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ORIGINAL ARTICLE

Successful Enteral Nutritional Support in the Neurocritical Care Unit

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Abstract
Purpose Adequate caloric intake is associated with improved outcome in neurocritical illness, but factors influencing the provision of enteral nutrition (EN) have not been systematically evaluated. The primary goal of the study was to determine the EN intake of neurosurgical intensive care unit (ICU) patients within the first week of illness and investigate the factors contributing to achieving caloric goals.
Methods A retrospective cohort of adult patients admitted to the neurosurgery service (NS) during August 2005–August 2006 were randomly selected and stratified into three groups based on their ICU-admission Glasgow Coma Scale Score (GCS) (GCS > 11, GCS 8–11, GCS 4–7). Daily EN intake, GCS, and other clinical data were collected.
Results A total of 71 patients were included (GCS > 11 = 23, GCS 8–11 = 23, GCS 4–7 = 25). Admitting diagnoses included traumatic brain injury (TBI) (32%), subarachnoid hemorrhage (SAH) (32%), and intracerebral hemorrhage (17%). The overall in-hospital mortality was 23.9%. Overall, the maximum daily mean calories provided was 1,100 kcal (mean of 55% of caloric goal on hospital day 6). The median time to feeding was approximately 3 days in each group. GCS did not appear to significantly affect the mean % of caloric goal administered in patients with a minimum daily GCS $\leq$ 11 ($P = 0.053$). Multivariate analysis revealed that clinical care factors, such as time to EN orders and enteral access confirmation, were significant impediments to EN provision ($P = 0.001$).
Conclusion System-based clinical care factors appear to have great impact on the successful provision of EN in the first week of neurocritical illness.

Keywords Traumatic brain injury · Early nutrition · Critical illness

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Introduction

Almost immediately after a critical neurologic insult, a hypermetabolic, hypercatabolic state is evident [1]. Provision of enteral nutrition (EN) in neurosurgical patients, particularly within 48 h, has been associated with beneficial effects such as attenuation of the hypercatabolic response, gut atrophy, muscle mass loss (negative nitrogen balance), and infection [2–4]. Previous studies in patients with traumatic brain injury (TBI) have also shown an improved outcome by providing nutrition as early as possible [4]. Currently, specific recommendations for providing nutrition in the general critically ill population are available; however, guidelines addressing the provision of nutrition to neurologically injured individuals are limited to those with TBI, spinal cord injury (SCI), and ischemic stroke [5–8].

Commensurate with available guidelines, our institutional philosophy of providing nutrition to critically ill individuals, including those with neurologic insult, is a consistent, proactive approach to establishing early enteral access (typically a nasoduodenal tube) in patients unable to take in nutrition by mouth [9]. Infusion of EN products

should begin as soon as medically and surgically appropriate, with the rate advancing as tolerated to the goal infusion rate (optimally within the first 48 h of illness). However, numerous challenges exist in providing adequate EN to neurologically injured patients such as alterations in gastrointestinal motility, elevated intracranial pressure, and altered levels of consciousness and overall neurologic function.

The precise impact of these challenges related to neurocritical illness on nutrition provision has not been ascertained, but many of these factors may limit the extent of nutrition provided in the first week of illness. In particular, it has been hypothesized that the severity of neurologic illness is inversely related to the likelihood of a patient receiving adequate early EN. Therefore, the aim of this study was to begin to define the relationship of these factors (such as Glasgow Coma Scale score, GCS) to nutrition provision in the neurocritically ill population.

Methods

The study was a retrospective review of medical records of patients admitted to an adult ICU at a 473-bed academic, tertiary-care health center. Subjects were selected for recruitment based upon a review of a hospital database to identify patients admitted to the neurosurgery service (NS) between August 2005 and August 2006. Subjects were randomly screened for inclusion without regard to diagnosis, severity of illness, or time of admission. Eligible patients included those that were at least 18 years of age and admitted to an ICU for at least 72 h with one of the following insults: TBI, SCI, intracranial hemorrhage (ICH), subarachnoid hemorrhage (SAH), or brain tumor. Eligible patients also had an admitting ICU GCS of >3. The study population goal was to achieve approximately 20–25 patients for each GCS group. Patients were excluded from the study if they were receiving total parenteral nutrition (TPN) or oral intake on ICU admission (patients could later be transferred to oral intake if they clinically improved enough to discontinue EN), an ICU stay <72 h, and admitting GCS of 3.

