Outcomes in Critically Ill Patients Before and After the Implementation of an Evidence-Based Nutritional Management Protocol*

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Objective: **To determine whether the implementation of a nutritional management protocol in the ICU leads to the increased use of enteral nutrition, earlier feeding, and improved clinical outcomes in patients.**
Design: **Prospective evaluation of critically ill patients before and after the introduction of an evidence-based guideline for providing nutritional support in the ICU.**
Setting: **The medical-surgical ICUs of two teaching hospitals.**
Patients: **Two hundred critically ill adult patients who remained npo > 48 h after their admission to the ICU. One hundred patients were enrolled into the preimplementation group, and 100 patients were enrolled in the postimplementation group.**
Intervention: **Implementation of an evidence-based ICU nutritional management protocol.**
Measurement and results: **Nutritional outcome measures included the number of patients who received enteral nutrition, the time to initiate nutritional support, and the percent caloric target administered on day 4 of nutritional support. Clinical outcomes included the duration of mechanical ventilation, ICU and in-hospital length of stay (LOS), and in-hospital mortality rates. Patients in the postimplementation group were fed more frequently via the enteral route (78% vs 68%, respectively; p = 0.08), and this difference was statistically significant after adjusting for severity of illness, baseline nutritional status, and other factors (odds ratio, 2.4; 95% confidence interval [CI], 1.2 to 5.0; p = 0.009). The time to feeding and the caloric intake on day 4 of nutritional support were not different between the groups. The mean (± SD) duration of mechanical ventilation was shorter in the postimplementation group (17.9 ± 31.3 vs 11.2 ± 19.5 days, respectively; p = 0.11), and this difference was statistically significant after adjusting for age, gender, severity of illness, type of admission, baseline nutritional status, and type of nutritional support (p = 0.03). There was no difference in ICU or hospital LOS between the two groups. The risk of death was 56% lower in patients who received enteral nutrition (hazard ratio, 0.44; 95% CI, 0.24 to 0.80; p = 0.007).**
Conclusion: **An evidence-based nutritional management protocol increased the likelihood that ICU patients would receive enteral nutrition, and shortened their duration of mechanical ventilation. Enteral nutrition was associated with a reduced risk of death in those patients studied.**
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Key words: critical care; enteral nutrition; intensive care; nutrition protocols; nutritional management; outcomes research; parenteral nutrition

Abbreviations: CI = confidence interval; HR = hazard ratio; LOS = length of stay; NG = nasogastric; OR = odds ratio; SAPS = simplified acute physiology score; TPN = total parenteral nutrition

Malnutrition is a common problem in hospitalized patients. As many as 40% of adult patients are seriously malnourished at the time of their hospital admission, and two thirds of all patients experience deterioration of their nutritional status during their hospital stay.[1] Acute illness further exacerbates patients' poor nutritional status by increasing their metabolic rate and by impairing their utilization of nutritional substrates.[2,3] Critically ill patients frequently receive inadequate nutritional support during their ICU stay because physicians underestimate the nutritional needs of patients, and the initiation of nutritional therapy is often delayed.[4,5] Malnutrition in ICU patients is associated with increased morbidity, mortality, and length of

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ICU stay due to increased ventilator dependency, higher rates of infection, and impaired wound healing.[3,6–9]

Nutritional support plays a vital role in the prevention and treatment of nutritional deficiencies in ICU patients.[10] Studies suggest that initiating nutritional support in ICU patients within 48 to 72 h of ICU admission is associated with improved clinical outcomes, lower infection rates, and reduced hospital lengths of stay.[11,12] The route of administration of nutritional support also appears to influence clinical outcomes. Enteral nutrition is generally preferred over parenteral nutrition as it is more physiologic, is less likely to be associated with hepatobiliary dysfunction and metabolic derangements, and is substantially less expensive.[12–14] In animal models, parenteral nutrition is associated with a higher incidence of bacterial translocation in the gut and with impaired IgA-dependent immune function in the upper respiratory tract, compared with enteral feeding.[15,16] Clinical studies[11,17–26] of ICU patients receiving parenteral nutrition have demonstrated a higher incidence of infections, postoperative wound complications, GI bleeding, pressure ulcers, and greater immune compromise than in patients receiving enteral nutrition. In both animal models and in humans, the early use of enteral nutrition in the setting of acute illness improves immune function, augments the cellular antioxidant system, decreases the hypermetabolic response to tissue injury, preserves intestinal integrity, and improves nitrogen balance and wound healing.[27–31] In ICU patients, the use of early enteral nutrition compared with either parenteral or delayed enteral nutrition is associated with lower complication rates and improved clinical outcomes.[18,32–35]

