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Enteral Nutrition for TBI Patients in the Rehabilitation Setting: Associations with Patient Pre-injury and Injury Characteristics and Outcomes

Susan D. Horn, PhD, Merin Kinikini, RD, FNP, DNP CNSC, Linda W. Moore, MS, RDN, CCRP, Flora M. Hammond, MD, Murray E. Brandstater, MD, Randall J. Smout, MS, and Ryan S. Barrett, BS

Institute for Clinical Outcomes Research, International Severity Information Systems, Inc, Salt Lake City, UT (Horn, Smout, Barrett). Neuro Specialty Rehabilitation Unit, Intermountain Medical Center, Salt Lake City, UT (Kinikini). Houston Methodist Hospital, Houston, TX (Moore). Carolinas Rehabilitation, Charlotte, NC and Indiana University, Indianapolis, IN (Hammond). Loma Linda University Medical Center, Loma Linda, CA (Brandstater)

Abstract

Objective—To determine the association of enteral nutrition (EN) with patient pre-injury and injury characteristics and outcomes for patients receiving inpatient brain injury rehabilitation.

Design—Prospective observational study using propensity scores to isolate the effect of EN

Setting—9 rehabilitation centers in the US

Participants—Patients (n=1701) admitted for first full inpatient rehabilitation after a TBI index injury

Interventions—Not applicable

Main Outcome Measures—Functional Independence Measure (FIM) at rehabilitation discharge, length of stay (LOS), weight loss, and presence of infections.

Results—There were many significant differences in pre-injury and injury characteristics for patients who received EN compared to patients who did not. After matching patients with a propensity score >40% for the likely use of EN, patients with greater than 25% of their rehabilitation stay receiving EN with either standard or high protein formulas (greater than 20% of calories coming from protein) had better FIM Motor and FIM Cognitive scores at rehabilitation discharge and less weight loss than similar patients not receiving EN.

Corresponding author: Susan D. Horn, PhD, University of Utah School of Medicine, Department of Population Health Sciences, Health System Innovation and Research Program, Williams Building, Rm. 1N461, 295 Chipeta Way, Salt Lake City, Utah 84108. susan.horn@hsc.utah.edu cell 801-718-9149.

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Conclusions—For patients receiving inpatient rehabilitation following TBI and matched on a propensity to use EN of >40%, clinicians should strongly consider, when possible, EN for at least 25% of the patient's stay and especially with a formula that contains at least 20% protein rather than a standard formula.

Keywords

brain injuries; traumatic; comparative effectiveness research; rehabilitation; enteral nutrition; propensity score

The provision of adequate nutrition support for patients with moderate to severe TBI has been a clinical challenge for decades.^{1–3} Patients' primary and secondary injuries create unique metabolic derangements that pose issues such as optimal timing and route of nutrition, appropriate fluid and electrolyte balance, drug administration, and dysphagia. Additionally, it may be difficult to maintain tubes and lines in a confused or agitated patient, particularly in a rehabilitation setting.

Individuals with traumatic brain injury (TBI) have a much higher resting metabolic expenditure (RME) acutely than patients without TBI.⁴ In fact, with severe TBI, RME has been found to range up to 240% of RME of patients without TBI; they are similar in metabolic response to patients with burns over 20% to 40% of their body surface.⁴ The consequences of hypermetabolism, hypercatabolism, and altered immune function in patients with acute TBI result in excessive protein breakdown and can lead to malnutrition.⁵ However, patients with TBI requiring hospitalization often do not, or cannot, consume enough nutrition to support their increased requirements for recovery and rehabilitation.⁵

Enteral nutrition (EN) administered as early as possible has been established as the preferential route of nutrition support for this population versus total parenteral nutrition (TPN); some centers utilize a combination of EN and TPN in the early stages of injury if the patient does not tolerate adequate amounts of EN alone.⁶ Courdakakis et al recently reported that early EN may impact hormonal response to TBI and suggests this may reduce catabolic and inflammatory processes induced by TBI.⁷ There appears to be a consensus on early initiation of EN, but less definitive are recommendations on advancement timing and formula components (e.g., whether to use specialty formulas such as those containing immune-enhancing properties).^{8–12} The Institute of Medicine recommended inclusion of nutrient additives (e.g., n-3 fatty acids, creatine, choline, and zinc) as potentially beneficial for recovery following TBI.³ Patients with TBI, similar to other trauma patients, likely require 2.0 to 2.5 gm of protein/kg at a minimum, especially during the early period following injury.^{6,13} Evaluation of the duration of a higher protein requirement has not been reported in the literature, but it likely correlates with metabolic status. If increased metabolic rates extend into the rehabilitation setting, increased protein needs may also be present.

