Research article

Enteral feeding in the critically ill: comparison between the supine and prone positions
A prospective crossover study in mechanically ventilated patients

Peter HJ van der Voort* and Durk F Zandstra†

*Department of Intensive Care, Medical Centre Leeuwarden-Zuid, Leeuwarden, The Netherlands
†Department of Intensive Care, Onze Lieve Vrouwe Gasthuis, Amsterdam, The Netherlands

Correspondence: Peter HJ van der Voort, phjvdvoort@wxs.nl

Abstract

Introduction Prone position is effective in mechanically ventilated patients to improve oxygenation. It is unknown if prone position affects gastric emptying and the ability of continued enteral feeding.

Aim To determine tolerance of enteral feeding by measuring gastric residual volumes in enterally fed patients during supine and prone positions.

Methods Consecutive mechanically ventilated intensive care patients who were turned to prone position were included. All patients were studied for 6 hours in supine position, immediately followed by 6 hours in prone position, or visa versa. The rate of feeding was unchanged during the study period. Gastric residual volume was measured by suctioning the naso-gastric tube after 3 and 6 hours in the same position. Wilcoxon test and regression analysis were used for analysis.

Results The median volume of administered enteral feeds was 95 ml after 6 hours in supine position and 110 ml after 6 hours in prone position ($P = 0.85$). In 10 patients, a greater gastric residual volume was found in prone position. In eight others a greater volume was found in supine position. In 18 of 19 patients, gastric residual volumes in both positions were ≥150 ml in 6 hours or ≤150 ml in 6 hours. Significantly more sedatives were used in prone position. Regression analysis excluded dopamine dose and the starting position as confounders.

Conclusion Our results suggest that enteral feeding can be continued when a patient is turned from supine to prone position or vice versa. The results indicate that patients with a clinically significant gastric residual volume in one position are likely to have a clinically significant gastric residual volume in the other position.

Keywords critically ill patients, enteral feeding, gastric residual volume, prone position, supine position

Introduction

Enteral feeding in critically ill patients is currently preferred to parenteral feeding [1,2]. Among other beneficial effects, enteral feeding stimulates mucosal blood flow, maintains gut barrier function and mucosal integrity [3,4], and improves liver dysfunction [5]. Enteral feeding also decreases the length of stay in hospital and the costs. The mortality rate and septic complications are lower in patients who are enterally fed compared with patients who are parenterally fed [6,7].

Gastric emptying in critically ill patients can be delayed for various reasons, such as opiates, dopamine, acidosis and electrolyte disorders, and can lead to impaired toler-

---

ANOVA = analysis of variance; APACHE = Acute Physiology and Chronic Health Evaluation; PaO_2 = arterial oxygen tension; FiO_2 = fractional inspired oxygen concentration.

ance of enteral feeds [8]. Enteral feeds are normally given by continuous drip through a nasogastric tube to achieve sufficient caloric intake. Interruption of enteral feeding may lead to insufficient nutrition. It is therefore important to know whether enteral feeding can be continued in a position other than the supine position. The prone position is effective in mechanically ventilated patients to improve oxygenation and mobilisation of bronchial secretions [9]. It is sometimes necessary to continue the prone position for days or to turn patients in the prone position several times a day [10]. It is unknown whether the prone position affects gastric emptying and the ability of continued enteral feeding. We studied tolerance of enteral feeding in mechanically ventilated patients in the prone position by measuring the gastric residual volume in comparison with the gastric residual volume during the supine position.

Materials and methods

Consecutive mechanically ventilated intensive care patients who were turned to the prone position over a 1-year period were included. Enteral feeding started within 24 hours after admission. The rate of feeding was determined by measuring the gastric residual volume every 6 hours. A gastric residual volume below 150 ml was followed by an enhanced feeding rate until 80 ml/hour was achieved. The feeding rate was held constant during the study period. Acute Physiology and Chronic Health Evaluation (APACHE) II scores and associated mortality prediction were calculated within 24 hours of admission. The prone position was indicated for an arterial oxygen tension (PaO_2)/fractional inspired oxygen concentration (FiO_2) ratio below 100 mmHg or pneumonia with excessive production of bronchial secretions. All patients were studied for 6 hours in the supine position and for 6 hours in the prone position. The position that was studied first was not defined but both study periods had to be consecutive. The stomach was emptied at the beginning of each study period by suctioning the nasogastric tube. Gastric residual volume was measured by suctioning the nasogastric tube after 3 and 6 hours in the same position without interruption of enteral feeding. At 3 hours, the gastric residue was returned to a maximum of 100 ml in the stomach. Immediately after the 6-hour study period, the patient was turned to the other position and the gastric residual volume was again measured after 3 and 6 hours. None of the patients received acid-suppressive drugs. The head was elevated in both positions to a maximum of 30°.