The null hypothesis of this study is during the first 7 days of admission of a neurosurgical patient to an adult ICU, enterally administered caloric intake of the patients is inversely related to the severity of the neurologic injury. The primary objective of the study was to demonstrate the relationship between severity of neurologic illness and caloric intake in neurocritical care patients for the first 7 days of ICU stay. Secondary objectives included identifying the factors that contributed to EN intake and determining the differences in nutritional intake among patients with differing neurologic insults. The percentage of caloric intake for each patient was compared to their estimated needs determined by the Harris–Benedict Equation (HBE), and a pre-defined stress factor as defined by institutional practice and national guidelines [7, 10]. Daily nutritional intake was compared to the GCS (and other factors listed below).

Patients were stratified into one of three categories of neurologic injury based on ICU-admission GCS: mild (GCS $>$ 11); moderate (GCS between 8 and 11); and severe (GCS between 4 and 7). Initial GCS may be used in neurologic illness as a general predictor of severity of neurologic disease and as a surrogate for ultimate outcome. Stratification by GCS was necessary in order to have a balanced number of patients representing the spectrum of severity of neurologic illness. The following information was collected for each subject meeting inclusion criteria: patient age, gender, height, weight, minimum daily GCS, ICU length of stay (ICU LOS), receipt of EN, and type of neurologic insult. Other factors such as prealbumin, albumin, actual body weight, adjusted body weight if obese were collected in the baseline data, however not consistently evaluated in the course of clinical practice.

The actual calories received and percent goal calories received were calculated for the first 7 days. The HBE is the standard of care for calculating our patient's goal non-protein calorie requirements. The HBE is used in conjunction with a stress factor to account for additional caloric needs based on the patient's clinical situation. For example, the stress factor typically applied to a patient with TBI is 1.4; stroke, 1.2–1.3; major surgery, 1.2–1.3. The percent goal calories received was defined as the number of calories received for a given day divided by the goal as calculated by the stress-factor adjusted HBE. Calories received from all sources, including enteral and parenteral solutions, were included in the caloric calculations. Oral caloric intake was not recorded due to inconsistencies in documentation.

Patient factors or system-based issues were recorded daily for the first 7 days of ICU admission (Table 1). Specific factors from this table were examined including clinical care issues (feeding tube order, abdominal radiograph order, verification of appropriate feeding tube placement, EN order); patient factors before feeding (abdominal distention, absence of bowel sounds, diarrhea, elevated intracranial pressure [ICP], facial or unstable cervical fracture); severity of illness (GCS); medication factors (prokinetic agents, vasopressors, sedatives); and mechanical failure (malplacement of feeding tube, tube occlusion). These factors were identified a priori as potential causes of delay or failure to receive adequate EN.

The standard of care at the study institution is for each adult ICU patient to receive a nutritional assessment by a Nutrition Support Services (NSS) team member within 48 h of admission. The NSS, a multi-disciplinary team of

Table 1 Factors affecting the provision of enteral nutrition (*italicized* factors were included in the analysis for this study)

Factors	Examples
Clinical care issues	*Feeding tube order*
	Abdominal radiograph order
	Verification of appropriate feeding tube placement
	Enteral nutrition order
Patient factors	*Abdominal distention*
	Absence of bowel sounds
	Diarrhea
	Elevated intracranial pressure [ICP]
	Facial or unstable cervical fracture
	Pancreatitis
	Paralytic ileus
	Shock
	Severe GERD
	Clostridium difficile colitis
Severity of illness	*GCS*
Medication factors	*Prokinetic agents*
	Vasopressors
	Sedatives
Mechanical failure	*Misplacement of feeding tube*
	Feeding tube occlusion
Others	Operating room procedures
	Interventional radiology procedures
	Canceled procedures
	CT procedures

physicians, pharmacists, dieticians and respiratory therapists, also makes specific recommendations for the initiation of nutrition support, including the appropriate EN formula, initial administration rate, and goal rate (Table 2)

