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# Rate and Volume of Intermittent Enteral Feeding

MARGARET E. HEITKEMPER, M.N., DEBORAH L. MARTIN, M.N., BARBARA C. HANSEN, PH.D., ROBERT HANSON, M.N., AND VERLENE VANDERBURG, B.S.

*From the School of Nursing, University of Washington, Seattle, Washington and the School of Nursing, University of Michigan, Ann Arbor, Michigan*

**ABSTRACT.** The purpose of this investigation was to determine the effects of the volume of enteral feedings and the rate at which they were administered on subject tolerance and gastric pressure changes. Fourteen normal volunteers received enteral feedings on 9 or 10 separate days. These feedings (Ensure) were administered in combinations of 3 volumes (250, 350, and 500 ml) and of 2 rates (30 and 85 ml/min). The effect on gastric motility was monitored by an open-tipped catheter. Nine of the subjects also received 750 ml administered at 30 ml/min. Six of the 14 subjects experienced nausea and/or discomfort during the first feeding trial (250 ml at 30 ml/min); however, subsequent feedings were tolerated without this discomfort. The rate at which feedings were administered had little effect on the time following feeding until the return of regular motility or on the mean motility index when 250 ml were administered; however, when larger volumes were administered at the faster rate, longer time was taken for the return of regular motility. Feedings administered at the faster rate were associated with a greater number of subjective complaints of abdominal discomfort, nausea, fullness, and cramping. The volume of a feeding has a significant effect on both the time required for regular motility to return following feeding and on the mean motility index, with the larger feeding volumes suppressing activity progressively longer. The volume of feeding (up to 750 ml) had little effect upon symptomatic tolerance of subjects when these feedings were administered at 30 ml/min. There was no significant interaction effect of rate and volume on the time required for motility to return following feedings. The results of this study indicate that normal subjects can tolerate bolus feedings of (250–750 ml) administered at 30 ml/min without distress. Additional studies are needed to compare bolus and continuous feedings in relation to patient tolerance, gastric emptying, and nutritional outcome.

Frequently cited causes of intolerance to tube feedings are diet contents, tube tip location, and/or method of administration which includes volume per feeding, frequency, and rate of feedings.[1-3] Although the methods used in the administration of intermittent bolus feedings are frequently cited as the cause of diet intolerance and adverse effects, no studies have been reported in which rate of administration and volume of bolus tube feedings were controlled and compared.

Two methods of tube-feeding administration are commonly used: bolus, involving the administration of 200–600 ml diet 4–8/day, and continuous feeding with infusions given over an 18–24 hr period. In 1977, Dobbie and Butterick[4] reported the use of continuous, controlled enteral feedings in 14 patients with esophageal disease, with caloric intake averaging 2,400–3,600 cal/day and resultant weight gain, without sepsis, aspirations, or diarrhea in any of them. In another survey of 60 patients on this protocol, Dobbie stated that none complained of abdominal fullness or cramping. Others have since reported positive results with the continuous feeding method. Intermittent bolus feedings, however, remain the most common method of administration of enteral liquid diets. They have the obvious advantage of freeing the patient from continuous attachment to a feeding device and simulate more normal eating patterns.

A survey of tube-fed patients in 4 major medical centers and 21 smaller hospitals and extended care facilities indicated that all of the 121 tube-fed patients were receiving intermittent bolus feedings.[5] This survey, recently repeated, continues to indicate that most patients receive bolus-type feedings, which are generally given in less than 20 min/feeding. The earlier study also showed that the average number of cal/day for the 1730 hospital days examined was 1321, suggesting a significant caloric deficit for this patient sample. Thus, the current studies of enteral feedings are also aimed at determining ways to generally increase diet intake levels during enteral nutrition without producing adverse effects.

Gastric motility serves as one index of the degree to which various feeding methods alter gastrointestional function. Weisbrodt et al[6] and Stemper and Cooke[7] have previously demonstrated a positive relationship between gastric emptying and contractile activity, using strain gauges implanted on the gastric serosal surface of dogs.