Statistical analysis

The Wilcoxon test was used for comparison of residual volumes in the prone and supine positions. The difference in residual volumes between the prone and supine positions was analysed with the one-sample t test. Paired-sample t tests used in other analyses were appropriate. Linear regression was used to analyse the relat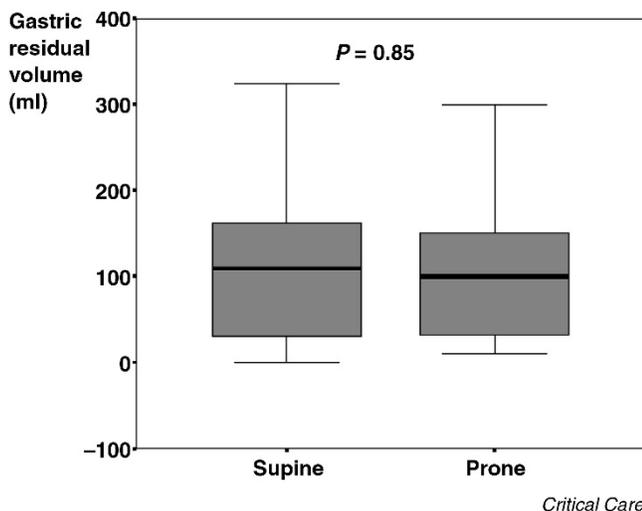ion between gastric residual volumes in the prone and supine positions and for the regression of APACHE on residual volumes. Univariate analysis of variance (ANOVA) and multiple regression analysis were used to analyse the factors contributing to residual volume. A two-tailed $P < 0.05$ was considered statistically significant. All analyses were made using SPSS statistical analyser release 8.0.0 (SPSS Inc., Cary, North Carolina, USA, 1997).

Results

Twenty patients were included. One patient was not eligible because of insufficient data collection, so we studied 14 male and 5 female patients. The mean age was 65.1 years (range, 41–82 years). Nine patients were admitted for pneumonia, 5 for septic shock, 2 for congestive heart failure and 1 patient for each of the following: pancreatitis, serotonin syndrome and aortic surgery. The indication for the prone position was PaO_2/FiO_2 ratio <100 in 17 and excessive sputum retention in 2 patients. The mean APACHE II score on admission was 25.5 (SD = 8.98) with a mean predicted mortality of 0.48 (SD = 0.26). The median length of intensive care unit stay was 14.9 days (range, 0.79–105 days). We studied six patients in the supine position first and turned them to the prone position after 6 hours. The other 13 patients were studied in the prone position first and were then turned to the supine position. The median volume of administered enteral feeds in all 19 patients was 360 ml (range, 0–960 ml) after 6 hours in the prone position as well as after 6 hours in the supine position ($P = 0.59$).

The mean gastric residual volume after feeding for 3 hours in the prone position was 59.7 ml (range, 0–200 ml), compared with 59.5 ml (range, 0–180 ml) after 3 hours in the supine position ($P = 0.69$). Feeding for 6 hours in the prone position resulted in a median gastric residual volume of 110 ml (range, 0–325 ml), and that in the supine position resulted in a median of 95 ml (range, 10–340; $P = 0.85$) (Fig. 1). Gastric residual volumes in the prone and supine positions showed a significant correlation ($r = 0.63$, $P = 0.003$). Regression analysis showed that the volume in the prone position was 54 ml plus 0.56 times the volume in supine position ($r^2 = 0.41$), which means that 41% of the residual volume in the prone position can be explained by the volume in the supine position. Univariate ANOVA could not detect the use of pro-kinetics, sedation or the type of enteral nutrition as significant factors in explaining the amount of gastric residual volume in either position. Gastric residual volumes were not related to APACHE II score. The individual gastric residual volumes in the prone and supine positions are presented in Figure 2. A gastric residual volume of more than 150 ml in 6 hours was considered clinically significant. Six patients had, in both positions, a gastric residual volume of at least 150 ml after 6 hours. Both positions in 12 patients resulted in a gastric residual volume of 150 ml or less after 6 hours. One patient had a gastric residual

Figure 1

Gastric residual volumes in the supine and prone positions after 6 hours of feeding.

volume of less than 150 ml after 6 hours in the supine position and greater than 150 ml after 6 hours in the prone position. This represents the only patient with a change from a non-significant to a clinically significant gastric residual volume. One patient vomited in the prone position. This patient had a gastric residual volume of 150 ml excluding the vomited volume at the end of the 6-hour period in the prone position, and the residual volume in the supine position was 330 ml after 6 hours.