Table 2 Key factors for successful nutrition support

1. Obtain post-pyloric access early (preferably within 24 h).
2. Initiate enteral nutrition early (preferably within 48 h).
3. Increase enteral nutrition rate to goal quickly as tolerated.
4. Use a consistent, systematic method of estimating caloric and protein needs.
5. Utilize prokinetic agents and a bowel regimen early in feeding to facilitate tolerance when necessary.
6. Account for additional calorie sources such as propofol.
7. Avoid complications due to diarrhea, constipation, and hyperglycemia.
8. Dysphagia assessment for those attempting oral intake to avoid aspiration.
9. Assess calorie intake for patients with oral diets to ensure adequate supplementation.
10. Adjust calorie and protein provision according to phase of illness and metabolic parameters.

[9]. Also included are the patient's caloric and protein goals, stress factor, current nutritional status, and pertinent laboratory values. Each patient's nutrition is assessed two to three times weekly depending on the severity of the nutrition status and changes are suggested as appropriate. All nutrition data for this study were collected from NSS nutrition assessments in each patient's chart.

Descriptive statistics were used in analyzing the population characteristics. Fisher's exact and chi-squared (x^2) tests were used for categorical data where appropriate. Continuous data were analyzed by ANOVA and the student's *t*-test. To investigate the presence of an association in the primary outcome with factors which may affect nutrition provision, linear regression was used with multivariate analysis.

Results

A total of 187 patients were admitted for >72 h to an adult ICU under the care of the neurosurgical service during the study period. A total of 114 charts were reviewed until a total of 71 patients were included in the study, in order to have a similar number of patients in each GCS group. The total number of patients excluded was 43; 73 medical records were not reviewed because the desired sample size had been reached. The most common reason for exclusion was the ability to tolerate an oral diet on admission.

The baseline characteristics of each cohort were similar except for the degree of neurologic illness (Table 3). Overall, the average age of the patients was 55 ($\pm$15.9) years and 46.5% of the patients were female ($n = 33$). On average, the population had an ICU LOS of approximately 10 days ($\pm$5). The in-hospital mortality was 23.9%, with an approximate 7-day mortality of 9.9% (7 total patients). Based upon the degree of neurologic injury, there were no significant differences in these demographic characteristics among the GCS groups ($P > 0.05$). There were significant differences among ICU-admission GCS, APACHE III, and admission motor score as might be predicted based on stratification by ICU-admission GCS. The majority of the patient population was admitted with hemorrhagic stroke (49%, 32% with SAH and 17% with ICH), followed by TBI (32%) and brain tumor (10%). Spinal cord injuries comprised 8% of the population. These results are reflective of the typical distribution of neurosurgery ICU admissions for this institution.

Many patients did not receive EN during each day in the ICU and were either taking in oral nutrition or nothing. When considering days in which EN was provided (EN day), the total amount and percent of caloric goal provided was calculated and compared among each GCS group (Fig. 1). The average amount of kcal/day received for each

Table 3 Baseline demographics

Characteristic	Mean (standard deviation)			
	Total ($n = 71$)	Mild injury* ($n = 23$)	Moderate injury* ($n = 23$)	Severe injury* ($n = 25$)
Age—years	55.3 (15.9)	57.1 (14.8)	59.2 (11.2)	50.3 (18.9)
Female gender—%	46.5%	44.8%	47.1%	48.0%
Weight—kg	78.4 (21.2)	81.9 (18.5)	75.7 (26.6)	76.1 (20.3)
Height—cm	169.4 (14.5)	171.2 (9.4)	164.6 (22.1)	172.5 (11.9)
ICU LOS—days	10.0 (5.0)	9.5 (4.4)	10.2 (5.9)	10.4 (5.1)
7-day mortality—%	9.9%	7.0%	0%	20%
In-hospital mortality—%	23.9%	20.7%	11.8%	36%
APACHE III score**	51.2 (22.5)	42.3 (18.8)	53.9 (25.5)	59.7 (21.7)
Median ICU-admission motor score**	6 (1–6)	6 (1–6)	5 (1–6)	3 (1–6)
Median ICU-admission GCS**	10 (4–15)	13 (11–15)	9 (8–11)	6 (4–7)

