J Vet Intern Med 2010;24:520–526

Intermittent and Continuous Enteral Nutrition in Critically Ill Dogs: A Prospective Randomized Trial

M. Holahan, S. Abood, J. Hauptman, C. Koenigsknecht, and A. Brown

Background: Malnutrition is a common problem in critically ill dogs and is associated with increased morbidity and mortality in human medicine. Enteral nutrition (EN) delivery methods have been evaluated in humans to determine which is most effective in achieving caloric goals.

Objectives: To compare continuous infusion and intermittent bolus feeding of EN in dogs admitted to a critical care unit.

Animals: Fifty-four dogs admitted to the critical care unit and requiring nutritional support with a nasoenteric feeding tube.

Methods: Prospective randomized clinical trial. Dogs were randomized to receive either continuous infusion (Group C) or intermittent bolus feeding (Group I) of liquid EN. The percentage of prescribed nutrition delivered (PPND) was calculated every 24 hours. Frequencies of gastrointestinal (GI), mechanical, and technical complications were recorded and gastric residual volumes (GRVs) were measured.

Results: PPND was significantly lower in Group C (98.4%) than Group I (100%). There was no significant difference in GI or mechanical complications, although Group C had a significantly higher rate of technical complications. GRVs did not differ significantly between Group C (3.1 mL/kg) and Group I (6.3 mL/kg) and were not correlated with the incidence of vomiting or regurgitation.

Conclusions and Clinical Importance: There was a statistically significant difference in the PPND between continuously and intermittently fed dogs, but this difference is unlikely to be clinically relevant. Critically ill dogs can be successfully supported with either continuous infusion or intermittent bolus feeding of EN with few complications. Increased GRVs may not warrant termination of enteral feeding.

Key words: Clinical trials; Gastric residual volumes; Intensive care medicine; Nasoenteric feeding tubes.

The provision of adequate nutrition is essential in critically ill patients. Malnutrition remains a common condition of patients in the intensive care unit, and has been associated with increased morbidity and mortality.[1] Malnutrition can develop from underprescribing calories, patient intolerance, or frequent interruptions of feedings for nursing care or diagnostic procedures.[1–3] Several studies have demonstrated that nutritional goals for both human and veterinary intensive care patients are not being met.[4,5] A recent, prospective study with 25 dogs and cats documented a median of 91% prescribed kilocalories delivered daily on a per patient basis.[6] Eighteen of the 25 animals in this report had at least 1 day in which calories received were fewer than prescribed. Vomiting and treatment interruptions were the most common reasons recorded for incomplete feeding.[6]

Increased gastric residual volume (GRV) can disrupt effective delivery of nutritional support. GRV is defined as the volume of fluid aspirated from the stomach after a given time period and before each new feeding.[7] Increased GRVs in human patients may result in decreased nutrient delivery because of potential concerns for increased risk of gastroesophageal reflux and associated aspiration pneumonia.[8–10] GRVs have not been critically evaluated in veterinary patients.

Many questions regarding effective delivery of enteral nutrition (EN) remain unanswered in both human and animal populations. Optimal substrates, timing, ideal routes, and amount of nutritional support for varying populations of critically ill veterinary patients are not known.

The 2 most common EN delivery methods for veterinary and human patients are continuous infusion or intermittent bolus feedings. Critically ill patients with impaired gastrointestinal (GI) motility may tolerate continuous infusion of nutrition better, whereas intermittent bolus feeding represents a more physiologic method of providing calories. Randomized, controlled trials in human patients have failed to determine which delivery method is superior in providing prescribed calories with minimal complications.[9,11–15] Few studies have examined EN delivery systems in critically ill small animals. A pilot study evaluating continuous infusion and intermittent

Abbreviations:

BCS	body condition score
CAP Score	canine acute physiology score
EN	enteral nutrition
GI	gastrointestinal
GRVs	gastric residual volumes
MSU-VTH	Michigan State University Veterinary Teaching Hospital
NE	nasoenteric
NJ	nasojejunal
PPND	percent of prescribed nutrition delivered
RER	resting energy requirements

From the Section of Critical Care, Department of Small Animal Clinical Sciences, D208 Veterinary Medical Center, College of Veterinary Medicine, Michigan State University, East Lansing, MI. This project was done at the Veterinary Teaching Hospital, Michigan State University, East Lansing, MI.

Corresponding author: Dr Melissa L. Holahan, D208 Veterinary Medical Center, College of Veterinary Medicine, Michigan State University, East Lansing, MI 48824-1314; e-mail: dettlof6@cvm.msu.edu.

