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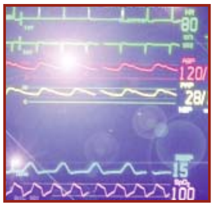

Evaluation of Delivery of Enteral Nutrition in Critically Ill Patients Receiving Mechanical Ventilation

By Debra O'Meara, RN, Eduardo Mireles-Cabodevila, MD, Fran Frame, RN, A. Christine Hummell, RD, MS, CNSD, LD, Jeffrey Hammel, MS, Raed A. Dweik, MD, and Alejandro C. Arroliga, MD

Background Published reports consistently describe incomplete delivery of prescribed enteral nutrition. Which specific step in the process delays or interferes with the administration of a full dose of nutrients is unclear.

Objectives To assess factors associated with interruptions in enteral nutrition in critically ill patients receiving mechanical ventilation.

Methods An observational prospective study of 59 consecutive patients who required mechanical ventilation and were receiving enteral nutrition was done in an 18-bed medical intensive care unit of an academic center. Data were collected prospectively on standardized forms. Steps involved in the feeding process from admission to discharge were recorded, each step was timed, and delivery of nutrition was quantified.

Results Patients received approximately 50% (mean, 1106.3; SD, 885.9 Cal) of the prescribed caloric needs. Enteral nutrition was interrupted 27.3% of the available time. A mean of 1.13 interruptions occurred per patient per day; enteral nutrition was interrupted a mean of 6 (SD, 0.9) hours per patient each day. Prolonged interruptions were mainly associated with problems related to small-bore feeding tubes (25.5%), increased residual volumes (13.3%), weaning (11.7%), and other reasons (22.8%). Placement and confirmation of placement of the small-bore feeding tube were significant causes of incomplete delivery of nutrients on the day of admission.

Conclusions Delivery of enteral nutrition in critically ill patients receiving mechanical ventilation is interrupted by practices embedded in the care of these patients. Evaluation of the process reveals areas to improve the delivery of enteral nutrition. (*American Journal of Critical Care.* 2008;17:53-61)

Underfeeding is common in critically ill patients receiving invasive mechanical ventilation.[1-7] Whether underfeeding has adverse effects is unclear[8,9]; however, evidence indicates that malnutrition has adverse effects on critically ill patients.[10,11] Although the prescribed nutrition is expected to be delivered, published reports[1-6,8,12-14] consistently describe incomplete delivery of prescribed enteral nutrition. It is unclear which specific step in the process of administering enteral nutrition delays or interferes with the administration of a full dose of nutrients.[1,12]

The objective of this study was to identify the reasons enteral nutrition was interrupted in acutely ill patients receiving mechanical ventilation, resulting in incomplete delivery of the prescribed calories.

Methods and Materials

This observational prospective study was performed in a closed 18-bed medical intensive care unit (MICU) of the Cleveland Clinic, Cleveland, Ohio, from January to May 2005. The study was approved by the institution's investigational review board. Consecutive patients receiving mechanical ventilation and with no contraindication (eg, gastrointestinal bleeding, ileus, suspected perforation) for initiation of enteral nutrition or insertion of a small-bore feeding tube (SBFT; eg, active variceal bleeding, sinusitis) were considered for inclusion in the study. Patients receiving noninvasive mechanical ventilation or parenteral nutrition were excluded.

Enteral nutrition should begin within 24 to 48 hours following ICU admission.

Decisions related to care, time of insertion of the feeding tube, and initiation of enteral nutrition were guided by the multidisciplinary team caring for the patient, not by protocol. The team was composed of a critical care physician, fellows, internal medicine residents, a registered nurse, a pharmacist, and a registered dietitian.

After admission, each patient's nurse inserted an SBFT (10F, 109-cm CORFLO, VIASYS Healthcare Medsystems, Wheeling, Illinois), preferentially by the oral route. Feeding was started once a physician on the team confirmed postpyloric positioning of the tube on an abdominal radiograph. All patients received enteral nutrition via continuous infusion by a feeding pump (COMPAT, Novartis Medical Nutrition, Minneapolis, Minnesota). The amount of enteral nutrition delivered was quantified hourly. Daily caloric intake was determined by multiplying the total amount of enteral nutrition delivered by the caloric content of the formula(s) and was recorded every morning. Residual volumes were determined by syringe aspiration through the existing SBFT every 4 hours. Patients had a large-bore orogastric tube placed when clinically indicated. Interventions in response to measured residual volume were not specified by protocol.