Although there are clear clinical contraindications to patients receiving enteral nutrition, the routine practice of instituting early enteral nutritional support in otherwise eligible ICU patients is not widespread.[36] The use of tube feeding protocols shortens the time to achieve caloric targets and increases the delivery of calories in ICU patients receiving enteral tube feeds.[37,38] To date, there have been no studies looking at the efficacy of a more comprehensive nutritional management protocol in optimizing nutritional support of all critically ill patients. We conducted a prospective study to determine whether the implementation of a nutritional management protocol resulted in the increased use of enteral nutrition, the earlier initiation of nutritional support, and improved caloric delivery in adult medical and surgical ICU patients. As secondary end points, we evaluated the impact of the protocol on the duration of mechanical ventilation, the length of ICU and hospital stay, and in-hospital mortality rates in these patients.

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Materials and Methods

Study Design

Using a prospective sequential study design (to prevent cross-contamination of the study groups), we measured nutritional and other outcomes in adult medical and surgical ICU patients before and after implementing a nutritional management protocol. The institutional review board approved the study protocol and waived the need for consent. We sequentially screened all admissions to the medical-surgical ICUs of a university teaching hospital and an affiliated Department of Veterans Affairs hospital for eligible patients. Men and women ≥ 18 years of age who had been admitted to the ICU, and were expected to remain unable to take oral nutrition and to be admitted to the ICU for at least 48 h were eligible. At both hospitals, a multidisciplinary ICU team had primary management responsibility for all medical patients. The ICU team and surgical teams jointly managed all surgical patients.

Prior to beginning enrollment, the investigators developed a nutritional management protocol that was based on a review of the ICU nutrition literature (Fig 1). We searched Medline by using the following MeSH terms: intensive care; critical care; nutrition; enteral nutrition; parenteral nutrition; nutritional support; and early enteral nutrition. Data from randomized controlled trials, meta-analyses, review articles, and consensus statements were used to develop the protocol.[2,10,11,19,33,39,40] We hypothesized that the introduction of an evidence-based nutritional management protocol in the ICU would lead to an increase in the number of critically ill patients who were fed enterally, and that nutritional support would be initiated sooner (*ie*, within 48 h of ICU admission) and advanced more rapidly in ICU patients who were unable to take oral nutrition.

The protocol instructed physicians to evaluate the need for nutritional support in each patient at the time of their admission to the ICU. We classified patients by nutritional class as being normal (class I), mildly malnourished (class II), moderately malnourished (class III), or severely malnourished (class IV).[41] Physicians were encouraged to feed patients enterally and to place feeding tubes in patients within 24 h of ICU admission, if they did not have any contraindications to receiving enteral nutrition and were unable to take oral nutrition. Contraindications to enteral nutrition were based on the American Society of Parenteral and Enteral Nutrition guidelines, and included pro-