Submitted November 19, 2009; Revised January 15, 2010; Accepted February 2, 2010.

10.1111/j.1939-1676.2010.0487.x

bolus feeding was performed in 10 healthy dogs with gastrotomy tubes. The author found no difference in weight maintenance, GI adverse effects, γ-glutamyl transpeptidase, nitrogen balance, or feed digestibility.[16] More recently, a retrospective study was performed at our institution to evaluate the percentage of prescribed nutrition delivered (PPND) in 37 dogs that were supported with nasoenteric (NE) feeding tubes.[17] PPND in these patients was not significantly different between continuous (98.1%) and intermittent (91.7%) delivery.[17] This study also found that the frequencies of GI complications were not significantly different between the 2 techniques. The retrospective nature of the study precluded the authors from making conclusions regarding the discrepancy in the PPND because a consistent algorithm among cases or clinicians was not utilized.

To our knowledge, there have been no published randomized, prospective clinical studies evaluating continuous versus intermittent delivery systems in critically ill veterinary patients. Therefore, we designed a randomized, prospective trial to compare the PPND in dogs receiving EN by continuous infusion or intermittent bolus feeding. We hypothesized that there would be no difference in attainment of daily caloric goals or frequency of complications in dogs receiving EN support by either continuous pump infusion or intermittent bolus feeding. Specific aims to address our hypothesis included (1) determining if intermittent bolus feeds or continuous infusion of EN is more likely to achieve prescribed daily caloric goals for critically ill dogs, (2) comparing GI, mechanical, and technical complications between the 2 delivery methods, and (3) measuring GRVs to determine if any correlation exists between GRVs and frequency of vomiting or regurgitation. Our long-term goal is to develop a hospital protocol, which minimizes complications and technician time, while maximizing delivery of calories and nutrients to critically ill patients.

Materials and Methods

Dogs admitted to the Critical Care Unit of the Michigan State University Veterinary Teaching Hospital (MSU-VTH) and requiring EN support via a NE tube (nasoesophageal or nasogastric) were recruited from November 1, 2008 through October 31, 2009. The MSU-VTH Hospital Committee and the MSU Institutional Animal Care and Use Committee approved the study protocol. Subjects were excluded if owner consent was not obtained, $>50\%$ of the intestine had been resected, placement of a feeding tube was contraindicated, an enteric tube was already in place, or EN was delivered for <24 hours.

After owner consent, the attending clinician determined the type of NE feeding tube to be placed. Tube sizes ranged from 36 to 42 cm in length, and 8–12 Fr in diameter.[a] NE tube placement was confirmed with a lateral survey radiograph (nasoesophageal tubes were placed past the carina at the level of the 8th–10th thoracic ribs). Dogs were randomized to receive liquid EN either by continuous infusion (Group C) or by intermittent bolus (Group I). Randomization of subjects into each group was performed by a computer-generated random number spreadsheet.[b] RER was calculated at the initiation of tube feeding by each patient's current body weight (kg) with the following equation: $70 \times \mathrm{BW(kg)}^{0.75}$. All dogs received a complete, balanced commercial liquid veterinary formula containing 1 kcal/mL.[c] Clinicare or Clinicare renal formula (RF)[c] was chosen at the discretion of the attending clinician.

Feeding Protocol

Both groups had feeding begin at a scheduled treatment time in the critical care unit (eg, 8:00 AM, 12:00 PM, 4:00 PM, 8:00 PM). Total prescribed calories were administered to meet 1/3 RER; then increased by 1/3 increments every 24 hours over the course of 72 hours, and continued to deliver full RER if patient hospitalization continued (Table 1). Refrigerated liquid diets were brought to room temperature before feeding. GRVs were checked on all nasogastric feeding tubes and recorded every 4 hours. Tubes were flushed with 5 mL water to maintain patency before and after each feeding. The patient's water requirement was administered by means of IV fluid therapy at the discretion of the attending clinician.

Protocol for Group I

With a syringe pump, intermittent boluses of liquid nutrition[c] were delivered over 30 minute every 4 hours, and the volume was confirmed and recorded at the end of each feeding period. The intermittent group was permitted to have feedings given off schedule (within 30 minute of scheduled treatment) due to owner visitation, and diagnostic or therapeutic procedures.

Protocol for Group C

With a syringe pump, liquid nutrition[c] was delivered at a constant rate infusion and the volume was confirmed and recorded every 4 hours.