Our present study used a measure of gastric contractile activity to examine the independent and interacting effects of rate and volume of bolus enteral feedings. Healthy volunteers were given 3 different volumes of bolus tube feedings in association with 2 different rates of infusion. Tolerance for various combinations of rate and volume of feeding was assessed by 1) monitoring of gastric motility by means of continuous recording of intragastric pressure before, during, and following diet infusions, and 2) observation and recording of the nature, frequency, and severity of adverse responses. Correlations between such responses, including nausea, diarrhea, and abdominal cramping, and the records of gastric motility, were also examined.

## METHODS

Fourteen healthy paid volunteers, ages 20–35 yr, including 5 males and 9 females, were each studied for 10–

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12 trials on separate days; none had a previous history of gastrointestinal surgery, renal disease, diabetes, or heart disease. The procedures were explained, and written consent obtained prior to the initiation of the series of experiments.

Subjects fasted 10 hr prior to coming to the clinical research laboratory. A nasogastric tube was inserted to assure a consistent tube tip location. Subjects rested in bed with the head elevated to a 45° angle. Gastric motility was monitored continuously via the recording of intragastric pressure changes. Each experimental trial was carried out on a separate day and consisted of 30 min of baseline recording, followed by the infusion of a specified volume of liquid diet given at a controlled rate. Volumes of 250, 350, and 500 ml were administered twice to each subject at a rate of 30 ml/min and once to each subject at 85 ml/min. These bolus feedings were administered in random order except for the first rate/volume combination, which was always 250 ml at 30 ml/min and was used to assess the subject's ability to tolerate the experimental procedure. Nine subjects also received one 750-ml feeding at 30 ml/min. Following the diet infusion, gastric pressure recording was continued for 1 hr in 62 experiments and 2 or more hr in 64 experiments.

A double-lumen tube was constructed by securing a small PE-#60 cannula (id 0.030 in, od 0.048 in) to the side of a size 12-French feeding tube. The tip of the cannula was located 1 cm above the tip of the feeding tube and was used to record gastric motility.

Because of the importance of consistency in location of the tube tip between subjects and from one experiment to the next, the location of the lower esophageal sphincter (LES) was determined for each subject on the first trial. The tube was then marked externally and inserted each day to the point which placed the tip 10 cm below the LES. The LES location was initially identified by recording the pressure change during withdrawal of the tube from the stomach (usual intragastric pressure is −5 mm Hg) through the lower esophageal sphincter which is a zone of high pressure (5–40 mm Hg above intragastric pressure) and into the esophagus where pressure fell to below intragastric pressure.

Intraluminal pressure changes were recorded by connecting the small open-tipped cannula to a Statham pressure transducer (Model P23AA) the output of which was amplified and recorded on a 4-channel Beckman Dynograph. To avoid artifacts produced by mucous or diet clogging of the cannula's small lumen, a Harvard infusion pump (Model #950) maintained a constant slow flow of water (0.2 ml/min) through the tube. This infusion did not affect the pressure recording, as indicated by identical motility patterns when the pump was briefly turned off.

Gastrointestional sensations were recorded by each subject during and following the intragastric infusions. A hand-held button connected to the marker channel of the Dynograph recorder was used by the subjects to designate their specific subjective sensations via a Morse code-type signal system. This system resulted in the direct recording of sensations on the record of gastric motility and eliminated the need for verbal comment which interfered with the gastric pressure recordings.

A motility index, adapted from the method of Anderson et al,[8] was used to quantify gastric motility changes. Scores were assigned to contractions having the following ranges of amplitudes: 4–6.9 cm water (score = 1); 7–12.9 cm (2); 13–18.9 (3); 19–24.9 (4); 25 or more cm water (5). These scores were then summed in each of 3 predetermined post-feeding periods: 6–12 min, 24 to 30 min, and 42–48 min. The frequency or number of contractions in each of these periods was also determined. The mean motility index for each time period was determined by dividing the sum of the amplitude scores by the number of contractions. Where a subject received more than one trial at a given rate and volume combination, the results were averaged. Thus, for each subject 4 parameters were analyzed: 1) amplitude of contractions, as indicated by the motility index during the 3 post-feeding periods; 2) frequency of contractions during the same periods; 3) time taken for regular "digestive type" contraction activity to begin after feeding (defined by the presence of 12 or more contractions/6 min); and 4) subjective sensations indicated by the subject.