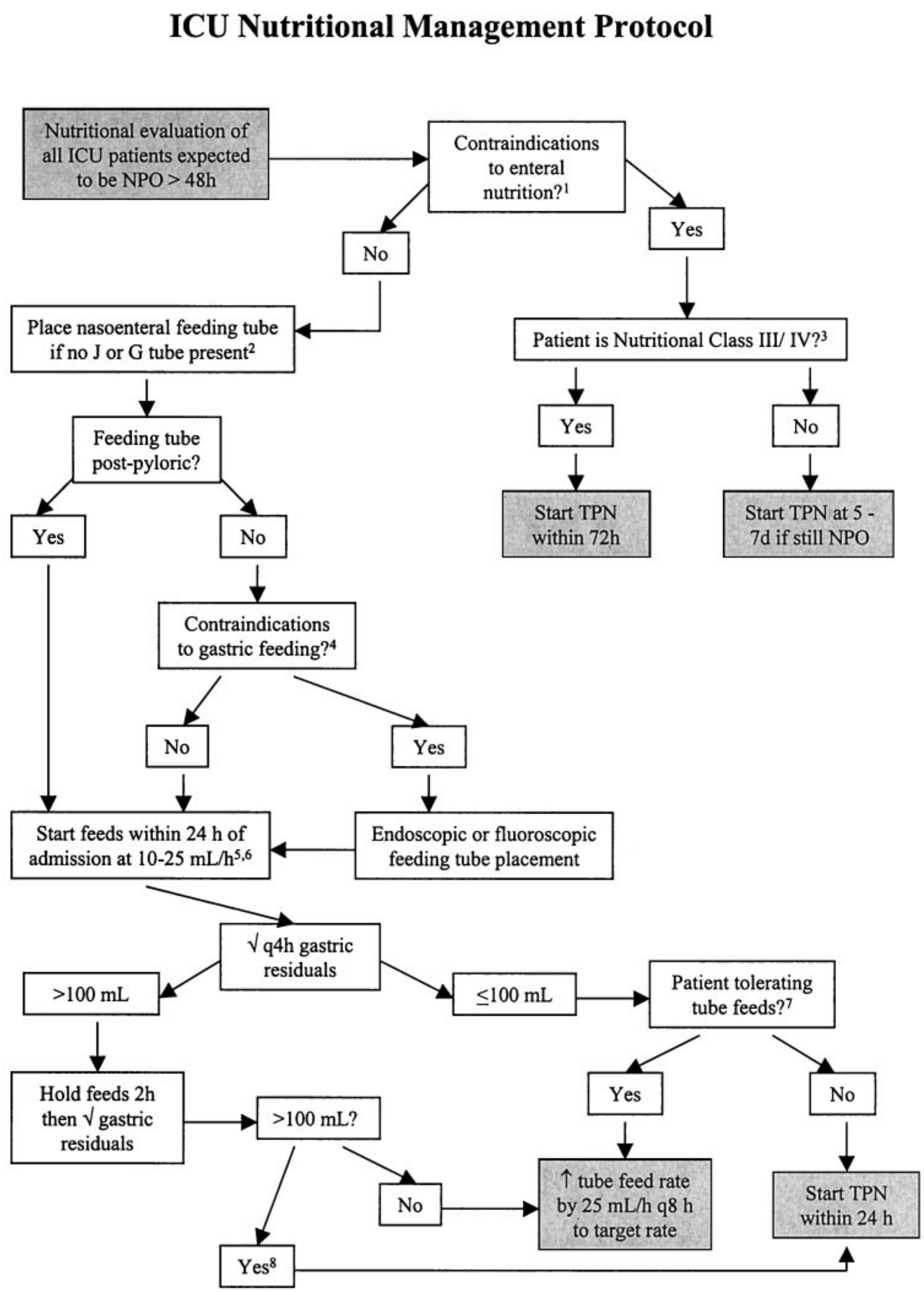

FIGURE 1. ICU nutritional management protocol. (1) Contraindications to enteral nutrition include protracted nausea and vomiting, severe diarrhea, malabsorptive syndromes, extensive small bowel resection, severe pancreatitis, bowel obstruction, perforation, or peritonitis.[42] (2) Jejunal or gastric feeding tube. (3) Nutritional classification system is as follows: normal nutritional status (class I), mildly malnourished (class II), moderately malnourished (class III), or severely malnourished (class IV).[41] (4) Contraindications to gastric feeding include, for example, recent gastric surgery, evidence of significant gastric atony, and gastric outlet obstruction. (5) Use full-strength feeds with isotonic formulas, and half-strength feeds with hypertonic formulas. (6) Maintain head-of-bed elevation of $> 30°$ at all times to prevent aspiration. (7) No evidence of nausea, vomiting, abdominal pain, distension, or aspiration. (8) If a patient receiving intragastric enteral feeds every 4 h has gastric residuals of > 100 mL on more than one occasion, consider postpyloric feeding tube placement before starting TPN.