Rescue Protocol

A rescue protocol was implemented for patients that exhibited GI complications associated with intolerance to NE feeding (Fig 1). Feeding intolerance was defined as vomiting or regurgitation twice within a 24-hour period. In the rescue protocol, enteral feedings were stopped for a 12-hour period and then resumed at the last recorded caloric volume and rate. If the patient vomited or regurgitated within the 12-hour rescue protocol, feedings were stopped for an additional 12-hour period. When feedings resumed, they were started at the lowest rate (1/3 RER). EN was discontinued if the 24-hour rescue protocol failed. All patients requiring the rescue protocol were included in data analysis.

Specific medical and dietary information collected at the time of enrollment included signalment, presenting complaint, length of time from last meal to tube placement, canine acute physiology (CAP) score,[d] malnutrition score, number of episodes of vomiting, regurgitation or diarrhea within the previous 24 hours, body weight, and body condition score (BCS) on a scale of 1–9. Data collected at the time of discharge included time to voluntary ingestion of food, body weight, BCS, time from hospital admission to initiation of NE feedings, total hour of EN, total days of hospitalization and patient outcome.

The percent of PPND was calculated as the number of calories administered in a 24-hour period divided by calories prescribed according to the feeding protocol (Table 1) and then converted to a percentage. If the patient received NE feeding for more than a single day, the mean PPND per day was calculated. Reasons for interruptions or discontinuation of nutrition support were recorded, as well as 24-hour period in which a patient ate voluntarily. Additionally, the frequency of complications was recorded for each patient.

Table 1. Enteral feeding protocol for dogs admitted to the critical care unit receiving nutrition support through nasoenteric feeding tubes.

Time	Continuous	Intermittent	Gastric Residual Volumes[a]
0–24 hours	(1/3 RER) ÷ 24 hours and delivered at X mL/h	(1/3 RER) ÷ 6 feedings and delivered over 30 minutes every 4 hours	Aspirated every 4 hours[b]
24–48 hours	(2/3 RER) ÷ 24 hours and delivered at X mL/h	(2/3 RER) ÷ 6 feedings and delivered over 30 minutes every 4 hours	Aspirated every 4 hours
48–72 hours, continue until goal reached	(3/3 RER) ÷ 24 hours and delivered at X mL/h	(3/3 RER) ÷ 6 feedings and delivered over 30 minutes every 4 hours	Aspirated every 4 hours

[a]Gastric residual volumes were only measured in those patients with nasogastric feeding tubes.
[b]Aspirated volume was returned back to the patient over 5 minutes.
RER, resting energy requirements; nasoenteric (nasoesophageal and nasogastric).

Documenting Complications

Patients receiving EN were continually monitored for complications. Episodes of vomiting, regurgitation, and diarrhea were recorded for each dog for every 24-hour period. GRVs were measured every 4 hours in patients with nasogastric feeding tubes. If residual volumes were present, totals were documented and then slowly administered back through the nasogastric tube over 5 minutes and flushed with 5 mL of water. Total GRVs for each 24-hour period also were recorded. Mechanical complications such as tube dislodgement or tube occlusion were recorded. Technical complications associated with NE feedings were identified as equipment malfunction, errors in pump rates, and delivery interruptions because of treatments, owner visits, procedures, or patient walks longer than 10 minutes in duration. Dogs that developed aspiration pneumonia after the initiation of NE feedings were identified (diagnosed using thoracic radiographs reviewed by a board-certified radiologist).

Statistical Methods

Data were collected and recorded by a single investigator (C.K.) and tested for normality by the D'Agostino & Pearson omnibus normality test. Descriptive data that were normally distributed were analyzed by an unpaired T-test. Data that were not normally distributed and ordinal data were compared by a Mann-Whitney U-test. Nonparametric data are reported as median (range) and parametric as mean (±SD). Frequencies of complications were compared by χ^2 or Fisher's exact test (sample size < 5) and reported as a percentage. Spearman's rank correlation coefficient was used to evaluate the correlation between GRVs and vomiting or regurgitation. Statistical analyses were performed by commercially available software.[e] Statistical significance was set at $P < .05$.

Results

Sixty-nine dogs were enrolled in the study, of which 15 dogs were excluded for failure to achieve 24 hours of EN. Data analysis was performed on 54 dogs: 28 cases in Group C and 26 cases in Group I. There were 43 nasogastric tubes and 11 nasoesophageal feeding tubes placed; 31/54 (57.5%) dogs required no sedation for feeding tube placement, 19/54 (35.1%) required sedation, and 4/54 (7.4%) dogs had feeding tubes placed postoperatively while anesthetized. Two patients received Clinicare RF (an 8-year-old intact male Doberman Pinscher [Group C] and a 10-year-old spayed female Dalmatian [Group I]), both diagnosed with acute-on-chronic renal failure.