Swallowing disorders and decreased behavioral/cognitive skills frequently are present in patients with severe brain injury and significantly affect oral intake.¹⁴ Persons who swallow abnormally take much longer to start eating and to achieve total oral feeding, and they require non-oral supplementation three to four times longer than those who swallow normally.¹⁴ Patients with severe TBI may also have intolerance to EN, which hampers

survival and rehabilitation.¹⁵ Haddad and Arabi discuss proactive use of prokinetic agents, such as erythromycin and metoclopramide, as well as post-pyloric feeding as ways to overcome problems of gastric distention and intolerance experienced by patients with TBI.^{16,17}

Most reports regarding nutrition in patients with TBI address the route (TPN vs EN) and/or timing (early versus late) of initiation of nutrition support related to hospital admission and have addressed outcomes such as mortality or length of stay in the acute care setting.^{11,13,18} We could not find any published reports that address the role of nutrition support during rehabilitation of patients with TBI. A practice-based evidence (PBE) study in stroke rehabilitation found that use of EN support for greater than 25% of the stroke rehabilitation stay was a significant factor in predicting better discharge total and motor FIM scores, controlling for patient and other treatment differences.^{19,20} It is not known if these findings are applicable to the TBI rehabilitation population. This paper describes nutritional support methods used for patients in a TBI Practice-Based Evidence (PBE) study during rehabilitation,²¹ and examines associations of patient pre-injury and injury characteristics with use and duration of EN support, as well as association of EN with outcomes, controlling for patient differences.

METHODS

This comparative effectiveness PBE study examined the differential effects of a wide array of specific treatments administered in 10 acute inpatient rehabilitation facilities serving patients with TBI in a brain injury specialty unit enrolled from October 2008 to September 2011. The 10 participating centers constituted a convenience sample of TBI adult inpatient rehabilitation centers based on their willingness to conduct the research. The Institutional Review Board at each center approved the study; each patient or his/her proxy gave informed consent.

Participants

Inclusion criteria were as follows:²¹

1. Sustained a TBI, defined as damage to brain tissue caused by external force and evidenced by loss of consciousness, post-traumatic amnesia, skull fracture, or objective neurological findings; Diagnoses included International Classification of Diseases (ICD-9-CM) codes consistent with the CDC Guidelines for Surveillance of Central Nervous System Injury
2. Received inpatient care on a designated brain injury rehabilitation unit of one of the participating rehabilitation facilities
3. Patients were 14 years old and older and treated in an adult rehabilitation unit.

Patient Variables—Patient characteristics, including demographics and injury characteristics, were recorded based on clinician suggestions as well as previous research indicating their importance in TBI populations. Besides patient data available on admission, we collected information on patients' status during the course of their rehabilitation stay

including the presence of aphasia and dysphagia. See table 1 for a list of characteristics of study patients.

Functional Dependence—We used admission Functional Independence Measure (FIM), an assessment of independent functioning consisting of 18 items in two domains: Motor (13 items) and Cognitive (5 items). Each FIM item was rated on a 7-category scale, ranging from 1: total assistance required, to 7: complete independence. To eliminate distortion in quantifying the status of patients whose capability is at the extremes of the instrument's range, motor and cognitive FIM subscores were re-coded separately using tables published by Heinemann et al. that were based on Rasch analysis of FIM data of a large brain injury sample.²²

Injury Severity and Comorbidity—The primary medical severity measure used was the Comprehensive Severity Index (CSI[®]), which defines severity as the physiologic and psychosocial complexity presented due to the extent and interactions of a patient's disease(s).²¹ CSI is age- and disease-specific, and is independent of treatments. It provides an objective, consistent method to operationalize patient severity of illness based on over 2,100 individual signs, symptoms, and physical findings and over 5,600 disease-specific criteria sets related to all of a patient's disease(s). More details about CSI appear elsewhere.²¹ The CSI modification used here allowed separating severity of brain injury (called BICSI) from severity of illness of all other injuries, complications, and comorbidities called non-brain injury CSI (non-BICSI). BICSI allowed detection of differences in amount of brain damage among patients that might otherwise be hidden in an overall injury severity score.

Treatment Factors—We collected treatment variables related to EN from chart review. These included formula type and start and stop dates. EN was classified as either high-protein or standard. High-protein formulas were defined by having at least 20% of calories coming from protein (most of these formulas actually had 25%), or patient receiving a standard protein formula (usually 14–18% protein) with supplemental protein provided to increase the total amount to greater than 20%. Based on the finding of better outcomes for EN support for >25% of the rehabilitation stay for patients with severe stroke,¹⁹ we explored the same level of EN support in this study of patients with TBI.

Outcome Variables—Outcomes examined to assess the association with EN were discharge FIM Motor and Cognitive scores, weight loss during rehabilitation, length of stay (LOS), and various types of infections (aspiration pneumonia, pneumonia, urinary tract infections, and sepsis) defined by ICD-9-CM codes in the rehabilitation medical record.

Data Analyses

Analyses were performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC). When data were missing, one or more adjustments were made depending on the variable and its intended use in analyses. Sometimes we categorized values simply as “unknown” (and included an “unknown” category in analysis as a dummy variable representing missingness); at other times we deleted patients with missing data from analyses.

Since our sample had patients with a wide range of functional and cognitive disabilities and also had many patients who did not require EN, we needed to find a method to examine the effect of EN that was not biased by only the sickest patients or the most severely injured receiving EN. Our first step was to determine a subset of patients whom we predicted would benefit from EN, but may or may not have actually received it. To find this subset, we used the patient pre-injury and injury characteristics data to develop a propensity score based on a logistic regression model to predict receipt of EN.²³ We then matched patients with the same propensity score, where one received EN and the other did not, and compared outcomes.