tracted nausea and vomiting, severe diarrhea, malabsorptive syndromes, extensive small bowel resection, severe pancreatitis, bowel obstruction, perforation, or peritonitis.[42] The protocol encouraged postpyloric feeding tube placement to improve tolerance of tube feeds, although the method of feeding tube placement was left up to the patient's physician. Caloric target estimates for each patient were determined by using the Harris-Benedict equation.[43] The enteral feeding and/or total parenteral nutrition (TPN) preparation to be used for each patient was determined by the ICU physician in conjunction with the ICU dietician. Enteral tube feeds were to be started within 24 h of ICU admission at a rate of 10 to 25 mL/h, and then increased by 25 mL/h every 8 h in the absence of significant gastric residuals (*ie*, > 100 mL over a 4-h period) until the target tube-feeding rate was achieved in each patient. Patients who were not candidates for enteral nutrition were to receive TPN within 72 h of ICU admission if they were either moderately or severely malnourished at baseline (nutritional class III or IV), or within 5 to 7 days if mildly malnourished (nutritional class I or II) and they remained unable to take oral nutrition. TPN was initiated at half the target rate for the first 24 h, then advanced to the target rate as tolerated.

We conducted the study in three phases. During the preimplementation phase, we sequentially enrolled 100 eligible medical and surgical ICU patients (50 at each institution) who served as the control group. Following completion of the preimplementation phase, we implemented the nutritional management protocol simultaneously at both facilities over a 1-month period. During this phase, we held clinical training sessions for all ICU staff physicians, house staff, and nurses in order to familiarize them with the protocol. We repeated these training sessions at both study sites at the beginning of each month for new ICU house-staff during the postprotocol implementation phase of the study as well. Protocol modifications were made during the implementation phase based on feedback solicited from ICU physicians, nursing staff, and dieticians. Copies of the final version of the nutritional management protocol were posted throughout the ICUs at each patient's bedside, at the nursing stations, and in physician work areas. Following the implementation phase, an additional 100 eligible patients (50 at each institution) were enrolled.

Use of the nutritional management protocol was not mandatory in either ICU. All decisions about the route, timing, amount, and composition of nutritional support were ultimately left up to the patient's ICU physician (in consultation with ICU dieticians) during both the preprotocol and postprotocol implementation phases of the study. Although physicians and nurses were told that a nutrition study was being conducted, they were unaware of the details or purpose of the study.

Data Collection

Baseline data collection included age, sex, height, weight, admitting diagnosis, admitting service (*ie*, medical vs surgical), simplified acute physiology score (SAPS) II,[44] mechanical ventilation status, nutritional class,[41] and estimated caloric and protein targets for each patient. Nutritional outcome measures included type of nutritional support (enteral or parenteral), time to initiate nutritional support, and the percentage of the caloric target administered on day 4 of nutritional support. Other outcome measures included the duration of mechanical ventilation, ICU and in-hospital length of stay (LOS), and in-hospital mortality. The time to feeding in patients who received no nutritional support during their ICU stay was expressed as the total number ICU days. Study end points were defined as discharge from the ICU or death during ICU admission.