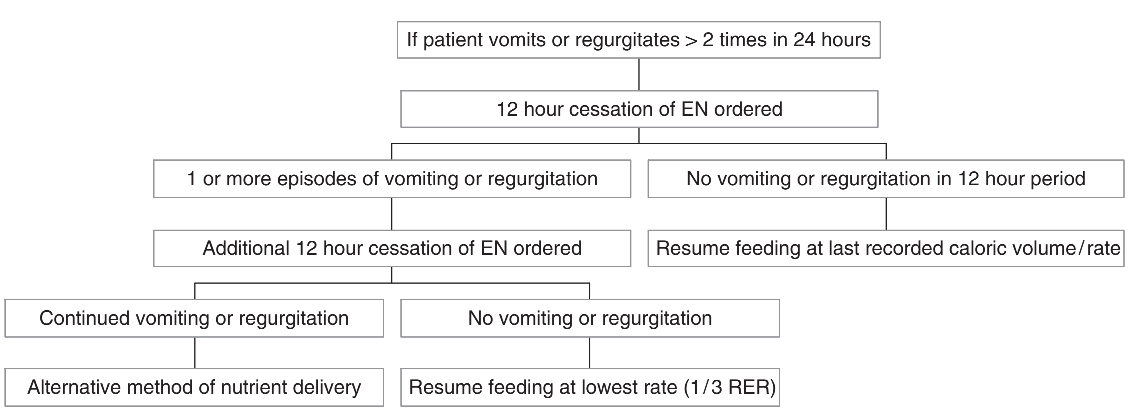

Fig 1. Rescue protocol for dogs admitted to the critical care unit receiving enteral nutrition support through nasoenteric feeding tubes. EN; enteral nutrition, RER; resting energy requirement.

Table 2. Population characteristics for 54 canine patients admitted to the critical care unit receiving enteral nutrition support through nasoenteric feeding tubes.

	Population	Continuous	Intermittent	*P* Value
Number	54	28	26	–
Age (years)	6.6±4.5	7.4±4.2	5.8±4.8	.1746
Sex				
Male	26	16 (57%)	10 (38.5%)	.1873
Female	28	12 (43%)	16 (61.5%)	
Weight (kg) at admission	18.8±18.1	19.5±18.6	17.9±17.7	.8280
Delta weight (admit to discharge)	0.4±1.8	0.4±2.0	0.4±1.7	.9885
BCS (1–9 scale) at admission[a]	4.8±1.6	5.1±1.4	4.5±1.8	.1713
Surgical status				
Nonsurgical	35	17 (61%)	18 (69%)	.5770
Surgical	19	11 (39%)	8 (31%)	
Days of anorexia before NE tube	5±2.9	5.3±2.9	4.7±3.0	.2665
Time from admit to initiation of EN	2±1.5	1.8±1.6	2.2±1.4	.2845
Hours of EN	61.3 (24–204)	61.5 (24–184)	61 (24–204)	.9104
Primary reason for admission				
GI/pancreatitis	6	4	2	
Trauma	4	3	1	
Medical oncology	3	1	2	
Immune mediated disease	9	5	4	
Surgical oncology	3	2	1	
Respiratory	3	2	1	
Renal/urinary tract	6	4	2	
Hepatic/biliary	2	1	1	
Sepsis	8	3	5	
Endocrine disorder	2	2	0	
Parvoviral enteritis	5	0	5	
Miscellaneous	3	1	2	
Rescue protocol used	9	5 (18%)	4 (15%)	1.000
Hours on EN until eating per OS	29.7	22 (0–92)	22 (0–68)	.8495
No. dogs not eating at discharge	20	11	9	.7831
CAP score (0–50)	22±6	22.3±5.8	21.7±6.3	.7947
Length of hospital stay (days)	6.6 (2–20)	6.5 (3–20)	6 (2–10)	.9652
Mortality—total deaths all cause	17 (31.4%)	8 (28.6%)	9 (34.6%)	.7710
Type of death				
Natural death	4	2	2	
Euthanasia due to				
Terminal disease diagnosis	3	2	1	
Current severity of illness	10	4	6	
Exclusions	15	6	9	–

Data reported as a median (minimum, maximum range), or mean±SD.
[a]The BCS was recorded by the admitting clinician and was only available for 44 patients.
NE, nasoenteric; EN, enteral nutrition; BCS, body condition score; CAP, Canine Acute Physiology Score.[e]

No statistical differences were found between Group C and Group I based on age, sex, weight, change in weight during hospitalization (delta weight), BCS, malnutrition score, CAP score,[d] time to initiation of EN, duration of EN, days of hospitalization, or outcome (Table 2). The average time from hospital admission to initiation of NE feedings was 1.8 days. There was no significant difference in the number of days of anorexia or hours of NE tube feeding between the 2 groups. Mean time from hospital admission to initiation of EN and median length of hospital stay also were not significantly different between Groups C and I (Table 2).