All observations were recorded on a standardized collection form completed by nursing staff, a dietitian, and 2 of the investigators (D.O., F.F.). We collected demographic data on each patient, including time of admission, time of initiation of enteral nutrition, type of enteral formula, diagnosis of ventilator-associated pneumonia,[15] and disposition. We collected data on the time interval from admission to insertion of the SBFT, time interval to confirmation of placement of the feeding tube, time interval to initiation of enteral nutrition, and the number of reinsertions. We recorded the calories prescribed by the physician, the calories recommended by the registered dietitian (based on the Harris-Benedict equation adjusted with stress factors[16]), and the calories delivered. We also collected data on residual volume measured via the SBFT or the orogastric tube (when present), episodes of emesis, use of prokinetic medication, and clinical comments on nutrition delivery.

About the Authors
Debra O'Meara and **Fran Frame** are registered nurses in the Department of Nursing; **Eduardo Mireles-Cabodevila** and **Raed A. Dweik** are physicians in the Department of Pulmonary, Allergy, and Critical Care Medicine; **A. Christine Hummell** is a registered dietitian in the Department of Nutritional Therapy; and **Jeffrey Hammel** is a biostatistician in the Department of Quantitative Health Sciences, Cleveland Clinic, Cleveland, Ohio. **Alejandro C. Arroliga** is the director of the Department of Pulmonary and Critical Care Medicine at Scott and White Hospital and professor of medicine at Texas A&M College of Medicine in Temple, Texas.

Corresponding author: Eduardo Mireles-Cabodevila, MD, Department of Pulmonary, Allergy, and Critical Care; Cleveland Clinic, Cleveland, OH 44195 (e-mail: mirelee@ccf.org).

To identify factors involved in interruption of the enteral nutrition, we recorded interruptions and quantified them in 15-minute intervals. The nursing staff involved in the care of each patient was responsible for recording the interruptions and the times when interruptions occurred. We did not record interruptions shorter than 15 minutes or note changes in rate of infusion. We used 11 arbitrary categories to define the reasons for the interruptions (Table 1). Nutrition delivery in the first 10 days of the MICU stay was analyzed in this cohort.

Statistical Analysis

Continuous variables were summarized by using means and standard deviations, with minimum, median, and maximum values and 95% confidence intervals for the mean reported as appropriate. Group comparisons with respect to quantitative variables were performed by using *t* tests, and group comparisons with respect to categorical variables were performed by using the Fisher exact test or a χ^2 test. Paired *t* test comparisons were used to assess temporal differences and differences between calories ordered and received. Spearman rank correlation was used to assess associations between continuous variables.

Table 1
Reasons for interruptions of enteral nutrition

Reason	Description of the event
Problems with the small-bore feeding tube	Tube absent, clogged, or not approved
Residual volumes	Measurement of residual volume that led to interruption of enteral nutrition
Weaning	Interruption of enteral nutrition in preparation for possible extubation
Procedures	Procedures that require patients to be supine or enteral nutrition to be interrupted
Radiology	Interruption of enteral nutrition to perform radiological procedures
Preparation for surgery	Fasting before surgical intervention
Shock	Hemodynamic instability for which enteral nutrition was interrupted
Bath	Required the patients to be flat, for which enteral nutrition was interrupted
Emesis[a]	Evidence of regurgitation or emesis of gastric contents
Skin care[a]	Procedure that required patient to be supine for skin care
Other	Cause of interruption not covered by the other descriptions

[a] Emesis and skin care were rare and were added to the "Other" category.

Results

Demographics

A total of 345 patients were admitted to the MICU; 128 (37%) received mechanical ventilation at admission, and 59 patients had enteral nutrition ordered on admission and were included in the analysis. Baseline demographics are shown in Table 2. The mortality in the MICU was 22% (13 of 59 patients); ventilator-associated pneumonia was diagnosed in 8% (5 of 59 patients).