Descriptive statistics were used to provide frequencies and percentages for categorical variables describing patients, treatments, and outcomes, and means, medians, quartiles, and SDs to summarize continuous measures. Bivariate analyses were conducted to examine how patients who received EN differed from those who did not. For discrete variables, we used the chi-square test or McNemar's test to determine significance of associations. For continuous variables we used t-tests, paired-t tests, analysis of variance (ANOVA), or Friedman's Rank Sum test. A two-sided p value <0.05 was considered statistically significant. Finally, we used ordinary least squares regression to determine associations of EN with continuous outcome variables, after controlling for other patient and injury characteristics. For independent variables with pairwise correlations $r > 0.75$, only one of the pair was allowed to enter the model.

In order to help clinicians more easily decide which patients might benefit from EN, we also used Recursive PARTitioning (RPART) to build a classification model using a two-stage procedure. First the single variable that best splits the data into two groups is found; the data are separated at this point, and then the process is repeated individually on the resultant subgroups until they either reach a minimum sample size (depending on the sample size of the data), or no improvement can be made in explaining an outcome.

The original study sample was 2,130 patients with TBI.²¹ We excluded patients who had TPN at any time during their rehabilitation stay (n=127) since we did not collect details about TPN start and stop times; hence, we could not determine for how long they received TPN or any details about the content of the TPN. We also excluded patients who had EN documented but no formula type was recorded or they only had fiber in their EN, which was not considered EN (n=15). Next, patients on EN at the time of rehabilitation discharge and having admission total CSI severity score >60 (indicating serious morbidity) were excluded (n=107). In addition, we excluded patients with rehabilitation length of stay >75 days (top 2%; n=31). The rationale for deleting these patients was that if they were discharged on EN and also were severely injured or stayed a long time in rehabilitation, it was unlikely that EN would have a significant impact on their outcomes. Patients with similar characteristics were deleted from the study of EN in the post-stroke rehabilitation study.¹⁹ The 107 patients discharged on EN were significantly different (sicker) than the patients with EN during rehab (n=451) in the following ways: (1) older age (43.4 vs 38.2 yrs, $P=.025$), (2) longer time from injury to rehabilitation admission (55.2 days vs 32.4 days, $P<=.001$), (3) higher max BICSI (78.6 vs 66.5, $P<.001$), (4) greater percent craniectomy (18.8% vs 9.9% $P=.015$), (5) lower admission Rasch-adjusted FIM Motor (11.9 vs 19.5, $P<.001$), and (6) lower

admission Rasch-adjusted FIM Cognitive (18.4 versus 25.6, $P=.0002$). Finally, we deleted patients from one site due to their practice of not using EN to treat their patients ($n=149$).

RESULTS

The final study sample was 1,701 patients (480 females and 1,221 males). Of these patients, 451 received EN for more than 1 day and 1,250 received either no EN or EN for only 1 day. Clinicians decided that 1 day of EN was too small to have any effect on outcomes and assigned these latter patients to the “no EN” category.

As shown in table 1, patients with TBI who received EN were more likely to be White and less likely to be Black, were more likely to be underweight or normal weight, have health maintenance organization (HMO) or no-fault auto insurance, were driving prior to injury, were paralyzed, received their TBI in a motor vehicle accident, had a facial or skull fracture, had a subarachnoid hemorrhage, intraventricular hemorrhage, craniectomy, post-traumatic amnesia during rehabilitation, and longer time from injury to rehabilitation admission. Patients receiving EN also had lower average admission Rasch-adjusted FIM Motor and Cognitive scores, and higher admission brain injury and non-brain injury CSI scores. Of the 451 EN patients, more than 90% had moderate to severe dysphagia and 50% had aphasia.

The propensity score determined the combination of patient and injury characteristics that were significantly associated with receiving EN. Significant variables are included in table 2. The strongest predictors of receiving EN included higher admission brain injury CSI score, lower admission Rasch-adjusted FIM Motor subscore, and having moderate to severe dysphagia ($c=0.903$). In table 2 we also present a second propensity score model that can be used if one does not have admission brain injury CSI score, admission non-brain injury CSI score, or Rasch-adjusted FIM Motor score. The second model is almost as good as the first model that we used for our subsequent analyses, and can be used to predict a patient's probability of receiving EN when CSI and Rasch-adjusted FIM measures are not available. If instead, a Recursive PARTitioning analysis was used to estimate a patient's probability of receiving EN, our data found that a close approximation for a propensity score for EN $>40\%$ is an admission motor FIM score of 20 or less, moderate to severe dysphagia, and greater than 8 days from injury to rehabilitation admission.

For each of the 1,701 patients, we computed a propensity score to receive EN. We decided to use a propensity score probability of receiving EN of $>40\%$ to indicate a need for EN. Among the 451 patients with EN, there were 335 (74.3%) with a propensity score greater than 40%; among the 1,250 patients without EN, there were only 145 (11.6%) with a propensity score greater than 40%. The average propensity score for the 335 patients with EN was 73.2%, while the average propensity score for the 145 patients without EN was only 60.5% ($P<0.001$). Hence, we needed to create a matched and balanced sample before examining the association of EN with outcomes; we selected one EN patient for each of the 145 non-EN patients, matching on propensity scores.