For all dogs, PPND was 100% (74.8–116%). The PPND was significantly less in Group C (98.4%) compared with Group I (100%: $P = .008$; Table 3).

Twenty-eight percent of all dogs (15 of 54) vomited, 24% (13 of 54) regurgitated, and 54% (29 of 54) had diarrhea while receiving EN. Five of the 15 dogs that vomited during EN also vomited in the 24 hours before initiation of EN. Likewise, 15 of 29 patients with diarrhea recorded during EN had diarrhea in the 24 hours before initiation. Seven of the 13 patients with regurgitation during EN had regurgitated before enrollment.

The frequency of GI complications during EN was not significantly different between Groups C and I (Table 3). Similarly, there was no significant difference in GRVs between groups. There was no significant correlation between average GRVs (mL/kg) and occurrence of vomiting ($r = 0.07$; $P = .65$) or regurgitation ($r = 0.23$; $P = .13$). No correlation was found between the average

Table 3. Outcome data for dogs admitted to the critical care unit receiving enteral nutrition support through nasoenteric feeding tubes.

Variables	Population	Continuous	Intermittent	*P* Value
PPND (median, range)				
Day 1 (n = 54)	100% (37.7–116)	100% (83.3–100)	100% (37.7–116)	.0133*
Day 2 (n = 53)	100% (88.9–116)	98.8% (88.9–100)	100% (80–116)	.0034*
Day 3 (n = 37)	100% (36.4–100)	99.3% (36.4–100)	100% (80–100)	.0596
Average PPND over hosp. (n = 54)	99.3% (74.9–100.8)	98.4% (74.9–100)	100% (82.1–100.8)	.0083*
Complication rates				
Gastrointestinal				
Average vomit/d	0 (0–3)	0 (0–3)	0 (0–1)	.6216
No. (%) with > 1 episode	15 (28%)	7 (25%)	8 (31%)	
Average regurgitation/d	0 (0–4.5)	0 (0–3)	0 (0–4.5)	.5638
No. (%) with > 1 episode	13 (24%)	6 (21%)	7 (27%)	
Average diarrhea/d	0.2 (0–4.25)	0.3 (0–3.4)	0.1 (0–4.25)	.4652
No. (%) with > 1 episode	29 (54%)	16 (57%)	13 (51%)	
GRVs (mL/kg/hospitalization)	4.5 (0–213)	3.1 (0–112)	6.3 (0–213)	.8902
Mechanical (average/d)	0 (0–1)	0 (0–0.4)	0 (0–1)	.7689
Technical				
Rate of occurrence	34/54 (63%)	22/28 (78.6%)	12/26 (46%)	.0210*
Hours of EN lost due to tech comp.	0.3 (0–12)	0.5 (0–12)	0 (0–6.4)	.4445

*P value <.05.

PPND, percent of prescribed nutrition delivered; EN, enteral nutrition; GRVs, gastric residual volumes.

GRVs per day and the average PPND ($r = -0.1869$; $P = .1937$).

A total of 16 mechanical complications occurred during the study. There was no difference in the number of mechanical complications between the 2 feeding groups. Dogs in Group C had 8 complications: regurgitation or vomiting of tube (1), occlusion of tube (4), and inadvertent tube removal (3). Group I had 8 mechanical complications: regurgitation or vomiting of tube (3), and inadvertent tube removal (5) (Table 3). All 4 dogs in C group that had tube occlusions had low infusion rates or were in the rescue protocol (2 at 4.5 mL/h; 2 at 0 mL/h).

A total of 74 technical complications occurred. Group C had significantly more technical complications (22/28 dogs; 78.6%) than Group I (12/26 dogs; 46%) (Table 3). There were 8 feedings in the intermittent group that were given off schedule (allowed within 30 minutes of scheduled treatment). Median hours of EN lost because of technical complications was 0.5 hour for Group C, and 0 hour for Group I ($P = .44$). Technical complications in Group C included treatment or procedure (15), owner visit (14), walk outside >10 minute (16), operator error (8), and equipment malfunction (10). In Group I, technical complications were feedings stopped for treatments or procedure (2), operator error (7), and equipment malfunction (2).