Table 2
Demographics of the study sample (N = 59)

Characteristic	Value
Age, mean (SD), y	56.5 (13.9)
Male sex, No. (%)	28 (47)
Race, No. (%)	
White	35 (59)
Black	21 (36)
Other	3 (5)
Diagnosis, No. (%)	
Acute respiratory failure	44 (75)
Cardiac problem	6 (10)
Sepsis	5 (8)
Other	4 (7)
Length of stay, mean (SD), d	10.5 (8.2)
Duration of enteral nutrition, mean (SD), d	4.7 (4.1)
Duration of mechanical ventilation, mean (SD), median, d	7.4 (7.2), 5

Insertion of Small-Bore Feeding Tube

All patients had an SBFT inserted; 4 patients were not fed during mechanical ventilation (shock developed in 1 patient shortly after admission and his family withdrew medical care, 2 patients had multiple attempts for placement and were extubated within 48 hours of admission, and 1 patient had multiple attempts and had bleeding in the gastrointestinal tract develop later). Mean time to insertion after admission to the MICU was 18.2 (SD, 26.9) hours (median, 9.5 hours; 95% confidence interval, 1.8-17.1). Mean time elapsed before tube placement was confirmed after initial insertion was 5.7 (SD, 6) hours. Feeding was started a mean of 39.7 (SD, 36.3) hours after the admission to the MICU (median, 26 hours; 95% confidence interval, 16.3-36.6; Figures 1 and 2). Repositioning of the SBFT was frequent in this cohort; 17 patients (29%) required at least 1 reinsertion, 8 (14%) required 2 reinsertions, and 10 (17%) required more than 2 reinsertions during the observation period.

Feeding was started on average 40 hours after admission to the MICU.

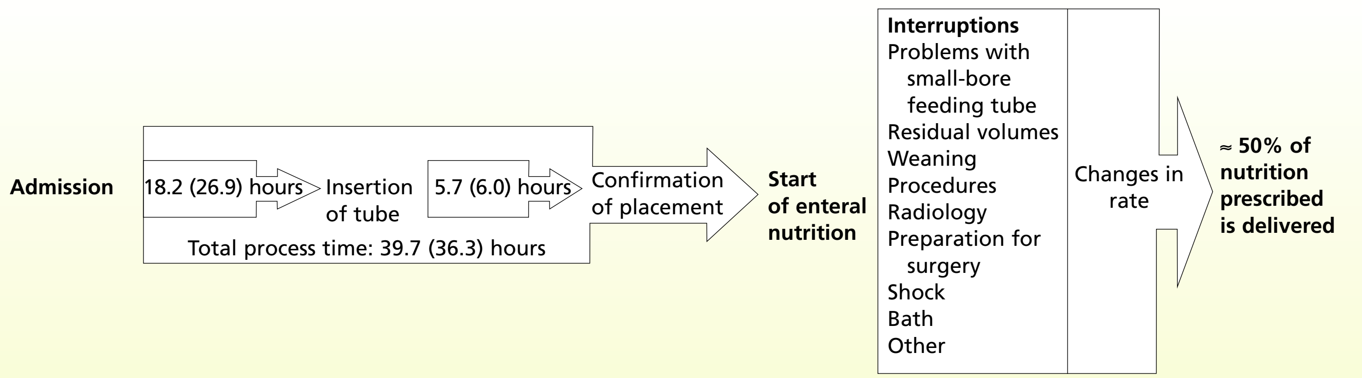

Figure 1 Factors involved in the incomplete delivery of prescribed amounts of enteral nutrition. Times are expressed as mean (SD).

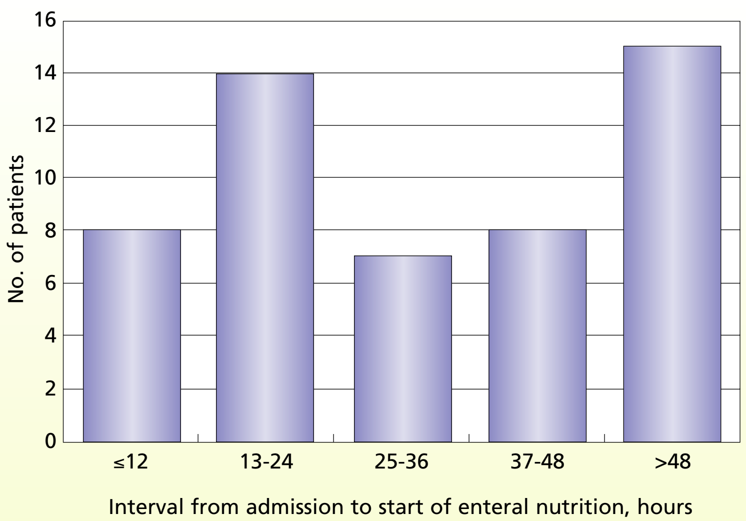

Figure 2 Histogram depicting the time from admission to initiation of enteral nutrition.