This resulted in average propensity scores for the 145 EN patients and 145 no-EN patients of 61% and 60.5%, respectively.

In table 3 we show how the 145 patients with EN and the 145 without EN compared on pre-injury and injury characteristics. None of the characteristics were significantly different between the two groups whether using paired or unpaired tests. Enteral nutrition duration ranged from 2 to 64 days (6% to 100% of the rehabilitation stay) with a mean of 16.6 days (SD 12.6) and a median of 13 days. The mean percentage of the stay with EN was 52.4% (SD 26.9%) with a median of 50.0%. Of the 145 EN patients, 80 (55.0%) had an order for nothing-by-mouth during the EN episodes that ranged from 2 to 33 days (5.6% to 100.0% of the rehabilitation stay) with a mean of 5.1 days (SD 7.4) and a median of 2 days. The percentage of the stay with nothing-by-mouth had a mean of 18.7% (SD 24.0%) with a median of 8.3%.

Table 4 shows bivariate associations of each outcome with receipt of EN. Patients receiving EN had borderline significantly better discharge Rasch-adjusted FIM Motor and Cognitive scores ($P=0.055$ and 0.050 , respectively), borderline longer LOS ($P=0.062$), and less weight change ($P=0.075$), but no significant differences in urinary tract infections, sepsis, pneumonia, or aspiration pneumonia. None of these bivariate analyses took into account how long the patient received EN or the type of formula used in the EN. Hence, we conducted multiple regression analyses to account for duration and type of EN and additional potentially confounding variables on outcomes.

In table 5 we present results of ordinary least squares regression analyses to predict discharge FIM Motor and Cognitive scores, weight change during rehabilitation, and LOS. We found that EN for more than 25% of the rehabilitation stay with either standard, or especially with a high-protein formula, was associated with significantly better discharge FIM subscale scores. The range of days receiving EN for the patients in the propensity score matched sample with EN for >25% of their stay was 3 to 64 days with a median of 15 and a mean of 19 days. This is the level of EN support that was associated with better outcomes. This was not related to the site where the patient was treated, since no site variables entered the models significantly after patient and treatment variables entered. Also, EN with a high-protein formula for >25% of the stay was associated with an almost two-pound weight gain from admission to discharge, compared with an almost two-pound weight loss for patients with no EN. However, EN for >25% of the stay with either formula was not significant in predicting LOS or infections.

DISCUSSION

This study of the potential benefit of EN for patients with TBI requiring inpatient rehabilitation found that EN for 25% or more of the rehabilitation stay with either high protein or standard formula was associated with better FIM Motor and Cognitive scores at discharge. Patients who received a higher protein formula had less weight loss and higher discharge FIM Motor subscale scores than those who received a standard formula.

There are a number of possible explanations for these results. Other studies have found that patients with TBI can have an increased metabolic resting rate following their injury.^{1,24} An imaging study focusing on biopathology of TBI reported a brief period of hypermetabolic activity in the brain immediately after a TBI, followed by several days of glucose metabolic

depression.²⁵ The period of metabolic depression typically lasts only a few days, but it may be that patients with TBI require a huge metabolic expenditure both locally in the brain and more systemically. This increased metabolic need may persist for some time after the injury and could be positively affected by nutritional interventions such as EN. This could help to explain why our study found greater improvement associated with EN in FIM Cognitive scores at discharge than in FIM Motor scores, and especially so with high-protein formula.

A challenge in studying the association of EN with outcomes following TBI rehabilitation is that patients who may receive EN are generally at the more severe end of the spectrum due to altered awareness and arousal or severe dysphagia. Hence, when one includes an indicator variable for receipt of EN in analyses, and does not have a sample with EN patients spread throughout the sample (a balanced sample), one finds that EN is associated with poorer outcomes. These poorer outcomes are not due to the EN, but to the fact that it is only more severely impaired patients who receive EN. Therefore, one needs to examine EN and its association with outcomes in a sample of TBI patients where EN patients are balanced and spread more evenly throughout the sample. There are various ways of accomplishing this in observational studies. We used patient and injury characteristics to develop a propensity score for EN and then matched patients with similar propensity scores, wherein one patient received EN and the other did not. For our original sample of 1701 patients, we were able to find only 145 no-EN patients who had a propensity score for EN >40%, which was the probability that the project team felt indicated a minimal need for EN. This may be an indication that in our study centers, patients who needed EN usually received it. There were only 145 patients with this indication of needing EN who did not receive it, and it is with this sample and a matched sample with EN that we were able to assess the potential associations of EN with outcomes for patients with TBI requiring inpatient rehabilitation. A close approximation, in our data, for a propensity score for EN >40% is an admission motor FIM score of 20 or less, moderate to severe dysphagia, and greater than 8 days from injury to rehabilitation admission.