Nine dogs required implementation of a rescue protocol: 5 in Group C and 4 in Group I. Of all 9 patients in a rescue protocol, 4 required a 2nd rescue protocol before resuming feedings. Only 1 dog that went through the rescue protocol required an alternative method of EN (nasojejunal [NJ] feeding tube). Two patients also had aspiration pneumonia, but both had radiographic evidence of pneumonia documented before the start of EN. Reasons for tube removal included 13 discharged, 13 eating well, 1 died, 12 euthanized, 6 patient removal, 2 occluded, 2 gastrotomy tube placements for long-term at-home management, 1 NJ tube placement at the clinician's discretion, and 1 for a diagnostic procedure (esophagram).

Discussion

In the current study, the method of liquid nutrition delivered via NE tube in critically ill dogs did impact PPND. Randomized controlled trials in human patients have compared continuous EN with intermittent bolus feeding with conflicting results.[9,11–15] Results of 2 recent studies suggest that patients fed intermittently reached goal feeds faster than continuously fed patients, and had a higher probability of being at goal feeds by day 7 of EN support.[9,15] Intermittently fed patients also maintained 100% of the goal for 4 of 10 days as compared with the continuously fed patients who maintained goal for only 3 of 10 days.[9] The authors attributed this difference to more frequent interruptions in feeding for procedures in continuously fed patients. Serpa et al[11] compared the 2 delivery methods in human patients and found that patients fed continuously received more calories on day 1, but by the 3rd day there was no difference. Although there is a significant difference in PPND between the 2 groups in the current study, this difference in only seen in the 1st 2 days and is of questionable clinical relevance. As in the human studies, there was no difference between the 2 groups by the 3rd day.[9,12]

PPND ranges of 61–96% have been reported in hospitalized human patients.[1,3,4,9,11] The use of a feeding algorithm in the human ICU demonstrated a significant increase in the percentage of daily nutritional requirements delivered.[18–20] In the current study, median PPND of all dogs was 100% of prescribed calories. This percentage is higher than that reported in other veterinary studies, where the median PPND ranged from 91 to 97%.[6,17] During this study a rescue protocol was followed which only allowed cessation of EN after the dog had vomited or regurgitated at least twice in a 24-hour period. Only 9 of 54 dogs required implementation of a rescue protocol and only 1 dog required an alternative method of EN. This protocol may have prevented unnecessary cessation of EN as it permitted the 1 time occurrence of vomiting or regurgitation and high GRVs. Achieving 100% of the daily PPND in the current study may be a reflection of the application of an algorithm and a rescue protocol for the consistent delivery of EN in the critical care unit.

In the present study, all causes for cessation of EN and time (hours) of cessation were recorded. Complications were recorded as technical, mechanical, or GI. The number of technical complications was found to be significantly higher in Group C (22/28) than in Group I (12/26). Reasons for technical complications included feeding stopped for diagnostic or therapeutic procedure, feeding stopped for owner visitation, feeding stopped for walks outside, equipment malfunction, syringe pump off, syringe pump disconnected, or accidental rate change. Dogs in Group C had a median of 0.5 hour, where as Group I had a median of 0 hour of EN lost because of technical complications. The 0.5 hour lost in Group C equates to 2% of the 24-hour PPND. This discrepancy accounts for the lower average PPND (-2%) of Group C (98.4%) when compared with Group I (100%). The high number of feedings stopped due to diagnostic or therapeutic procedures in Group C (14 versus 2 in Group I) also could explain why the difference in PPND was lost on the 3rd day of nutrition because by then most diagnostic procedures were likely to have been performed. Diagnostic or therapeutic procedures may necessitate the delay or omission of a scheduled feeding. Dogs fed intermittently had the opportunity to make up feedings by giving the feedings slightly off schedule (8 occurrences), whereas dogs fed continuously did not have the opportunity to gain back a portion of a feeding that was lost.

There was no significant difference in the number of mechanical complications encountered between the groups, and the overall number of mechanical complications was relatively low. Mechanical complications included regurgitation or vomiting of tube, occlusion of tube, and inadvertent tube removal. Dogs in Group I did not experience occlusion of the feeding tube compared with dogs in Group C, in which 4 occurrences of tube occlusion occurred. The higher rate in Group I and the flushing of the tube so that water remained within the tube for 3.5 hours until the next scheduled feeding may have prevented tube occlusion. Although continuous infusion would seem to decrease the likelihood of tube occlusion, all 4 dogs in Group C that had tube occlusions had a much slower infusion rate or cessation of feedings. In a small animal, a very slow rate may predispose to tube occlusion and the tube may need to be flushed more frequently.