Table 3
Calories received, by day[a]

Day	No. of patients	Calories received: Mean (SD)	Median	Maximum	% of prescribed Calories received
1	59	355 (395)	254	1563	16
2	56	971 (780)	1005	2600	45
3	53	1015 (893)	836	2880	47
5	35	1225 (818)	1385	2770	57
7	29	1178 (889)	1154	2854	55
10	14	1024 (905)	871	2700	47

[a] No difference was found after adjusting the calories for the first and last day effect; raw values are reported.

Calories Prescribed and Received

The amount of daily Calories recommended by the dietitians (mean, 2142; SD, 397 Cal) was greater than the amount of Calories ordered by the physicians (mean, 1965; SD, 523 Cal) on the day of admission ($P = .02$). The nutritional formulas used were Novasource 2.0 (Novartis Medical Nutrition) for 37 patients (63%), Ultracal (Novartis Medical Nutrition) for 8 patients (14%), Peptamen (Nestle Nutrition, Glendale, California) for 7 patients (12%), and Renalcal (Nestle Nutrition) for 6 patients (10%). These were prescribed by the physician and changed according to the recommendations of the dietitian.

Table 3 shows the number of Calories received during the first 10 days in the MICU. Patients received approximately 50% of the calculated nutritional requirements (mean, 1106.3; SD, 885.9 Cal). Because the day of admission (day 1) and the last day in the MICU were incomplete days, those days were excluded from the analyses in which days were compared. The amounts of Calories received did not differ between days. Figure 3 shows the trends in Calories received by day. The mean amount of Calories administered during the study period was always significantly lower than the amount of caloric requirements estimated by the dietitian ($P < .001$ on all days).

Interruptions

A total of 423 interruptions of enteral feeding occurred in the first 10 days (387 patient-days). The total time enteral nutrition was administered for the whole cohort was 9288 hours, of which 2540 hours (27.3%) were interruption time. A mean of 1.13 (SD, 0.1) interruptions of enteral nutrition occurred per patient per day. Enteral nutrition was interrupted a mean of 6 (SD, 0.9) hours in each patient each day. The event to patient ratio was similar throughout the observation period (range, 0.85-1.44 events per patient), as was the duration of the interruptions (range of means, 295-454 min). Interestingly, the mean time available for enteral nutrition on day 1 was 13.6 (SD, 6.0) hours, with 56 interruption events (mean, 337 min) recorded in 59 patients (0.95 events per patient). Although this level of interruptions is