Ten patients were treated with cisapride before inclusion in the study because of clinically significant gastric residual

volumes. The cisapride dose was unchanged during the complete study period and was 40 mg three times daily in all patients. These 10 patients had a greater gastric residual volume than 9 patients without cisapride (139 ml versus 103 ml after 6 hours in the prone position, and 150 versus 85 ml after 6 hours in the supine position). These differences did not, however, reach significance ($P=0.42$ and $P=0.21$), which is concordant with the univariate ANOVA analysis. The time interval between the last dose of cisapride and start of the study period was 3.8 hours for both the prone and supine positions. One patient was treated with erythromycin because of Legionnaires' disease.

Nine patients were sedated with morphine and midazolam at the time of inclusion in the study. All sedatives were given by continuous infusion. Three of these patients needed additional sedation in the prone position. Six other patients were sedated in the prone position but not in the supine position. The remaining four patients were not sedated in either position. The mean cumulative dose of morphine/midazolam during 6 hours in the prone position was 15.8/11.8 mg compared with 9.7/7.3 mg during 6 hours in the supine position ($P=0.005$). The use of sedation, however, was not a significant factor for gastric residual volume in either position.

Discussion

The prone position is used to improve oxygenation when patients are hypoxic in the supine position and for mobilisation of bronchial secretions [10–12]. As far as we know, however, no data have been published concerning gastric emptying in the prone position and the ability of continued enteral feeding. This crossover study in critically ill patients compared gastric residual volumes during the supine and prone positions. It has been shown that gastric residual

Figure 2
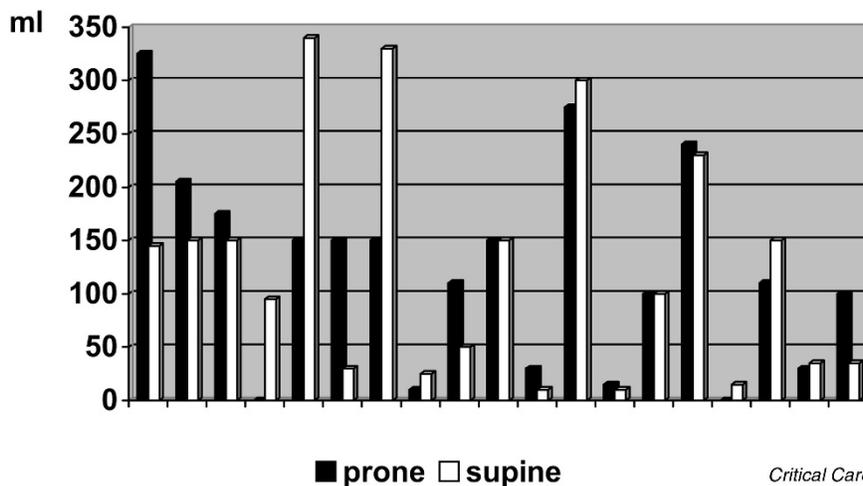
prone **supine**

Gastric residual volumes in the prone and supine positions for each individual patient after feeding for 6 hours.

Figure 3
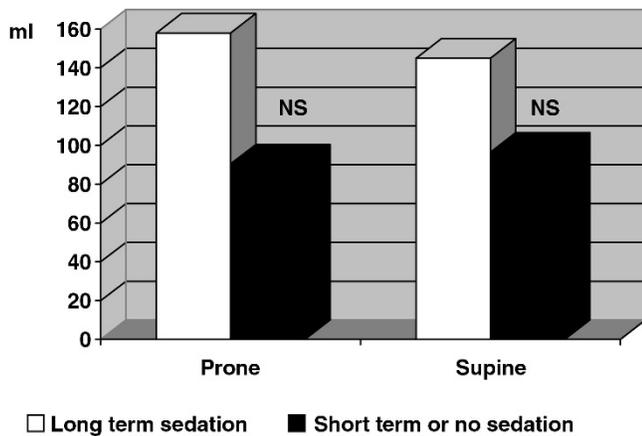
Critical Care

Gastric residual volumes after feeding for 6 hours in the prone and supine position for 10 patients without and 9 patients with long-term sedation with morphine and midazolam.

volumes after 3 or 6 hours in the prone and supine positions did not differ significantly between these positions.