## RESULTS

All 14 volunteers completed the full series of experiments, including nasogastric intubation and bolus diet infusions on at least 9 separate days/subject. Technical difficulties resulted in the exclusion of 4 trials from the data analysis. Records were analyzed from 122 experiments totaling 240 hr of gastric motility recordings; in addition, 9 subjects each received one 750 ml feeding followed by 4 hr of motility recording. Three distinct types of gastric pressure changes were recorded in all 14 subjects: fasting or burst, quiet, and regular (Fig. 1). Fasting or high amplitude contractions were observed in all subjects during the 30 min prefeeding period, which did not return during the 1–3 hr recorded after diet infusion. Feedings were usually followed by a period of quiescence, the duration of which was inversely related to the volume administered. The third type of activity

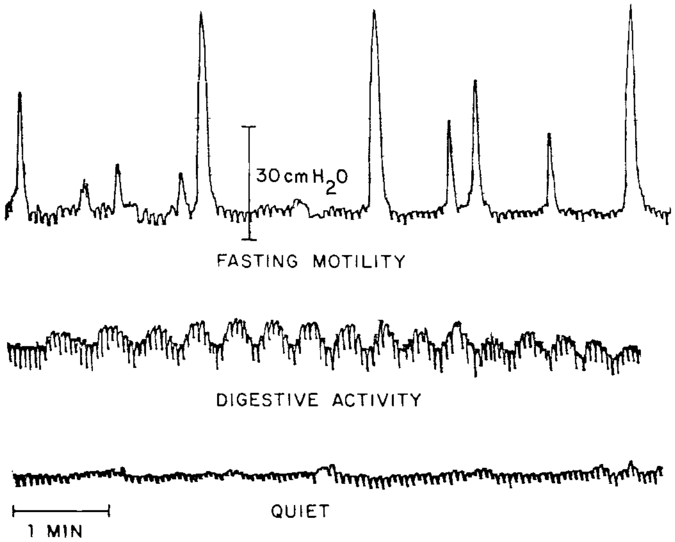

FIG. 1. Gastric pressure changes recorded in normal subjects: fasting or burst, quiet, and regular digestive type activity.

TABLE I

*Effects of combinations of rate and volume of feedings on dependent variables*[a]

| Rate of feeding (ml/min) | Volume (ml) | $\bar{X}$ time for return of regular motility | $\bar{X}$ motility index (6–12 min) | $\bar{X}$ motility index (24–30 min) | $\bar{X}$ motility index (42–48 min) |
|---|---|---|---|---|---|
| 85 | 250 | 31.00 ± 6.86 | 1.00 ± .10 | 1.21 ± .11 | 1.43 ± .14 |
| | 350 | 43.36 ± 8.60 | 0.71 ± .16 | 0.93 ± .13 | 1.14 ± .14 |
| | 500 | 67.92 ± 9.07 | 0.71 ± .22 | 0.57 ± .17 | 0.57 ± .14 |
| 30 | 250 | 31.00 ± 7.22 | 0.93 ± .13 | 1.14 ± .10 | 1.28 ± .16 |
| | 350 | 31.35 ± 6.54 | 0.79 ± .16 | 1.07 ± .07 | 1.14 ± .10 |
| | 500 | 53.28 ± 6.63 | 0.71 ± .12 | 0.64 ± .13 | 0.64 ± .13 |
| | 750 | 74.10 ± 12.1 | 0.64 ± .14 | 0.63 ± .13 | 0.84 ± .13 |

[a] N = 14 subjects (250, 350, 500 ml); 9 subjects (750 ml); N = 41 feedings (250 ml); 40 feedings (350 ml); 41 feedings (500 ml); 9 feedings (750 ml).

following the quiescent period was regular contractile motility, which was approximately half the amplitude of fasting motility and occurred at a rate of 2–3 contractions/min during mixing and emptying of the stomach.

