risk of VAP by promoting retrograde oropharyngeal colonization, vomiting, and aspiration.3,20 Aspiration has been reported as the leading cause of pneumonia in the ICU and the most serious complication of enteral tube feeding.12 Rates of intolerance to enteral feeding and VAP (46.1% and 19.6%, respectively) in our control group were similar to those reported in previous studies.21

In an attempt to minimize the risk for aspiration and VAP, many clinicians monitor RGV by regularly aspirating the gastric contents via the nasogastric tube. This practice has been included in recommendations on enteral feeding in the critically ill.11 It is based on the assumption that measured RGV is an accurate marker for intolerance to enteral feeding with a risk of aspiration and VAP. Thus enteral feeding is typically discontinued in patients who have large RGVs, with the goal of preventing VAP. In our ICU, until 2005, detection of intolerance to enteral feeding in mechanically ventilated patients was based on RGV measurement every 6 hours. However, studies found no relationship between RGV and the risk of vomiting or VAP.12,15 It has been suggested that RGV monitoring may be unnecessary.14 In July 2005, we removed RGV monitoring from our protocol for early EN of mechanically ventilated patients and designed a before–after study to assess the effects of this change. To our knowledge, our study is the first comparison of 2 large patient groups in the everyday clinical setting, one with and the other without RGV monitoring during early enteral feeding. Importantly, neither vomiting nor VAP were more common without RGV monitoring. Moreover, data from the group with RGV monitoring showed that episodes of vomiting were rarely associated with increased RGV values. These results are consistent with previous data obtained using colored microbeads.15 Furthermore, the daily volume of enteral feeding was higher without RGV monitoring. This result is important, as it indicates that RGV monitoring may hinder EN delivery by leading to unnecessary interruptions, which in turn may lead to underfeeding, a condition associated with increased rates of muscular, respiratory, and infectious complications.5,6,22,23 Therefore, stopping EN delivery when the RGV reaches an arbitrarily selected cutoff is not justified by scientific evidence, increases nurse workload, and fails to decrease the risk of VAP.

Several factors may explain these findings. First, aspirating the stomach using a syringe and a nasogastric tube may fail to provide an accurate estimate of the RGV.
Underestimation may occur if the entire gastric contents is not removed. Although used worldwide, this technique for RGV measurement is not standardized. Tube position, tube type, obstruction of the tube lumen, number of tube openings, syringe size, and the individual performing the aspiration may affect the results. Other, possibly more accurate, techniques are not applicable at bedside. Refractometry may hold promise but has not been evaluated in routine practice. Second, RGV measurement every 6 hours may miss short-lived RGV increases associated with aspiration. However, the timing of RGV increases is unpredictable. Third, the 250-mL cutoff value used in our study may be inappropriate. The optimal RGV cutoff above which enteral feeding should be discontinued has not been determined. Cutoffs ranging from 150 to 500 mL have been used. Moreover, high RGV values are not independently correlated with adverse outcomes, and there is no evidence that decreasing the cutoff leads to lower rates of aspiration or VAP. Last, aspiration of EN may not be the main determinant of VAP. Previous studies indicate that aspiration of oropharyngeal secretions colonized with pathogenic bacteria is the main pathogenic mechanism of VAP. The role of the stomach as a pathogen reservoir is still debated. Instead of RGV monitoring, other strategies such as orotracheal intubation, changes in ventilator circuits only for each new patient, use of closed endotracheal suction systems, weekly changes of heat and moisture exchangers, semirecumbent positioning, and subglottic secretion drainage may hold greater potential for decreasing VAP rates.

Our study has several limitations. First, the observational, nonrandomized, before–after design limits our ability to determine a causal relationship between the intervention and the increased enteral feeding volumes. An effect of time cannot be completely excluded. However, we considered that available scientific data supported removal of RGV from our enteral feeding protocol. The aim of the present study was to evaluate this change. Similar before–after designs have been considered appropriate to assess the effects of new protocols. Neither the nurses nor the patients could be blinded for RGV monitoring. However, the study was performed over 2 well-defined, consecutive, 1-year periods during which all eligible patients were screened for the study. No other treatments that might have influenced our results were introduced during either period. The ICU staff had extensive experience with early enteral feeding and standard ICU protocols. Moreover, we used a highly reliable fiberoptic quantitative technique for the diagnosis of VAP. Therefore, we are confident that routine RGV monitoring is not beneficial in clinical practice. Nevertheless, given the limitations of our study owing to its observational before–after design, a large, randomized trial is required to provide a definitive answer to this important question. A greater number of patients would be required to provide adequate power to confirm that RGV monitoring is not associated with a decreased VAP rate. Second, our study was performed in a single ICU and the results may not apply to other institutions. However, the demographic characteristics and rates of enteral feeding intolerance and VAP in our patients were similar to those reported in earlier studies, suggesting that our intervention might benefit patients in other ICUs. Third, the target volume of enteral feeding was not calculated for each individual patient. A mismatch may have occurred between the daily target volume and the nutrition needs of some of the patients. Tailoring enteral feeding volumes to the individual needs of each patient deserves to be investigated in future studies.

Conclusion

Compared to patients with RGV monitoring, patients without RGV monitoring during early enteral feeding received more EN without experiencing increased rates of vomiting or VAP. Therefore, stopping enteral feeding delivery when an arbitrarily selected RGV cutoff was reached failed to decrease the VAP rate or to induce other benefits. Routine RGV monitoring during early EN in mechanically ventilated patients may be able to be discontinued in most ICUs.

<table>
<thead>
<tr>
<th>Table 3. Clinical Outcomes of Patients in Each Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group (n = 102)</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Intolerance to enteral nutrition, n (%)</td>
</tr>
<tr>
<td>Vomiting, n (%)</td>
</tr>
<tr>
<td>Ventilation-associated pneumonia, n (%)</td>
</tr>
</tbody>
</table>

*Values of enteral nutrition are presented as median [interquartile range].

RGV, residual gastric volume. In the control group, intolerance to enteral nutrition was defined as vomiting or RGV >250 mL; in the intervention group, RGV was not measured, and intolerance was defined as vomiting.
Acknowledgments

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