The role that EN, and particularly protein, plays in rehabilitation settings for patients with TBI is rarely mentioned in the literature. In a recent observational study of patients with TBI treated at rehabilitation centers in Italy, the incidence of dysphagia on admission to the rehabilitation center was 42.3%, decreasing to 13.7% on discharge.²⁶ Only 45.8% of patients admitted to rehabilitation with TBI were on oral feeding, which improved to 84.2% by discharge, but no information on nutritional support during rehabilitation was provided.²⁶ Similarly, a multicenter report on rehabilitation of patients with complicated mild TBI provided insight into the role of admission FIM and Disability Rating Scale scores on LOS, but nutritional status or support required or utilized by these patients during rehabilitation was not mentioned.²⁷ The current study indicates that EN, and particularly protein, in the rehabilitation setting may play a significant role in recovery of patients with TBI: receiving EN at least 25% of the rehabilitation stay was associated with higher discharge FIM subscores for both motor skills and cognitive function.

Supporting the hypothesis that protein needs continue to be high in patients with TBI during rehabilitation, the current study demonstrated the strongest association with outcomes was of high-protein EN. Although this study did not assess nitrogen balance, clinical outcomes

of improved discharge FIM subscale scores for both motor and cognitive function, as well as less weight loss were greatest in patients receiving high protein EN. These findings suggest that protein catabolic rate may continue to be elevated during TBI rehabilitation. Therefore, research assessing protein requirements in the rehabilitation setting or extended recovery period and not just the acute phase of recovery is greatly needed. For example, a randomized trial of a dose-ranging study of EN protein levels comparing standard protein (15% of calories) to high protein (20% of calories), high-protein plus essential amino acids, low protein plus essential amino acids, and possible combinations with fish oil and other immune-modulating components within the formula would help to clarify whether higher protein would be beneficial in this population. Other aspects to study include: metabolic needs during phases of TBI, best management practices for meeting nutritional intake goals, and a more detailed look at daily caloric and protein intake among those with diets and/or EN. Clinical studies should follow.

As this study points to the possible benefits of EN, it is also important to note the potential risks of achieving EN in a TBI population. Enteral nutrition is invasive and generally not desired by patients. Additionally, the agitation and confusion that often characterizes the behavior of the individual with TBI receiving inpatient rehabilitation may make it difficult or prevent EN. Restraints or a 1:1 sitter observation may be required to maintain tubes. Patient removal of a gastrostomy tube may place the patient at risk for serious infection. Duodenal tubes introduced nasally require an abdominal radiographic examination to confirm placement. When a patient pulls the tube out or it is removed accidentally, rehabilitation therapies may be interrupted to allow time for the radiograph. Use of a nasal bridle system may be appropriate at times after TBI. The nasal bridle system has been used in burn patients with some success requiring fewer tube insertions and without sinusitis or aspiration pneumonia.²⁸ The use of restraints and just the presence of a tube (gastric or nasal) itself may make patients more agitated, potentially prompting the use additional medications (with risk of medication side effects), and carry important risks that may not outweigh the benefit of EN.

Pneumonia and aspiration pneumonia are often cited as complications of EN.^{29,30} However, the current study suggests attenuated risks. For example, our study found no differences in rates of aspiration pneumonia or pneumonia between EN patients and similar patients without EN. This finding is in contrast to prior findings in acute care settings.^{7,11,29,30} Additionally, our study found improved outcomes when EN was provided for at least 25% of the stay compared to patients with very similar characteristics who did not get EN, strongly suggesting a benefit that could be described to patients, staff, and family to support an EN decision.

Study Limitations

Some information that is relevant to this research was not available for our patient sample including: nutritional supplementation during acute care hospitalization, reason(s) for administration of EN, and total caloric intake during inpatient rehabilitation. Acute care records were not fully available, and thus, we do not know if EN was used there, how many days following injury it was started, what EN formula was used, and duration of EN prior to

rehabilitation admission. We also did not have accurate calorie counts of oral intake to determine the total calories and protein a patient received during either the acute care or rehabilitation hospital stay.

CONCLUSIONS

For patients in rehabilitation with moderate to severe TBI and having a likelihood of using EN based on a propensity score >40%, providers should strongly consider delivering EN for at least 25% of the patient's stay. These findings also suggest a role for higher protein EN formula in the rehabilitation setting.

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Abbreviations

BICSI	Brain injury component of CSI score
CSI	Comprehensive Severity Index score
EN	Enteral nutrition
FIM	Functional Independence Measure
PBE	Practice-Based Evidence
PTA	Post traumatic amnesia
non-BICSI	Non-brain injury component of CSI score
RME	Resting metabolic expenditure
TBI	Traumatic brain injury
TPN	Total parenteral nutrition

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Table 1

Characteristics of patients with and without enteral nutrition

Characteristics	Enteral nutrition (n=451)	No enteral nutrition (n=1250)	P
Demographics			
Male (%)	72.3	71.6	0.807 [*]
Age at rehabilitation admission (mean, SD)	38.5 (19.6)	47.1 (22.0)	<.001 [†]
Race/Ethnicity (%)			0.012 [‡]
Black	12.0	17.0	
White	80.0	72.7	
White Hispanic	4.9	7.4	
Other and unknown	3.1	2.9	
Highest education achieved (%)			0.268 [‡]
Some high school, no diploma	24.2	22.6	
High school diploma	24.2	26.6	
Work towards or completed Associate's degree	18.0	15.6	
Work towards or completed Bachelor's degree	20.8	19.5	
Work towards or completed Master's/Doctoral degree	9.5	9.8	
Unknown	3.3	5.8	
Marital status at injury (%)			0.114 [‡]
Single/never married	47.0	41.2	
Married/common law	34.6	35.8	
Previously married	15.7	19.8	
Other/unknown	2.7	3.1	
Able to drive before injury (%)			<.001 [‡]
No	5.5	12.6	
Yes	81.4	68.8	
Unknown	13.1	18.6	
Primary payer (%)			<.001 [‡]
Medicare	11.5	25.8	
Medicaid	12.2	17.0	
Private insurance	26.8	25.3	
Worker's compensation	9.1	6.8	
Self pay/None	6.9	4.6	
MCO/HMO	19.5	14.0	
No-fault auto insurance	8.9	3.4	
Other/unknown	5.1	3.1	
Admission body mass index (%)			<.001 [‡]
<16	1.3	1.4	
16–<=18.5	12.4	6.3	
>18.5–<=25	54.3	47.0	