Nearly all subjects reported hunger-like sensations, ie, grumbling, hunger "pangs," during the 30 min prefeeding recording period. These sensations correlated in time with the presence of high amplitude irregular or fasting-type gastric activity. Nausea was not observed in any subject beyond the first trial period. All subjects experienced discomfort with the passage of the feeding tube; however, they reported that discomfort decreased with repeated intubations.

The rate at which a feeding was administered (30 vs 85/ml/min) had little effect on the time following feeding until the return of regular motility or on the mean motility index 6–12 min after administration of the smallest volume feeding (Table I). When larger volumes were adminstered (350 and 500 ml) at the 2 rates, those administered at 85 ml/min resulted in an increase in the mean time following feeding until the return of regular motility. The 350-ml feeding administered at the slowest rate had a mean time of 31 min to return to regular motility (the same as the 250 ml feeding), which was less than the 43 min required for motility to return when the same volume was administered at 85 ml/min. The greatest difference in time required for motility to return was noted between the smallest volume (250 ml) administered at either rate (mean time 31 min) and the largest volume (500 ml) administered at the faster rate (mean time 67 min).

The rate of infusion appeared to be a factor in determining symptomatic tolerance to feedings. Following feedings administered at 85 ml/min, these normal subjects reported a greater number of adverse responses, including abdominal discomfort, nausea, fullness, and cramping. The maximum number of reported adverse responses occurred when a volume of 500 ml was administered at 85 ml/min; the same volume adminstered at 30 ml/min was subjectively well tolerated.

A repeated measured analysis of variance for a balanced design was done, where each subject was observed under combinations of 2 rates and 3 volumes (250, 350, 500 ml). This analysis removed the main effect due to subject from the error term before looking at the effect of rate. There was a significant rate effect on the time required for motility to return (F = 11.41, p = 0.005) (Table II). Similar analyses of the mean motility index at 6–12, 24–30, and 42–48 min following feedings did not demonstrate any significant effect of rate on motility index (Table III).

TABLE II

*Effect of rate, volume, and combined effects of rate and volume on time required for motility to return following feeding*

| Sources | df | SS | MS | F | P value |
|---|---|---|---|---|---|
| Between subject | | | | | |
| Error | 13 | 40677.1 | 3129.0 | | |
| Rate | 1 | 1656.3 | 1656.3 | 11.41 | 0.005 |
| Error | 13 | 1886.9 | 145.1 | | |
| Volume | 2 | 13603.8 | 6801.9 | 14.68 | 0.0001 |
| Error | 26 | 12043.4 | 463.2 | | |
| Rate and volume | 2 | 852.9 | 426.3 | 1.44 | 0.256 |
| Error | 26 | 7708.7 | 296.5 | | |

TABLE III

*Effect of rate, volume, and combined effects of rate and volume on the motility index 42–48 min after feeding*

| Source | df | SS | MS | F | P value |
|---|---|---|---|---|---|
| Within subject | | | | | |
| Error | 13 | 3.39 | 0.11 | | |
| Rate | 1 | 0.01 | 0.01 | 0.05 | 0.818 |
| Error | 13 | 2.82 | 0.21 | | |
| Volume | 2 | 8.36 | 4.18 | 19.25 | 0.0001 |
| Error | 26 | 5.64 | 0.21 | | |
| Rate and volume | 2 | 0.17 | 0.08 | 0.25 | 0.777 |
| Error | 26 | 8.50 | 0.33 | | |

The volume of a feeding had significant effects on the mean motility indices and the time required for regular motility to return following feeding (Table I). The time from diet infusion to the return of regular motility increased as the volume of the feeding increased, resulting in a mean time for return of motility of 74 min when 750 ml were administered in contrast to 31 min when 250 ml were adminstered. The volume of the feeding had an effect on the mean motility index at 6–12, 24–30 and 42–48 min post-feeding, when same volume administered at both rates was compared (Fig. 2). The mean motility index was significantly higher at all time intervals for the 250 than for 350 ml meals (paired t, p = <0.01). Larger volumes (500 and 750 ml) continued to result in a lower mean motility index over the time period.