* Mild = GCS > 11; Moderate = GCS 8–11; Severe = GCS 4–7

** *P*-values <0.05

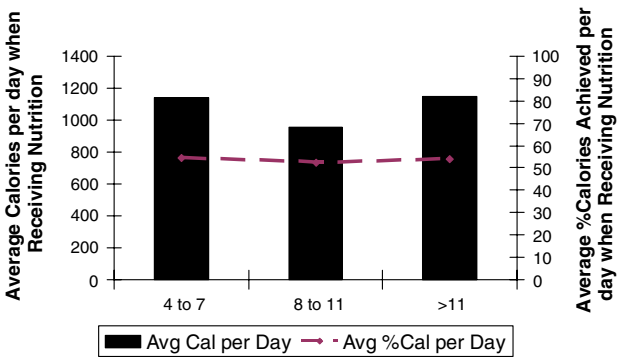

Fig. 1 Calories achieved on each nutrition day (Grouped per GCS)

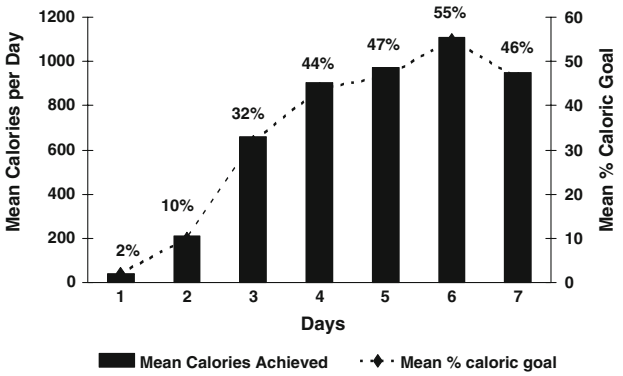

Fig. 2 Mean calories and mean % caloric goal per day

GCS category was: GCS 4–7 1143 (±540) kcal/day ($n = 24$); GCS 8–11 956 (±613) kcal/day ($n = 17$); and GCS > 11 1150 (±888) kcal/day ($n = 27$, $P = 0.637$). In addition, there was no difference in the percent calories achieved for a given EN day: GCS 4–7 54.5% (±32.8%), GCS 8–11 52.6% (±29.7%), and GCS > 11 54.2% (±54.2%, $P = 0.986$). The lack of difference in percent calories provided in patients with varying GCS scores may indicate that severity of neurologic illness (as measured by GCS) does not impact the provision of EN.

When considering all ICU days, the maximum mean daily calories provided was 1,100 kcal (mean of 55% of caloric goal on hospital day 6, Fig. 2). Delay in initiating EN appeared to be a contributing factor in not achieving early caloric goals, particularly in the first 2–3 days after admission. No statistical difference was found between GCS category and the hospital day EN was initiated (2.4 days in GCS 4–7, 3.2 days in GCS 8–11, and 3.4 days in GCS > 11; $P = 0.069$). The only major factors influencing time to providing EN were clinical care issues ($P = 0.001$). Severity of illness, as measured by admission-GCS ($P = 0.352$), APACHE III score ($P = 0.462$), or admission GCS motor score ($P = 0.926$), was not a statistically significant factor affecting the provision of EN. The use of medications associated with gastrointestinal dysmotility ($P = 0.227$) or used to facilitate EN ($P = 0.086$) did not affect time to receiving EN.

Discussion

This study compared the severity of neurologic illness to caloric intake in adult neurosurgical patients admitted to an ICU during the first 7 days of admission. We hypothesized that patients with more severe neurologic insults and more pronounced neurologic dysfunction (as measured by ICU-admission GCS) would receive less calories than patients with lesser neurologic insults and neurologic dysfunction. However, our results show that the ICU-admission GCS did not affect the mean percent of caloric goal provided.