Statistical Analysis

For the purpose of the sample size calculation, the primary outcome measure was the number of days to the initiation of nutrition. We calculated that we needed to enroll 100 patients in each group in order to have 80% power to detect a 1-day improvement in the time to feeding at a significance level of 0.05, assuming a SD in the time to feeding of 2.5 days. We expressed continuous variables (*ie*, age, SAPS II score, caloric and protein targets, number of days until feeding, percentage of caloric target administered at 72 to 96 h of nutritional support, duration of mechanical ventilation, and the length of ICU and hospital stay) as the mean ± SD, and categoric variables (*ie*, gender, admitting service, nutritional class, mechanical ventilation, route of nutritional support, and mortality) as counts and percentages. For bivariate comparisons between groups, we used the Student *t* test for continuous data, and either the χ^2 test or Fisher exact test as appropriate for categoric data. We performed multivariable logistic regression to identify independent predictors of enteral feeding and predictors of achieving 90% of the caloric target by day 4. We performed Cox proportional hazard analysis to identify independent predictors of the time to initiate feeding and survival. To identify independent predictors of the duration of mechanical ventilation, ICU LOS, and hospital LOS, we performed multiple linear regressions.

Results

The baseline characteristics of the 200 patients enrolled in the preprotocol and postprotocol implementation groups are summarized in Table 1. The two groups were comparable except that the patients in the postimplementation group were older ($p = 0.02$). Although the caloric requirements for both groups were similar, patients in the postimplementation group had lower protein targets than those in the preimplementation group ($p = 0.04$). Patients in both groups were predominately male, moderately to severely malnourished at the time of their admission (*ie*, nutritional class III or IV), were admitted with a medical (vs surgical) diagnosis, and were mechanically ventilated. The most common admission diagnoses for medical patients were respiratory failure/pneumonia, sepsis, liver failure, GI bleeding, and cerebrovascular accidents. Surgical patients most frequently underwent cardiac surgery, general surgery, or neurosurgical procedures.

In the preimplementation group, 63% of patients received enteral nutrition alone, 21% received parenteral nutrition alone, 5% received both enteral and parenteral nutrition, and 11% received no nutritional support during their ICU stay (Table 2). In the postimplementation group, 68% of patients received enteral nutrition alone, 9% received parenteral nutrition alone, 10% received both enteral and parenteral nutrition, and 13% received no nutritional support ($p = 0.08$). Overall, 78% of patients in the postimplementation group received enteral nutrition (with or without TPN), compared with 68% in the preimplementation group ($p = 0.11$). The mean

Table 1—*Baseline Demographics and Nutritional Characteristics**

Variables	Preimplementation (n = 100)	Postimplementation (n = 100)	p Value
Age, yr	61.0 ± 38.1	65.6 ± 13.7	0.02†
Male gender, %	80	73	0.24†
SAPS II score	55.1 ± 14.7	59.1 ± 17.1	0.08†
Medical admissions, %	76	66	
Respiratory failure	36	29	
Sepsis	12	13	
Liver failure	3	4	
GI bleeding	6	5	
Cerebrovascular accident	7	7	0.12§
Other‡	12	8	
Surgical admissions, %	24	34	
Cardiac surgery	8	11	
General surgery	6	5	
Neurosurgery	4	10	
Other‖	6	8	
Mechanical ventilation, %	70	74	0.53†
Nutritional class, %			
I	1	1	
II	18	11	
III	54	68	
IV	27	20	
(Class I–IV) pre vs post:			0.23¶
Caloric target, kcal/24 h)#	2,146 ± 310	2,082 ± 291	0.16†
Protein target, g/24 h**	94.2 ± 75.1	76.4 ± 28.8	0.04†

*Values given as mean ± SD, unless otherwise noted.
†Student *t* test.
‡Other medical admission diagnoses were as follows: myocardial infarction; unstable angina; s/p cardiopulmonary arrest; bacterial meningitis; metastatic cancer; acute renal failure; severe pancreatitis; altered mental status; and ischemic colitis.
§A 2 × 2 χ^2 analysis of the percentage of medical and surgical patients in the preimplementation and postimplementation groups.
‖Other surgical admissions were as follows: otolaryngology; orthopedics; urology; and vascular surgery.
¶A 4 × 2 χ^2 analysis of nutritional class in the preimplementation and postimplementation groups.
#Caloric targets: preimplementation group, 96; post-implementation group, 80.
**Protein targets: preimplementation group, 96; postimplementation group, 83.

time to feeding was 3.2 ± 2.0 days in the preimplementation group and 2.9 ± 1.7 days in the postimplementation group (p = 0.26). The mean percentage of caloric target achieved on day 4 following the initiation of feeding was 72.9 ± 38.1% in the preimplementation group and 66.9 ± 39.8% in the postimplementation group (p = 0.36).