The increasing volumes resulted in significantly fewer contractions when successively increasing volumes were compared (paired t, p = <0.01). The number of contractions became significantly more frequent as the time following the feeding progressed for each volume (Fig. 3). The relationship between the volume of feeding and the number of contractions was apparent with larger volumes continuing to suppress activity more than smaller volumes even at 42–48 min post-feeding.

The volume of feeding appeared to have little effect upon symptomatic tolerance of feeding. During the first trial period 6 of 14 subjects experienced nausea with small (250 ml) feedings which were administered slowly (30 ml/min). During all trials after the first for any subject, this volume was well tolerated; all volumes, even 750 ml, were tolerated well when administered slowly. The 9 subjects who received 750 ml feedings at 30 ml/min reported no adverse symptoms.

When a repeated measured analysis of variance using 2 rates and 3 volumes (250, 350, and 500 ml) was done, after removing the main effect due to subject, there was a significant volume effect on the time required for motility to return (F = 14.68, p = 0.001). No significant effects of volume were evident on the mean motility index at 6–12 min post-feeding; however, at 24–30 min post-feeding there was a significant effect of volume on motility index, with increasing volumes associated with lower motility indices (F = 10.58, p = <0.001). This volume effect on mean motility index persisted at 42–48 min post-feeding (Table III).

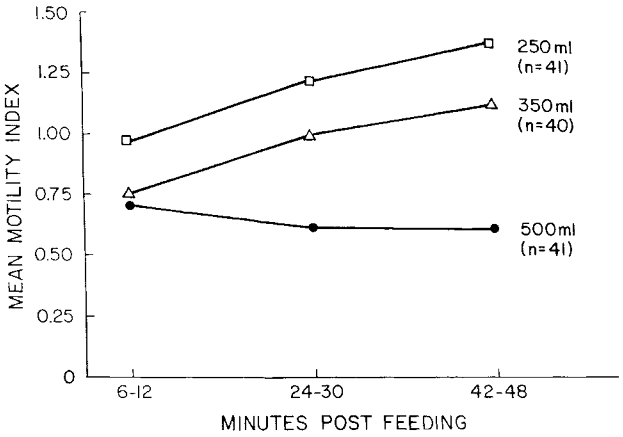

FIG. 2. The mean motility index at 3 post-feeding periods (6–12, 24–30, 42–48 min) for 3 feeding volumes (250, 350 and 500 ml).

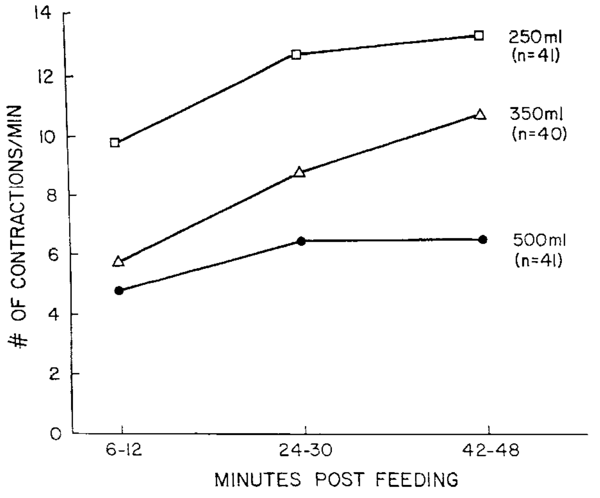

FIG. 3. The number of contractions occurring during 3 post-feeding time intervals (6–12, 24–30, 42–48 min) for 3 feeding volumes (250, 350 and 500 ml).

The interaction of rate and volume on the time required for motility to return following feeding was not significant. Likewise, there was no significant interaction of rate and volume on the mean motility index at any of the 3 observation periods post-feeding. Subjectively, small volumes could be administered at any rate (after the first enteral feeding experience) without causing distress. Larger volumes, up to 750 ml, were well tolerated when administered slowly (30 ml/min).