Measurements of gastric residual volume can be used to judge the tolerance of enteral feeding [13,14]. Paracetamol excretion or isotope studies are probably better methods to determine gastric emptying [8,13] but gastric residual volume measurements are easy to use in daily practice for determining the tolerance of enteral feeding. A cut off of 150 ml was chosen on arbitrary grounds but in conformity with other studies [15]. Figure 2 shows the gastric residual volumes in the prone and supine positions for each patient. In one patient, a smaller volume (150 versus 330 ml) in the prone position was caused by vomiting in the prone position. The risk for gastro-oesophageal reflux, vomiting and pulmonary aspiration have not been studied for the prone position. In contrast, it is known that the semi-recumbent position reduces reflux and subsequent aspiration and infection [16,17]. At first view in the present study, gastric residual volumes in individual patients changed considerably between both positions. In 18 out of 19 patients, however, gastric residual volumes in both positions were concordantly high (≥150 ml in 6 hours) or low (≤150 ml in 6 hours). This relation was confirmed by linear regression analysis. Patients with a clinically significant gastric residual volume in one position are therefore likely to have a clinically significant gastric residual volume in the other position.

The feeding rate should be lowered and pro-kinetic drugs should be considered in the patients with a large residual gastric volume. In this study, 10 out of 19 patients were treated with cisapride before inclusion because of a gastric residual volume greater than 150 ml in 6 hours.

Cisapride tends to increase gastric emptying by enhancing gastro-intestinal motility and reduces gastric residual volumes [18,19]. The tolerance of enteral feeds may, as a consequence, be enhanced by the administration of cisapride. Cisapride cannot be responsible for change in gastric residual volume between positions in this study as it was not stopped or started during the study period.

It is known that morphine reduces intestinal motility and may therefore lead to impaired tolerance of enteral feedings. The patients in this study were sedated only when necessary, which was the decision of the attending physician. Morphine with midazolam by continuous infusion was the standard sedation and, during this study, no other sedatives were used. Sedation in most patients was necessary in the prone position but not in the supine position. Significantly more sedatives were therefore used in the prone position compared with the supine position. Morphine/midazolam during the prone position did not lead to greater gastric residual volumes compared with the supine position in this small study. However, we did find a trend towards greater gastric residual volume in 9 patients with long-term sedation with morphine and midazolam compared with 10 patients with no sedation or only short-term sedation during the prone position, but these differences did not reach significance (Fig. 3). These results imply that short-term sedation during the hours that the patient is ventilated in the prone position does not influence the gastric residual volume in a negative way, but long-term sedation may do so.

All patients were treated with dopamine but the mean dose did not differ significantly in the prone compared with the supine position. Dopamine inhibits gastric motility in a dose-dependent way via DA2 receptors of the gastric wall and independently of extrinsic innervations [20,21]. This reduction in gastric emptying can be counteracted by cisapride [21]. The use of cisapride in 10 patients may have reduced the inhibitory effect of dopamine.

Limitations of this study may be the relatively small sample size and the lack of randomisation for body position. On the contrary, the crossover design eliminates many potential confounders, and regression analysis excluded the starting position as a confounder. The equal gastric residual volumes in both positions makes it unlikely that a larger sample size would reveal other results.

In conclusion, we have shown that gastric residual volumes in the prone and supine position do not differ significantly. Enteral feeding by nasogastric tube can be delivered in the prone position at the same rate as in the supine position.

References

1. Frost P, Edwards N, Bihari D: **Gastric emptying in the critically ill – the way forward?** *Intensive Care Med* 1997, **23**:243–245.
2. Preiser JC, Berre J, Carpentier Y, Jolliet P, Pichard C, Van Gossum A, Vincent JL: **Management of nutrition in European intensive**

care units: results of a questionnaire. Working Group on Metabolism and Nutrition of the European Society of Intensive Care Medicine. *Intensive Care Med* 1999, **25**:95–101.