Characteristics	Enteral nutrition (n=451)	No enteral nutrition (n=1250)	P
>25–<=30	20.4	26.2	
>30–<=35	6.4	9.0	
>35–<=40	1.6	2.9	
>40	1.3	1.7	
Unknown	2.2	5.5	
Pre-existing and co-existing conditions			
History of alcohol abuse before injury (%)	34.8	36.9	0.458*
History of drug abuse before injury (%)	20.0	22.8	0.233*
Anxiety before or during rehabilitation (%)	22.0	21.1	0.736*
Depression before or during rehabilitation (%)	32.2	30.4	0.513*
Hypertension before or during rehabilitation (%)	39.7	45.0	0.053*
Paralysis before or during rehabilitation (%)	53.9	30.3	<.001*
Renal failure before or during rehabilitation (%)	8.6	8.9	0.923*
Brain injury and severity information			
Cause of injury (%)			<.001 [‡]
Fall	21.3	36.8	
Motor vehicle crash	69.6	50.0	
Sports	1.6	2.0	
Violence	5.1	7.3	
Other	2.4	3.9	
GCS score immediately after injury or upon arrival in acute care (%)			<.001 [‡]
Mild (13–15)	8.4	18.2	
Moderate (9–12)	5.8	8.2	
Severe (3–8)	44.6	23.8	
Intubated/sedated	14.9	11.0	
Unknown	26.4	38.8	
Nature of brain injury (%)			0.277 [‡]
Skull closed, contusion/hemorrhage present	67.6	70.4	
Skull closed, no contusion/hemorrhage	23.9	23.3	
Skull open, contusion/hemorrhage present	8.4	6.3	
Facial fracture (%)	18.2	12.5	0.003*
Skull fracture (%)	31.3	24.6	0.006*
Brain injury location (%)			0.300 [‡]
Bilateral	65.9	61.8	
Left	17.3	19.0	
Right	16.9	19.2	
Midline shift (%)			<.001 [‡]
>0–5 mm	9.8	13.6	
>5 mm	13.1	11.2	

Characteristics	Enteral nutrition (n=451)	No enteral nutrition (n=1250)	P
Midline shift, mm not specified	11.8	10.2	
No midline shift	22.6	34.3	
Unknown	42.8	30.6	
Subdural hematoma (%)	43.0	47.5	0.110 [*]
Epidural hematoma (%)	10.0	7.4	0.086 [*]
Subarachnoid hemorrhage (%)	66.3	53.2	<.001 [*]
Intraventricular hemorrhage (%)	24.6	14.0	<.001 [*]
Brain stem involved (%)	6.9	4.7	0.086 [*]
Craniotomy during care episode (%)	10.2	4.9	<.001 [*]
Craniectomy during care episode (%)	20.0	18.9	0.626 [*]
Weight bearing precaution during rehabilitation (%)	27.9	26.9	0.666 [*]
Days from injury to rehabilitation admission (mean, SD)	31.9 (24.5)	19.8 (24.4)	<.001 [†]
PTA clearance before rehabilitation admission (%)	17.3	47.8	<.001 [*]
Admission brain injury component of CSI score (mean, SD)	61.8 (20.1)	36 (17.8)	<.001 [‡]
Admission non-brain injury component of CSI score (mean, SD)	22.6 (16.1)	15.2 (13.1)	<.001 [‡]
Moderate to severe dysphagia on admission (%)	90.2	35.2	<.001 [*]
Moderate to severe aphasia on admission (%)	49.9	43.7	0.024 [*]
Functional status and length of stay			
Admission FIM motor score - raw (mean, SD)	21.5 (11.3)	38.6 (16.4)	<.001 [‡]
Admission FIM motor score - Rasch transformed (mean, SD)	19.6 (16.2)	38.4 (13.5)	<.001 [‡]
Admission FIM cognitive score - raw (mean, SD)	10.5 (5.4)	16.7 (6.6)	<.001 [‡]
Admission FIM cognitive score - Rasch transformed (mean, SD)	25.8 (18.1)	43.2 (16.1)	<.001 [‡]
Length of rehabilitation stay	32.2 (15.0)	18.3 (10.0)	<.001 [‡]

NOTE: Abbreviations: MCO/HMO, Managed care organization/Health maintenance organization; GCS, Glasgow Coma Scale; CSI, Comprehensive Severity Index; FIM, Functional Independence Measure;

^{*} Fisher's exact test.