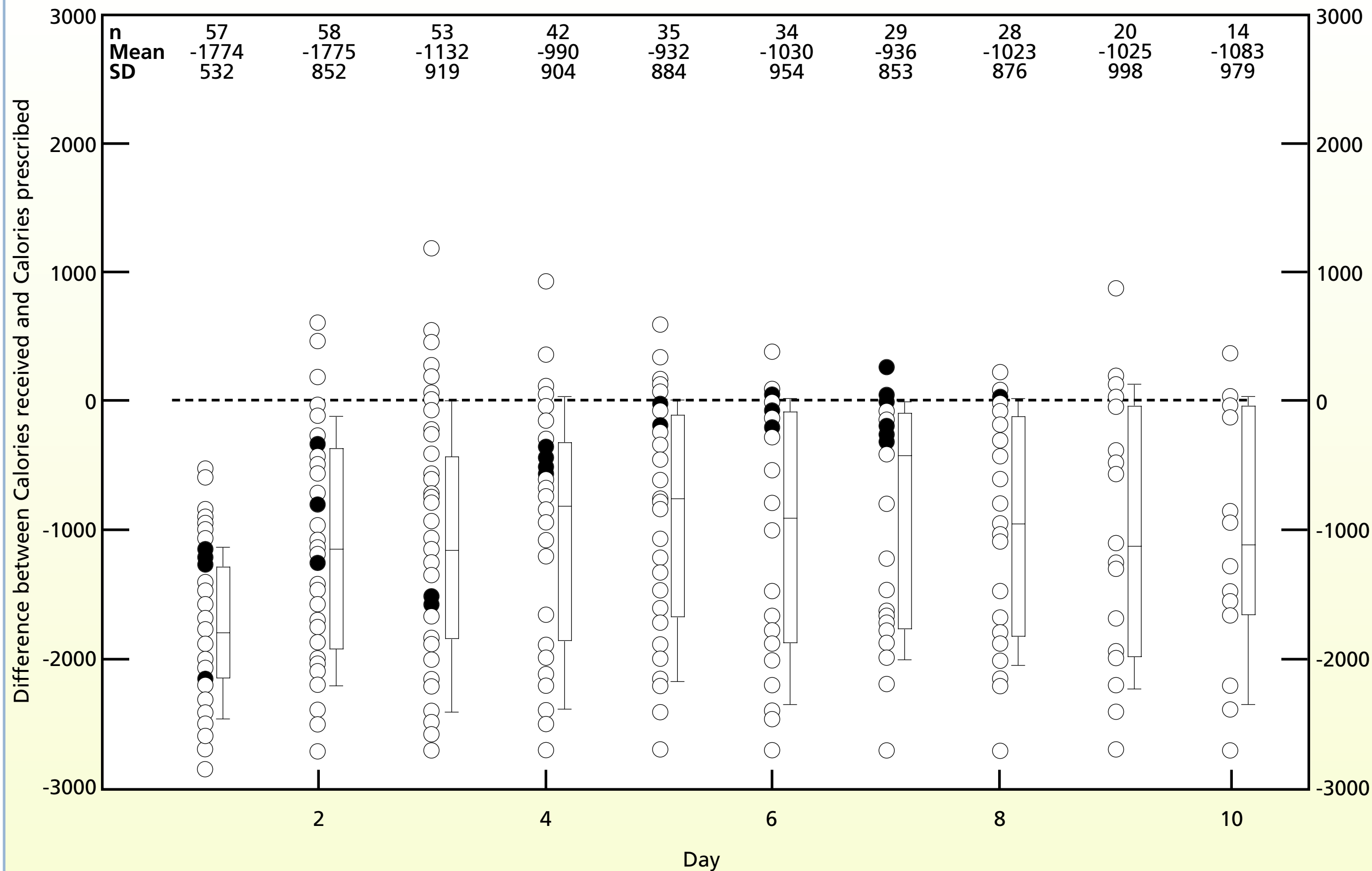

Figure 3 Difference between Calories received and Calories ordered, by day. The horizontal dotted line represents 0, when there were no differences between Calories prescribed and given. The number of patients decreased over time, but the mean amount of Calories less than what was prescribed by the dietitian did not change. *P* values from paired *t* tests were all less than .001.

Table 4
Interruptions in enteral nutrition

			Duration of interruption, min						
Type	No. of events	% of total interruption time	Subtotal	Mean	SD	95% confidence interval	Minimum	Median	Maximum
Problems with the small-bore feeding tube	73	25.6	38975	533.90	437.96	431.72-636.09	60	360	1440
Other	48	22.8	34785	724.69	486.63	583.39-865	15	520	1440
Residual volumes	41	13.3	20315	495.49	446.13	354.67-636.30	60	360	1440
Weaning	60	11.7	17855	297.58	302.14	219.53-375.63	30	180	1440
Procedures	46	7.9	12015	263.20	318.28	168.64-357.67	15	135	1440
Preparation for surgery	22	7.7	11765	534.77	330.52	388.23-681.32	240	450	1440
Radiology	19	5.0	7555	397.63	301.85	252.14-543.12	30	300	970
Shock	9	3.7	5640	626.67	521.44	225.85-1027.48	120	120	1440
Bath	105	2.3	3525	33.57	20.07	28.54-36.31	15	30	120

similar to the levels on other days, it is relatively greater when the shortened observation time is considered.

The longest interruptions (Table 4) were due to problems with the SBFT (25.6%), other reasons