The mean duration of mechanical ventilation was 17.9 ± 31.3 days in the preimplementation group, and 11.2 ± 19.5 days in the postimplementation group (p = 0.11) [Table 2]. The mean ICU LOS was 14.9 ± 18.0 days in the preimplementation group, and 14.1 ± 18.8 days in the postimplementation group (p = 0.78). The mean hospital LOS was 31.2 ± 37.0 days in the preimplementation group, and 29.0 ± 30.4 days in the postimplementation group (p = 0.65). Twenty-seven percent of patients died in the preimplementation group, and 30% died in the postimplementation group (p = 0.64).

Independent predictors of enteral feeding are summarized in Table 3. After adjusting for age, gender, severity of illness, type of admission (medical vs surgical), and nutritional class, patients in the postimplementation group were more than twice as likely to receive enteral nutrition than were patients in the preprotocol implementation group (odds ratio [OR], 2.44; 95% confidence interval [CI], 1.22 to 5.0; p = 0.009). Sicker patients in both groups (*ie*, those with a higher SAPS II score) were less likely to receive enteral nutrition. The likelihood of patients receiving enteral nutrition decreased by 4% for every additional 1-point increase in their SAPS II score (OR, 0.96; 95% CI, 0.93 to 0.98; p = 0.0002). Medical patients were more than twice as likely to receive enteral nutrition as surgical patients (OR, 2.35; 95% CI, 1.03 to 5.36; p = 0.04). Patients with a better baseline nutritional status (class I or II) were more likely to receive enteral nutrition than were moderate or severely malnourished patients (class III or IV), but this difference was not statistically significant (OR, 3.43; 95% CI, 0.93 to 12.67; p = 0.06). There was a trend toward a shorter time to feeding in the postprotocol implementation group, but this difference did not achieve statistical significance

Table 2—*Nutritional and Clinical Outcomes**

Outcome	Preimplementation (n = 100)	Postimplementation (n = 100)	p Value
Enteral nutrition only, %	63	68	
Parenteral nutrition only, %	21	9	
Enteral and parenteral nutrition, %	5	10	
No nutrition, %	11	13	
Types of nutritional support in the preimplementation and postimplementation groups			0.08†
Time until feeding, d	3.2 ± 2.0	2.9 ± 1.7	0.26§
Caloric target received on day 4 of nutritional support, %‡	72.9 ± 38.1	66.9 ± 39.8	0.36§
Duration of mechanical ventilation, d	17.9 ± 31.3	11.2 ± 19.5	0.11§
ICU LOS, d	14.9 ± 18.0	14.1 ± 18.8	0.78§
Hospital LOS, d	31.2 ± 37.0	29.0 ± 30.4	0.65§
Death, %	27	30	0.64‖

*Values given as mean ± SD, unless otherwise noted.
†A 4 × 2 χ^2 analysis of nutritional support in the preimplementation and postimplementation groups.
‡IN = 75 for the preimplementation and 67 for the postimplementation groups.
§Student *t* test.
‖A 2 × 2 χ^2 analysis of mortality rates in the preimplementation and postimplementation groups.

(hazard ratio [HR], 1.28, 95% CI, 0.93 to 1.75; p = 0.13) [Note that an HR of > 1 indicates a greater likelihood of being fed sooner]. Our analysis did not identify any predictors of the percentage of target caloric intake received on day 4 of nutritional support.