One factor that did appear to affect the amount of EN provided in the first week was time to initiation of EN. The median time to initiation of EN was approximately 3 days

in each GCS group. This delay stymied the provision of adequate EN to the overall study population (Fig. 2). The principal reasons for a delay in initiating EN were clinical care factors such as delays in ordering feeding tube placement, ordering of an abdominal radiograph to verify appropriate tube placement, and orders for the EN regimen. This is not uncommon. It is important to note that tolerance was not the issue in achieving successful EN (as it is commonly reported in the nutrition literature). Rather, it was getting the feeding tube in place and EN adequately started within 24 h. Other published studies investigating factors which delay or limit the provision of EN have identified the ordering of EN and the inappropriateness of initial orders to meet estimated or measured caloric goals as mitigating factors in providing EN to critically ill patients [11, 12].

Early, adequate nutrition has proven to be an important factor in the outcome and recovery of neurologically injured patients. In early studies where nasogastric EN and TPN were compared in brain injured patients, TPN appeared to be associated with less mortality and infectious complications at 18 days after admission [13]. This may have been due to a number of factors including gastric feeding intolerance, which is often evident early in the acute, severe neurologic injuries. The TPN patients also received more adequate nutrition earlier in the course of their illness as indicated by the metabolic variables evaluated in this study, such as nitrogen balance and serum albumin concentration, which were significantly better in the patients receiving TPN compared to those receiving nasogastric EN. Later studies comparing TPN and nasoduodenal or nasojejunal feedings showed no differences in outcome, likely due to the improved tolerance to post-pyloric EN and a more similar provision of calories between the two groups [2, 3, 14].

Although TBI patients have demonstrated tolerance of goal rates of EN within the first 48 h of their injury in a study setting and there exists ample data supporting the shift from TPN to EN in the general critical care population, there are a number of factors which may thwart the provision of early EN in neurocritically ill individuals in clinical practice [4, 15]. Neurologically injured patients suffer from both systemic and central insults. Therefore, patients must overcome damage to the metabolic control center and altered metabolic response to injury [1]. Enteric innervation, swallowing, and ICP all may be abnormal, which can affect the patient's ability to tolerate and receive nutrition. Medications administered in the supportive care of these patients, such as morphine, barbiturates, or vasopressors, often diminish gastrointestinal motility.

Limitations to this study include inconsistency in medical record documentation, including amount of calories received from oral diets. Oral caloric intake was not well recorded; therefore this data was not included in total amount of calories a patient received. It is possible that some patients, particularly those with less severe neurologic injuries, improved clinically in the first week and were able to accept oral nutrition. In addition, subjects were stratified based upon ICU-admission GCS, a value that may change during the first 24 h from time of ICU admission and even hourly based upon the patient's neurologic status. The ICU-admission GCS may not be applicable to a wide spectrum of neurologic injury. For example, a patient with an epidural hematoma may have a poor ICU-admission GCS, but after evacuation may rapidly improve. Conversely, aneurysmal SAH patient may have a progressive neurologic decline from their initial event as cerebral vasospasm occurs. However, the ICU-admission GCS was used only for initial stratification of patients and the multivariate analysis used the minimum daily GCS as a variable, which should take into account the variations in disease progression or improvement.

Despite the limitations, this study provides information for clinicians regarding factors that affect the provision of nutrition support for the neurocritically ill patient. To overcome these impeding factors, protocols should be established to improve patient care and establish new standards of care (Table 2 and Fig. 3) [7, 16]. For example, unless clinically contraindicated, all ICU patients with a CGS of <11 should have automatic orders for post-pyloric enteral access, radiology confirmation, and an EN formula to be initiated at a standard goal rate until the patient can be assessed for their specific requirements. Self-advancing small bore feeding tubes may have a role in facilitating duodenal or jejunal nutrition soon after admission. Initial nurse or protocol-driven incremental increases in EN rate should be avoided in most patients, as neurologically injured patients may tolerate goal or near-goal rates of nutrition infusion from the beginning of their ICU stay. If intolerance occurs, the EN rate should be lowered to a rate more likely to be tolerated and then systematically increased back to goal. Bowel regimens and routine assessment of the need for prokinetic agents could be initiated upon admission or nutrition initiation to mitigate distention, gastroparesis, and constipation associated with acute illness and the anesthesia/analgesic agents commonly received by the neurocritically ill patient.