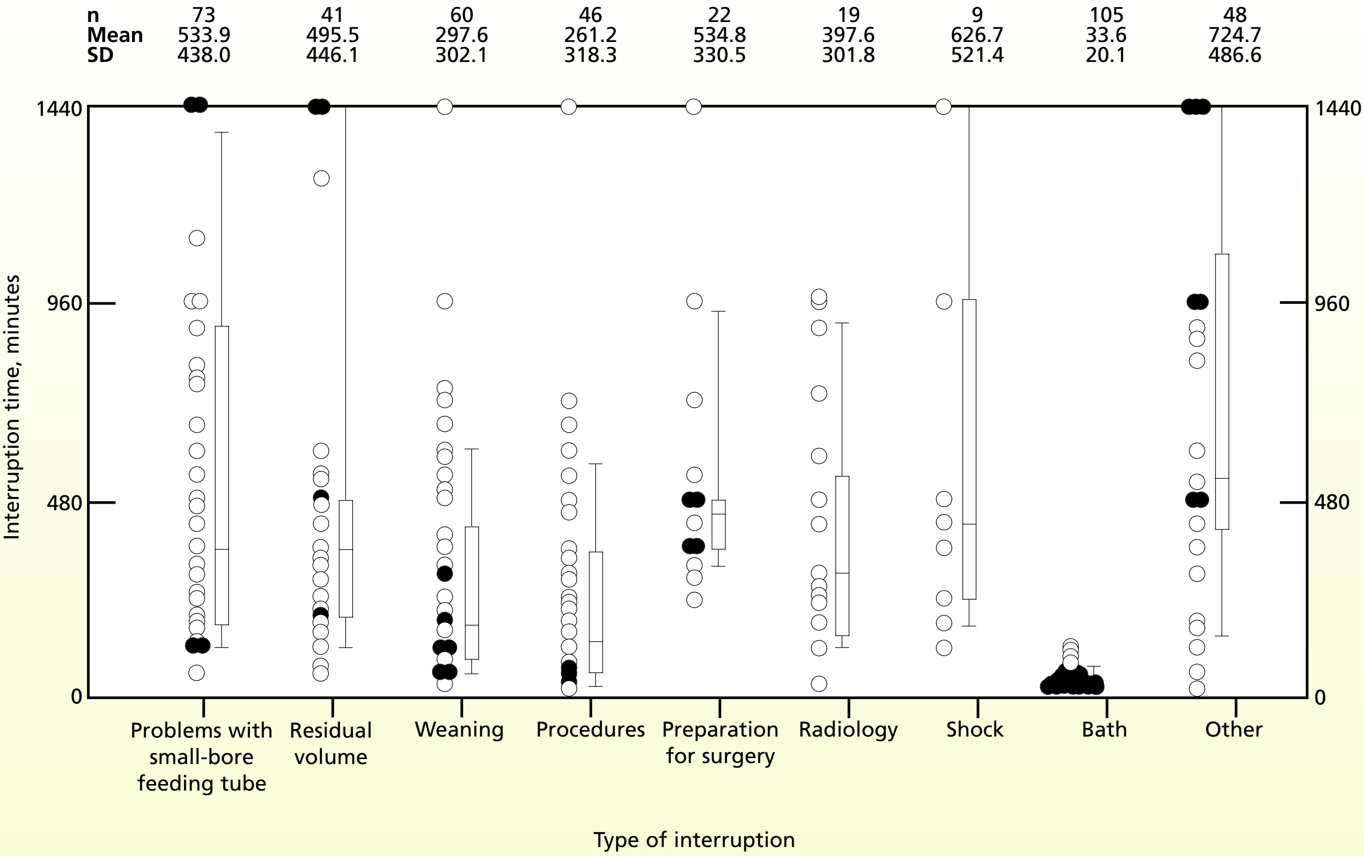

Figure 4 Total interruption time of the different categories. The most common reason for interruption was to give the patient a bath, although the interruption times in this category were short. The categories with the longest interrupted time were Other, shock, preparation for surgery, and problems with the small-bore feeding tube.

Subjects received 50% of the calculated nutritional requirements.

(22.8%), residual volumes (13.3%), and weaning (11.7%; Figure 4). These 4 categories account for 73% of the time when no enteral formula was delivered. Although the most frequent category of interruption was bath, it accounted for only 2.3% of total interruption time. Interruptions related to procedures, preparation for surgery, and radiology were less frequent but accounted for 21% of total interruption time.

We further analyzed the percentage of interruption time per day for the different categories of events. Overall, the most prolonged daily interruption was due to problems with the SBFT, which were more common in the beginning and in the later days after admission. Interruptions associated with weaning gradually increased after admission and were more frequent in the morning and after day 2. The Other category included the following interruptions: skin care, suspected gastrointestinal bleeding, withdrawal of care, equipment malfunction or delay in delivery, suspected acute abdomen, emesis, and unexplained interruption by nurses or physicians. This category had the longest interruption time per event, 725 minutes, but came in fourth in overall frequency.