[†] Two sample t test.

[‡] Chi-Square analysis.

Table 2

Propensity Score Model to predict patient's need for enteral nutrition

	Model One					Model Two				
	Parameter Estimate	Odds Ratio Estimate	Wald Chi-Square	P Value	Parameter Estimate	Odds Ratio Estimate	Wald Chi-Square	P Value		
Intercept	-1.74	NA	11.27	0.001	-0.36	NA	0.60	0.437		
Admission brain injury component of CSI score	0.03	1.03	44.31	<.001	NA	NA	NA	NA		
Admission non-brain injury component of CSI score	0.01	1.01	4.71	0.030	NA	NA	NA	NA		
Admission FIM motor score - Rasch transformed	-0.04	0.96	60.62	<.001	NA	NA	NA	NA		
Admission FIM cognitive score - raw	NA	NA	NA	NA	-0.13	0.88	87.79	<.001		
Moderate to severe aphasia on admission	-0.66	0.52	15.67	<.001	-0.46	0.63	8.83	0.003		
Moderate to severe dysphagia on admission	1.89	6.65	91.26	<.001	2.36	10.60	157.33	<.001		
Age on admission	-0.02	0.98	18.85	<.001	-0.02	0.98	25.18	<.001		
History of alcohol abuse before injury	0.33	1.39	4.37	0.037	NA	NA	NA	NA		
Skull fracture	0.48	1.62	7.86	0.005	NA	NA	NA	NA		
Days from injury to rehabilitation admission	0.01	1.01	8.24	0.004	0.01	1.01	20.83	<.001		
Cause of injury: Miscellaneous	-0.97	0.38	4.57	0.033	-1.02	0.36	6.02	0.014		
Marital status: Single	-0.47	0.63	5.17	0.023	-0.50	0.61	6.51	0.011		
Primary Payer: Medicaid	-0.72	0.49	10.54	0.001	-0.64	0.53	9.46	0.002		
Primary Payer: No fault auto	0.69	1.99	5.34	0.021	0.72	2.06	6.08	0.014		
Paralysis on admission	NA	NA	NA	NA	0.57	1.76	15.00	0.000		
Able to drive prior to injury	NA	NA	NA	NA	0.41	1.51	5.13	0.024		
Highest education achieved: high school diploma	NA	NA	NA	NA	-0.37	0.69	5.27	0.022		
Race: White	NA	NA	NA	NA	0.35	1.43	4.12	0.042		
# Observations Used c		1698: Yes=449, No=1249				1698: Yes=449, No=1249				
Statistic		0.903				0.883				

Table 3

Characteristics of propensity score matched patients with and without enteral nutrition

Characteristics	Enteral nutrition (n=145)	No enteral nutrition (n=145)	P
Demographics			
Male (%)	76.6	80.7	0.474*
Age at rehabilitation admission (mean, SD)	38.5 (18.2)	39.5 (19.4)	0.646 [†]
Race/Ethnicity (%)			0.111 [‡]
Black	13.1	14.5	
White	83.4	75.9	
White Hispanic	2.1	8.3	
Other and unknown	1.4	1.4	
Admission body mass index (mean, SD)	23.0 (4.5)	23.3 (4.7)	0.507 [†]
Admission body mass index (%)			0.921 [‡]
<16	2.1	2.8	
16–<=18.5	12.4	9.0	
>18.5–<=25	56.6	55.2	
>25–<=30	18.6	21.4	
>30–<=35	8.3	8.3	
>35–<=40	0.7	1.4	
>40	0.0	0.7	
Unknown	1.4	1.4	
Brain injury cause and severity			
Cause of injury (%)			0.658 [‡]
Fall	24.8	26.2	
Motor vehicle crash	64.1	66.9	
Sports	1.4	1.4	
Violence	5.5	4.1	
Other	4.1	1.4	
Days from injury to rehabilitation admission (mean, SD)	31.1 (18.0)	31.5 (34.9)	0.896 [†]
PTA clearance before rehabilitation admission (%)	15.2	13.8	0.868*
Admission brain injury component of CSI score (mean, SD)	61.3 (13.5)	59.5 (12.8)	0.246 [†]
Maximum brain injury component of CSI score (mean, SD)	64.4 (13.6)	63.1 (13.1)	0.405 [†]
Admission non-brain injury component of CSI score (mean, SD)	22.5 (16.6)	21.6 (14.5)	0.635 [†]
Maximum non-brain injury component of CSI score (mean, SD)	32.7 (22.8)	30.5 (18.8)	0.369 [†]
Moderate to severe dysphagia on admission (%)	95.2	95.9	1.000*
Functional independence measures			
Admission FIM motor score - raw (mean, SD)	20.9 (9.1)	21.0 (10.3)	0.900 [†]
Admission FIM motor score - Rasch transformed (mean, SD)	21.0 (14.3)	20.6 (14.7)	0.824 [†]
Admission FIM cognitive score - raw (mean, SD)	9.9 (4.4)	10.6 (4.6)	0.192 [†]