## DISCUSSION

The initial bolus tube feeding was accompanied or followed by nausea or abdominal discomfort in 6 of 14 normal subjects, even though the smallest volume and slowest infusion rate were always administered during this initial experiment. This series of experiments suggests that symptoms decrease and tolerance improves with repeated feedings. The first feeding is probably best given slowly and in small volume. While a negative response (ie, discomfort or nausea) on the first feeding is relatively common, such symptoms should not a priori deter further feeding of increasing volumes. Patients may tolerate the procedure better if the diet volume is increased gradually over the first 1–2 days postintubation.

After the first feeding, the rate of infusion of 30 ml/min was tolerated well by all subjects. These data support the results of a previous study conducted in this laboratory, in which there were no apparent differences between rates of infusion of 30 and 60 ml/min in terms of subjective responses or gastric motility changes. During feedings in which the rate of 85 ml/min was infused, adverse responses increased. On the basis of these data and prior studies using a greater range of rates of infusion, it is suggested that rates of >60 ml/min should not be used.

The appearance of regular low amplitude gastric contractions was delayed for longer periods of time with increasing volumes of feedings. Since gastric emptying was not studied, it is not possible to correlate the emptying rate with the duration of motility suppression. Rees et al[10] reported that no pressure changes occurred for 133 ± 12 min (mean ± SE) following the administration of a 500-ml meal in normal subjects; however, emptying proceeded even in the complete absence of distal antral activity. This finding is in conflict with the findings of Stemper and Cooke[7] who acknowledged that some emptying occurred in the absence of measurable antral activity, although little emptying occurred except in association with gastric contractions.

Volumes of 250, 350, 500, and 750 ml at 30 ml/min were not accompanied by an increase in subjective responses. Therefore, when caloric needs are high, large volumes of bolus feedings can be administered at a rate of 30 ml/min to adults with normal gastrointestinal function.

This study confirms earlier observations of a high correlation between subjective sensations of "hunger" or "grumbling" with active, large amplitude contractions of the stomach. These large amplitude contractions were damped for longer periods of time post-feeding as the volumes of the feedings were increased. A feeding schedule of every 3–4 hr while the patient is awake might suppress the return of "fasting" or "hunger" motility; however, the importance of this fasting type motility suppression on the hospitalized patient's tolerance of tube feedings is not known. Additional studies are needed to compare bolus and continuous feedings in relation to subjective and physiologic tolerance, gastric emptying, and enhanced nutritional status of patients.

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## REFERENCES

1. Dobbie RP, Hoffmeister JA: Continuous pump/tube enteric hyperalimentation. Surg Gynecol Obstet 143:273–276, 1976
2. Joyeux H, Solassol C: Basic problems of artificial nutrition. Biomed J 26:149–152, 1977
3. Shils ME: Enteral nutrition by tube. Cancer Res 37:2432–2439, 1977
4. Dobbie RP, Butterick OD: Continuous pump/tube enteric hyperalimentation use in esophageal disease. JPEN 1:100–104, 1977
5. Walike BC, Padilla GV, Bergstrom N et al: Patient problems related to tube feeding. IN Communicating Nursing Research, vol 7, MV Batey (ed). Western Interstate Commission for Higher Education, Boulder, Colo, 1974
6. Weisbrodt NW, Wiley JN, Overholt BF, et al: A relation between gastroduodenal muscle contractions and gastric emptying. Gut 10: 543–548, 1969
7. Stemper T, Cooke A: Gastric emptying and its relationship to antral contractile activity. Gastroenterology 69:649–653, 1975
8. Anderson JJ, Bolt RJ, Ullman B, et al: Effect of bile and fat on gastric motility under the influence of various stimulants. Am J Dig Dis 13:157–167, 1968
9. Heitkemper MM, Hanson R, Hansen BC: Effects of rate and volume of tube feeding in normal human subjects. IN Communicating Nursing Research, vol 10, MV Batey (ed). Boulder, CO., Western Interstate Commission for Higher Education, Boulder, Colo, 1977, pp 71–89
10. Rees WDW, Go VLW, Malagelada J-R: Antroduodenal motor response to solid-liquid and homogenized meals. Gastroenterology 76:1438–1442, 1979