Residual volume from an SBFT or an orogastric tube was the reason for interruption 41 times in 10 days, lasting a mean of 495 minutes. The residual volume measured from an SBFT was less than 100 mL in 386 events; the residual volume exceeded 100 mL in 26 events and exceeded 200 mL in 5 events. Changes in feeding rate after residual checks were not recorded. Emesis was observed 5 times in 4 patients, and in those patients the maximum residual volume from the SBFT on the day of emesis was 120 mL. During the day of emesis, enteral nutrition was on hold for weaning in 1 patient, because of a procedure in 1 patient, and because of clinical suspicion of small-bowel obstruction in 2 patients. Orogastric tubes were inserted when clinically indicated (eg, in patients with gastrointestinal bleeding, ileus, abdominal distention); the residual volume from the orogastric tube was greater than 200 mL in 22 events. Metoclopramide, a prokinetic, was used in 3 patients for a total of 10 patient-days.

Discussion

Our observations confirm the previously reported descriptions of the nutritional practices in critically ill patients receiving mechanical ventilation.[1-6,8,12-14] Such patients received fewer Calories than prescribed; approximately 50% of the prescribed amount of enteral nutrition was delivered. The most important contribution of this study is the detailed description of the process of administering enteral nutrition and the interruptions of that process (Figure 1).

Recent published guidelines recommend early enteral nutrition (started within 24-48 hours after admission in resuscitated patients and patients in stable condition) and, if feasible, the use of postpyloric nutrition. These recommendations are based on a trend toward a reduction in infectious complications, improvement in nutritional endpoints, and decreased mortality.[17,18] In our study, enteral nutrition was started a mean of 39.7 (SD, 36.3) hours after a patient's admission to the MICU. Clinical placement of a postpyloric SBFT took this long in usual care, resulting in a very low delivery of enteral nutrition on the day of admission (only 16% of caloric requirements). The clinicians had been under the impression that we were providing early and appropriate amounts of nutrition, but it seems evident that early enteral nutrition may not be the norm in everyday practice.[2,5,19-21] The effect of this situation on outcomes is debated and, given the inability to deliver what we prescribe, it is yet to be determined.[5,7,14,22]

On admission, physicians ordered significantly lower amounts of Calories than were recommended by the registered dietitian. Subsequently, enteral nutrition was adjusted to the dietitian's recommendations. Despite this adjustment, the amount delivered after admission was always low, approximately 50% of the prescribed calculated caloric requirements. Enteral nutrition was interrupted a mean of 6.0 (SD, 0.9) hours daily per patient. Approximately a quarter (27.3%) of the time available for feeding, the enteral nutrition was on hold. Previously, Elpern et al[12] described similar durations of interruptions in enteral nutrition.

The longest interruptions were due to problems related to the SBFT, 25.6% of the total interruption time. Our practice, at the time of the study, required postpyloric placement[17,23,24] for initiation of enteral nutrition. This requirement led to prolonged interruptions and in many instances multiple reinsertions. SBFT problems accounted for a mean of 19.7% of daily interruption time (range, 2.2%-28.3%). The day of admission had the highest interruption rate, with interruptions relating to the SBFT accounting for 59% of the daily total interruption time. It took a mean of 18.2 (SD, 26.9) hours to insert an SBFT. Our data agree with previously reported delays in initiation of enteral nutrition related to postpyloric placement of an SBFT in critically ill patients.[19,24,25] Interestingly, other researchers[2-4,13,20,21,26,27] have reported that, unrelated to the SBFT placement, it takes 1.1 to 5 days to initiate enteral nutrition. Although changing a feeding protocol to use gastric enteral feeding may decrease time to initiation of enteral nutrition, our analysis of the whole process (radiology response time, physician's approval, actual initiation of enteral nutrition after approval) reveals that multiple steps must be improved to decrease the total interruption time.

The Other category was the second longest cause of interruption, accounting for 22.8% of total interruption time. That category included causes that represent usual care of critically ill patients (withholding of enteral nutrition in patients with suspected acute abdomen and confirmed or suspected small-bowel obstruction), but also encompassed interruptions for which no explanation was found (physician's order). Most likely, further analysis of this category will reveal more practices that have no support in the literature. These interruptions may be unavoidable, but interventions such as electronic reminders (ie, the pump or the electronic chart) may help in reducing interruption time by increasing the frequency of evaluations.[28]

> Feedings were interrupted approximately 6 hours with each patient.