Characteristics	Enteral nutrition (n=145)	No enteral nutrition (n=145)	P
Admission FIM cognitive score - Rasch transformed (mean, SD)	25.3 (15.8)	27.5 (15.9)	0.232 [†]
Nutritional information			
Admission Braden total score (mean, SD)	14.8 (2.4)	14.9 (2.5)	0.751 [†]
Discharge Braden total score (mean, SD)	18.7 (2.3)	18.4 (2.5)	0.470 [†]
Lowest Braden nutrition (%)			0.721 [‡]
Very poor	2.1	4.8	
Probably inadequate	28.3	28.3	
Adequate	26.2	25.5	
Excellent	0.7	1.4	
Unknown	42.8	40.0	
Lowest serum albumin during rehabilitation (mean, SD)	3.2 (0.6)	3.2 (0.6)	0.968 [†]
Lowest serum albumin category (%)			0.646 [‡]
Very Low 1.0–3.0 g/dL	37.2	36.6	
Low >3.0–3.49 g/dL	21.4	20.0	
Normal ≥3.5 g/dL	31.7	29.0	
Missing	9.7	14.5	
Lowest serum transthyretin during rehabilitation (mean, SD)	25.2 (6.4)	24.4 (7.6)	0.535 [†]

Characteristics	Enteral nutrition (n=145)	No enteral nutrition (n=145)	P
Lowest serum transthyretin category (%)			0.386 [‡]
Elevated >29.6 mg/dL	10.3	8.3	
Normal >15.5–29.6 mg/dL	32.4	24.8	
Mild malnutrition 10–15.5 mg/dL	2.8	4.1	
Missing	54.5	62.8	

NOTE: Abbreviations: CSI, Comprehensive Severity Index; g/dL, grams per deciliter; mg/dL, miligrams per deciliter; FIM, Functional Independence Measure;

* Fisher's exact test.

[†]Two sample t test.

[‡]Chi-Square analysis.

Table 4

Outcomes: Complications during rehabilitation and discharge motor and cognitive FIM

Characteristics	Enteral nutrition (n=145)	No enteral nutrition (n=145)	P
Change in weight during rehabilitation (mean, SD)	-0.5 (9)	-2.8 (12.1)	0.075 [‡]
Discharge FIM motor score - raw (mean, SD)	60.9 (13.4)	57.1 (16.8)	0.032 [‡]
Discharge FIM motor score - Rasch transformed (mean, SD)	53.1 (9.2)	50.9 (10.7)	0.055 [‡]
Discharge FIM cognitive score - raw (mean, SD)	21.0 (5.9)	19.6 (5.5)	0.047 [‡]
Discharge FIM cognitive score - Rasch transformed (mean, SD)	52.5 (12.6)	49.7 (12)	0.050 [‡]
Length of stay (mean, SD)	31.2 (14.0)	28.4 (12.2)	0.062 [‡]
Pneumonitis/Aspiration pneumonia during rehabilitation (%)	0.7	1.4	1.000 [*]
Pneumonitis/Aspiration pneumonia before or during rehabilitation (%)	5.5	5.5	1.000 [*]
Pneumonia during rehabilitation (%)	24.1	22.1	0.781 [*]
Sepsis during rehabilitation (%)	2.1	4.8	0.335 [*]
Urinary tract infection during rehabilitation (%)	7.6	8.3	1.000 [*]

NOTE: Abbreviations: FIM, Functional Independence Measure;

^{*} Fisher's exact test.[‡] Two sample t test.

Table 5

Ordinary least squares regressions predicting discharge motor and cognitive FIM and weight loss during stay

Outcome:	Discharge FIM motor score - Rasch transformed			Discharge FIM cognitive score - Rasch transformed			Discharge weight		Length of stay	
	Parameter Estimate	Standardized Parameter Estimate	P	Parameter Estimate	Standardized Parameter Estimate	P	Parameter Estimate	Standardized Parameter Estimate	Parameter Estimate	Standardized Parameter Estimate
Intercept	44.9	0.00	<.001	47.1	0.000	<.001	10.96	0.00	28.22	0.00
Admission FIM motor score Rasch transformed	0.28	0.40	<.001				0.10	0.04	-0.34	-0.38
Admission FIM cognitive score - Rasch transformed				0.27	0.350	<.001				
Admission brain injury component of CSI score				-0.12	-0.132	0.026			0.13	0.13
Admission non-brain injury component of CSI score				0.10	0.122	0.020				0.016
Admission body mass index <=18.5									7.78	0.20
Admission body mass index >30							5.75	0.05	0.014	
Admission Weight							0.90	0.93	<.001	
Enteral nutrition 25% or more of rehabilitation stay	2.59	0.12	0.028	4.93	0.186	0.001				
nutrition 25% or more of rehabilitation stay	5.65	0.16	0.003	6.37	0.150	0.005	3.70	0.03	0.057	
# Observations Used		290			290			263		290
R-Square		0.189			0.240			0.935		0.224
Adjusted R-Square		0.181			0.227			0.934		0.216

Note: Abbreviations: CSI, Comprehensive Severity Index; FIM, Functional Independence Measure; Independent variables allowed into models include admission FIM motor and cognitive scores, admission brain injury and non-brain injury components of CSI score, admission body mass index categories of less than or equal to 8.5, 18.5 to 25, great than 25 to 30, and greater than 30, tube feeding 25% or more of rehabilitation stay, and high protein tube feeding 25% or more of rehabilitation stay.