3. Omura K, Hirano K, Kanehira E, Kaito K, Tamura M, Nishida S, Kawakami K, Watanabe Y: **Small amount of low-residue diet with parenteral nutrition can prevent decreases in intestinal mucosal integrity**. *Ann Surg* 2000, **231**:112–118.

4. Hadfield RJ, Sinclair DG, Houldsworth PE, Evans TW: **Effects of enteral and parenteral nutrition on gut mucosal permeability in the critically ill**. *Am J Respir Crit Care Med* 1995, **152**: 1545–1548.

5. Deitch EA: **Bacterial translocation: the influence of dietary variables**. *Gut* 1994, **35(suppl 1)**:S23–S27.

6. Chang RWS, Jacobs S, Lee B: **Gastrointestinal dysfunction among intensive care unit patients**. *Crit Care Med* 1987, **15**: 909–914.

7. Moore FA, Feliciano DV, Andrassy RJ, McArdle AH, Booth FV, Morgenstein-Wagner TB, Kellum JM Jr, Welling RE, Moore EE: **Early enteral feeding, compared with parenteral, reduces post-operative septic complications: the results of a meta-analysis**. *Ann Surg* 1992, **216**:172–183.

8. Heyland DK, Tougas G, King D, Cook DJ: **Impaired gastric emptying in mechanically ventilated, critically ill patients**. *Intensive Care Med* 1996, **22**:1339–1344.

9. Albert RK: **One good turn …** *Intensive Care Med* 1994, **20**: 247–248.

10. Fridrich P, Krafft P: **The effects of long-term prone positioning in patients with trauma-induced adult respiratory distress syndrome**. *Anesth Analg* 1996, **83**:1206–1211.

11. Langer M, Mascheroni D, Marcolin R, Gattinoni L: **The prone position in ARDS patients**. *Chest* 1988, **94**:103–107.

12. Pappert D, Rossaint R, Slama K, Grüning T, Falke KJ: **Influence of positioning on ventilation–perfusion relationships in severe adult respiratory distress syndrome**. *Chest* 1994, **106**: 1511–1516.

13. Tarling MM, Toner CC, Withington PS, Baxter MK, Whelpton R, Goldhill DR: **A model of gastric emptying using paracetamol absorption in intensive care patients**. *Intensive Care Med* 1997, **23**:256–260.

14. HeylandDK, Cook DJ, Winder B, Guyatt GH: **Do critically ill patients tolerate early intragastric enteral nutrition?** *Clin Intensive Care* 1996, **7**:68–73.

15. McClave SA, Snider HL, Lowen CC, McLaughlin AJ, Greene LM, McCombs RJ, Rodgers L, Wright RA, Roy TM, Schumer MP, *et al*: **Use of residual volume as a marker for enteral feeding intolerance: prospective blinded comparison with physical examination and radiographic findings**. *JPEN* 1992, **16**: 99–105.

16. Torres A, Serra-Batlles J, Ros E, Piera C, Puig de la Bellacasa J, Cobos A, Lomena F, Rodriguez-Roisin R: **Pulmonary aspiration of gastric contents in patients receiving mechanical ventilation: the effect of body position**. *Ann Intern Med* 1992, **116**: 540–543.

17. Drakulovic MB, Torres A, Bauer TT, Nicolas JM, Nogue S, Ferrer M: **Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: a randomised trial**. *Lancet* 1999, **354**:1851–1858.

18. Papen HD, Duinslaeger L, Diltoer M, Gillet R, Bossuyt A, Huygens LP: **Gastric emptying in critically ill patients is accelerated by adding cisapride to a standard enteral feeding protocol: results of a prospective, randomized, controlled trial**. *Crit Care Med* 1995, **23**:481–485.

19. Heyland DK, Tougas G, Cook DJ, Guyatt GH: **Cisapride improves gastric emptying in mechanically ventilated, critically ill patients**. *Am J Respir Crit Care Med* 1996, **154**: 1678–1683.

20. Nagahata Y, Azumi Y, Kawakita N, Wada T, Saitoh Y: **Inhibitory effect of dopamine on gastric motility in rats**. *Scand J Gastroenterol* 1995, **30**:880–885.

21. Muller-Lissner SA, Fraas C, Hartl A: **Cisapride offsets dopamine-induced slowing of fasting gastric emptying**. *Dig Dis Sci* 1986, **31**:807–810.