Residual volumes resulted in interruption of enteral nutrition 13.3% of the total interruption time; evaluation of the residual volume measured by using the SBFT did not reveal a clear explanation for this practice. Researchers in several studies[24,25,29-31] have relied on gastric and/or SBFT residual volumes as a marker of tolerance. In our study, 3 patients had documentation of suspected intolerance to enteral nutrition that led to the insertion of a gastric tube. Not surprisingly, the residual volumes were actually larger than the measurements from the SBFT indicated. However, only 5 episodes of emesis occurred in our study (in 4 patients), and in those instances the residual volume was not increased. It could be argued that the residual volume was lower because of the use of the SBFT (collapsibility, location).[32-34] This argument underscores the point that even the attempt to measure residual volume is not an effective use of a

> During one quarter of the time available for feeding, enteral nutrition was on hold.

nurse's time, leads to false conclusions, and increases the use of resources.[3,23,29,35] Therefore, removing measurement of residual volumes from feeding protocols may improve the delivery of enteral nutrition. However, no reliable marker of intolerance to enteral nutrition is currently available. In the absence of a better marker, clinical findings (eg, abdominal distention, absent bowel sounds) should be stressed in daily practice to detect intolerance to enteral nutrition. Further investigation is clearly needed in this area.

Interruptions for weaning and extubation caused about 5 hours in interruption of enteral nutrition per event (Table 4). The frequency increased between days 3 and 8 of a patient's stay in the MICU, probably because the weaning process was started in more patients on those days. Although this practice appears to be logical, evidence from a study[36] in children may challenge this concept and suggests the need for further evaluation.

Most procedures and radiological studies require the patient to be supine, a requirement that interrupts enteral nutrition because of the increased risk of aspiration. Together, procedures and radiological studies accounted for 13% of the interruptions in enteral nutrition. The bath is the most frequent but the shortest interruption, with a mean interruption time of 32 (SD, 20) minutes. Perhaps patients do not need to be supine during bathing; this potential problem is easy to remedy if patients are bathed in the semirecumbent or reverse Trendelenburg position. Placing patients in a semirecumbent position (at least 10°) partially prevents aspiration of gastric contents and reduces the incidence of ventilator-associated pneumonia.[37-39] The rate of ventilator-associated pneumonia was low in our study.

There is currently no reliable marker of enteral nutrition intolerance.

Preparation for surgery, procedures, and radiological studies seem to be necessary interruptions. Approximately 9 hours are spent fasting before surgery, 6.6 hours for radiological procedures, and 4 hours for other procedures. Of concern, some of these procedures may not require fasting, or the fasting time could be shortened for some.[40] In operational terms, the factors involved in the variability of the interruptions depended not on the intent to fast, but on the scheduling for surgery, because these surgeries were usually not scheduled procedures.

A discrepancy is apparent between the duration of interruption and the Calories received. Approximately 27% of the time available for delivery of enteral nutrition was spent on interruptions, but patients received only 50% of the Calories prescribed. This difference could be due to lack of detection of interruptions less than 15 minutes long or, although we did not record it, changes in the rate of administration of enteral nutrition. Possibly, after each interruption, the bedside nurses restarted enteral nutrition at a slower rate, increasing the rate gradually to the goal rather than resuming the previous rate of feeding.

Although implementation of a protocol increases the amount of enteral nutrition received, the amounts received are consistently less than the caloric target.[5,26,27] Recent evidence[41] suggests that even with the best intensive educational programs to increase compliance with enteral nutrition guidelines, patients will receive only 50% of the prescribed requirements. We think that unless a clear understanding of the process of feeding occurs, with emphasis on correcting the avoidable interruptions, the delivery of enteral nutrition will always be suboptimal.[26] Clinical trials to assess interventions and outcomes in enteral nutrition may not be applicable to everyday practice, given that delivery of prescribed enteral nutrition is commonly incomplete. Therefore, we think that the results of this "real world" study are a powerful tool to learn about the process used to feed patients.

Our study has several limitations. The most important is that it was done at a single institution. Second, we did not measure the rate of administration of enteral nutrition per hour and have no data on changes in rate due to interruptions or based on measurements of residual volume. Third, no clear definitions for feeding intolerance were generated a priori, and we relied on clinical documentation for this purpose. However, despite these limitations, our results describe the way nutrition is administered in a tertiary academic center and may be helpful to other intensive care units as they review their processes and remain aware of the different aspects that contribute to interruptions of delivery of enteral nutrition. At the Cleveland Clinic, our findings helped create and implement a new algorithm for enteral feeding that will soon be evaluated.

Conclusions

Critical evaluation of the nutritional practice in our MICU revealed practices embedded in the daily care of patients that cause interruptions in the delivery of enteral nutrition. Our evidence should raise awareness of these practices so that focused actions to correct them can be implemented.

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FINANCIAL DISCLOSURES
None reported.

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