No differences in GI complication rates were found between patients fed continuously and patients fed intermittently in this study. This finding is in agreement with previous retrospective study findings[17] and several studies reported in critically ill humans.[9,11,14] Data on adverse GI effects should be interpreted cautiously, because some patients had evidence of vomiting, regurgitating, or diarrhea before initiation of EN. Therefore, it is difficult to clearly associate GI complications with an underlying disease process, the administration of EN, or both. In this prospective study, GRVs were recorded every 4 hours and returned to the dog, but there was no change in the protocol if gastric aspirates were present. High residual volumes likely played a part in stopping nutrient delivery in previously published retrospective results from our institution.[17]

High GRVs have been reported as a reason for cessation of feeding in human patients. In a study of very-low-birth weight infants, delayed gastric emptying was defined as GRVs >5 mL/kg in any 4-hour period.[10] Gastric aspirates >150–250 mL in a 4-hour period were considered a marker of intolerance in adults, and cessation of EN was recommended to minimize risk of aspiration pneumonia.[9] In many hospitals, intolerance to enteral feeding has been assessed in part by serially measuring GRVs.[21,22] The presence of GRVs in excess of a predetermined volume has been associated with inadequate gastric emptying. The routine of suspending EN due to large GRVs has been questioned in human medicine, because there is no consistent relationship between aspiration and GRVs. To the authors' knowledge, this is the 1st clinical study to report on the association between GRVs and nasogastric tube feedings in dogs.

In the present study, there was no significant difference in GRVs between dogs in Group C and dogs in Group I. These results are similar to those of a study in human pediatrics in which the incidence of GRV (measured every 4 hours) was not different between the continuous and intermittent feeding groups.[10] It has been previously thought in veterinary and human medicine that high GRVs correlate with a higher incidence of vomiting, regurgitation, and the occurrence of aspiration pneumonia. However, no significant correlation between average GRVs (mL/kg) and occurrence of vomiting or regurgitation was found in the present study, and only 2 patients on EN had aspiration pneumonia, both of which had radiographic evidence of pneumonia documented before the start of EN. There is a lack of evidence in veterinary medicine to suggest what an acceptable GRV might be, or whether this measurement is a reliable means of assessing gastric intolerance. These findings suggest that termination of enteral feedings because of high GVRs in critically ill dogs may not be warranted, particularly in patients not exhibiting signs of vomiting or regurgitation.

The feeding protocol established for the present study was technician led, evaluated daily by the research technician and verified by the attending clinician. Three patients in Group I had PPND that was $>100\%$ during the study because of a miscalculation of their RER. The rate was corrected once identified by the research technician. Proactive implementation of an algorithm or feeding protocol improved the average time from hospital admission to initiation of NE feedings from 4.5 to 1.8

days.[17] Although, this is a reflection of our active enrollment of patients, a set of guidelines could be implemented in a veterinary practice to identify patients that would benefit from early EN.

A power analysis indicated that we had an adequate patient number; however, our small heterogenic study population precluded the evaluation of patient subsets where delivery method may have made a difference. Additional studies may be directed at evaluating patients with more severe dietary intolerance, such as those with persistent regurgitation.

There was a statistically significant difference in the percentage of PPND between those dogs fed continuously and those fed intermittently via NE tubes. However, this difference is likely not clinically relevant. The frequencies of GI and mechanical complications were not significantly different between dogs fed continuously and those fed intermittently; however, dogs in the continuous group did have a significantly higher occurrence of technical complications. There was no difference in the GRVs between the 2 delivery methods, and the incidence of high GRVs did not correlate with the frequency of vomiting or regurgitation. Data from this study indicate that both the continuous and intermittent methods of NE tube feeding can facilitate adequate nutrient intake with minimal GI complications in critically ill dogs.

Footnotes

[a] Ross Products Division, Abbott Laboratories, Columbus, OH

[b] Microsoft Excel 2004 for Mac version 11.5.1, Redmond, WA

[c] Clinicare Canine/Feline Liquid Diet & Clinicare RF Liquid Diet, Abbott Laboratories, Abbott Park, IL

[d] Hayes et al. The canine acute physiology (CAP) score: A severity of illness stratification system for hospitalized canine patients. J Vet Emerg Crit Care 2009;19:A3–4 (abstract)

[e] GraphPad Prism version 5.00 for Windows, GraphPad Software, San Diego, CA, www.graphpad.com

Acknowledgments

We thank Abbott Laboratories, Abbott Park, IL for donating Clinicare for this project. This study was supported by a grant from the Michigan State University College of Veterinary Medicine Companion Animal Fund.