Conclusion

The severity of neurologic illness as measured by ICU-admission GCS did not appear to have an impact on the administration of EN. However, system-based clinical care factors appeared to be a major contributing factor to the successful provision of EN in the first week of neurocritical

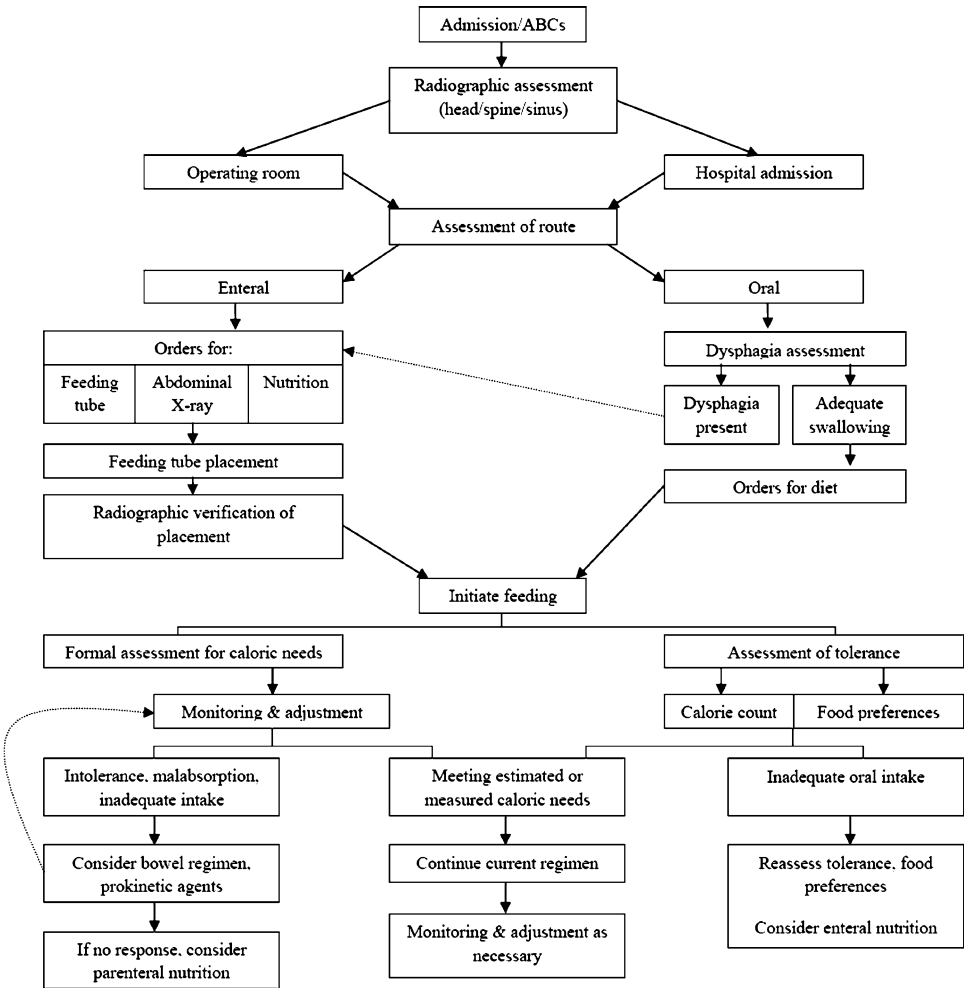

Fig. 3 Sample admission nutrition protocol

illness. These clinical care issues can be improved upon in the future through education and standardization of care. Implementing institutional nutrition protocols for all neurosurgical patients upon admission to the hospital could potentially be the foundation to achieving early nutrition support goals and overcoming barriers that may limit EN provision and, potentially, neurologic and infectious complications.

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