References

1. De Jonghe B, Appere-DeVechi C, Fournier M, et al. A prospective survey of nutritional support practices in intensive care unit patients: What is prescribed? What is delivered? Crit Care Med 2001;29:8–12.

2. Abood SK, Buffington CAT. Enteral feeding of dogs and cats: 51 cases (1989–1991). J Vet Med Assoc 1992;201:619–622.

3. Adam S, Batson S. A study of problems associated with the delivery of enteral feed in critically ill patients in five ICUs in the UK. Intensive Care Med 1997;23:261–266.

4. McClave S, Sexton L, Spain D, et al. Enteral tube feeding in the intensive care unit: Factors impeding adequate delivery. Crit Care Med 1999;27:1252–1256.

5. Remillard RL, Darden DE, Michel KE, et al. An investigation of the relationship between caloric intake and outcome of hospitalized dogs. Vet Ther 2001;2:301–310.

6. Michel KE, Higgins C. Investigation of the percentage prescribed enteral nutrition actually delivered to hospitalized companion animals. J Vet Emerg Crit Care 2006;16:S2–S6.

7. Edwards S., Metheny N. Measurement of gastric residual volume: State of the science. Med Surg Nursing 2000;9:125–128.

8. Metheny NA, Schallom L, Oliver DA, et al. Gastric residual volume and aspiration in critically ill patients receiving gastric feedings. Am J Crit Care 2008;17:512–519.

9. MacLeod JBA, Lefton J, Houghton D, et al. Prospective randomized control trial of intermittent versus continuous gastric feeds for critically ill trauma patients. J Trauma 2007;63:57–61.

10. Horn D, Chaboyer W, Schluter P. Gastric residual volumes in critically ill paediatric patients: A comparison of feeding regimens. Aust Crit Care 2004;17:98–103.

11. Serpa LF, Kimura M, Faintuch J, Ceconello I. Effects of continuous versus bolus infusion of enteral nutrition in critical patients. Rev Hosp Clin Fac Med S Paulo 2003;58:9–14.

12. Ciocon JO, Galindo-Ciocon DJ, Tiessen C, Galinda D. Continuous compared with intermittent tube feeding in the elderly. J Parenter Enteral Nutr 1992;16:525–528.

13. Hiebert JM, Brown A, Anderson RG, et al. Comparison of continuous vs. intermittent tube feedings in adult burn patients. J Parenter Enteral Nutr 1981;5:73–75.

14. Kocan MJ, Hickisch SM. A comparison of continuous and intermittent enteral nutrition in NICU patients. J Neurosci Nurs 1986;18:333–337.

15. Hacker R, Harvey-Banchik LP. Prospective randomized control trial of intermittent versus continuous gastric feeds for critically ill trauma patients. Nutr Clin Pract 2008;23:564–565.

16. Chandler ML, Guilford WG, Lawoko CRO. Comparison of continuous versus intermittent enteral feeding in dogs. J Vet Int Med 1996;10:133–138.

17. Campbell JA, Jutkowitz LA, Santoro K, et al. Continuous versus intermittent delivery of nutrition via nasoenteric feeding tubes in critically ill canine and feline patients. J Vet Emerg Crit Care 2010, doi: 10.1111/j.1476-4431.2010.00523.x.

18. Wøien H, Bjørk IT. Nutrition of the critically ill patient and effects of implementing a nutritional support algorithm in ICU. J Clin Nurs 2006;15:168–177.

19. Meyer R, Harrison S, Sargent S, et al. The impact of enteral feeding protocols on nutritional support in critically ill children. J Hum Nutr Diet 2009;22:428–436.

20. Spain DA, McClave SA, Sexton LK, et al. Infusion protocol improves delivery of enteral tube feeding in the critical care unit. J Parenter Enteral Nutr 1999;23:288–292.

21. McClave SA, Snider H. Clinical use of gastric residual volumes as a monitor for patients on enteral tube feeding. J Parenter Enteral Nutr 2002;26:43–50.

22. McClave SA, Snider HL, Lowen CC, et al. Use of residual volumes as a marker for enteral feeding intolerance: Prospective blinded comparison with physical examination and radiographic findings. J Parenter Enteral Nutr 1992;16:99–105.