After adjusting for other variables (*eg*, age, gender, SAPS II score, admission diagnosis, baseline nutritional class, and type of nutritional support), patients in the postimplementation group were mechanically ventilated for 9.5 fewer days than were patients in the preimplementation group (p = 0.03) [Table 4]. Additional predictors of a shorter duration of mechanical ventilation included medical (vs surgical) patients (p = 0.01) and better baseline nutritional status (*ie*, class I or II vs class III or IV) [p = 0.04]. Independent predictors of a shorter ICU LOS included medical admission (p < 0.001) and better baseline nutritional status (p = 0.01). There were no significant independent predictors of hospital LOS in the patients studied.

Table 5 summarizes the independent predictors of in-hospital mortality in both groups. Adjusting for age, gender, severity of illness, admitting diagnosis, and nutritional class, and whether patients received enteral nutrition or not, there was no difference in the risk of death between the preimplementation group and the postimplementation group (p = 0.98). However, correcting for these other factors, the risk of death was 56% lower in those patients who received enteral nutrition (HR, 0.44; 95% CI, 0.24 to 0.80; p = 0.007). Other independent predictors of mortality included increasing age (HR, 1.04; 95% CI, 1.02 to 1.06; p = 0.001), a higher SAPS II score (HR, 1.04; 95% CI, 1.02 to 1.06; p = 0.0001), and medical admission (HR, 3.61; 95% CI, 1.53 to 8.5; p = 0.003).

We also compared nutritional and clinical outcomes in patients based on their baseline nutritional

Table 3—*Independent Predictors of Enteral Feeding*

Variable	OR (95% CI)*	p Value†
Age	1.0 (0.98–1.03)	0.94
Gender (female vs male)	1.27 (0.55–2.91)	0.58
SAPS II score	0.96 (0.93–0.98)	<0.001
Admitting diagnosis (medical vs surgical)	2.35 (1.03–5.36)	0.04
Nutritional status (class I/II vs class III/IV)	3.43 (0.93–12.67)	0.06
Postimplementation group vs preimplementation group	2.44 (1.22–5.0)	0.009

*OR >1 indicates a greater likelihood of receiving enteral nutrition.
†Multivariate logistic regression analysis (n = 200).

Table 4—*Independent Predictors of Duration of Mechanical Ventilation*

Variable	Regression Coefficient*	SE	p Value†
Age	0.026	0.149	0.86
Gender (female vs male)	−3.38	4.963	0.50
SAPS II score	0.081	0.148	0.58
Admitting diagnosis (medical vs surgical)	−12.541	4.929	0.01
Nutritional status (class I/II vs class III/IV)	−12.398	6.033	0.04
Enteral nutrition	−4.337	5.134	0.40
Postimplementation group vs preimplementation group	−9.49	4.333	0.03

*Regression coefficients in days; negative values indicate shorter duration of mechanical ventilation.
†Linear regression analysis (n = 162).

Table 5—*Independent Predictors of Mortality*

Predictor	HR (95% CI)*	p Value†
Age	1.04 (1.02–1.06)	0.001
Gender (female vs male)	0.86 (0.42–1.79)	0.69
SAPS II score	1.04 (1.02–1.06)	0.0001
Admitting diagnosis (medical vs surgical)	3.61 (1.53–8.5)	0.003
Nutritional status (class I/II vs class III/IV)	1.37 (0.4–4.66)	0.62
Enteral nutrition	0.44 (0.24–0.8)	0.007
Postimplementation group vs preimplementation group	1.01 (0.56–1.82)	0.98

*HR > 1 indicates a greater "hazard" of death.
†Cox proportional hazards analysis (n = 199).

status. Patients with a better baseline nutritional status (*ie*, class I or II) were 29% more likely to receive enteral nutrition than were those patients with moderate-to-severe malnutrition at baseline (*ie*, class III or IV) [relative likelihood of class I/II patients being fed enterally, 1.29; 95% CI, 1.11 to 1.5; p = 0.02). Overall, 97% of class I and II patients received some sort of nutritional support during their ICU stay, with most of these patients (90%) receiving enteral nutrition exclusively (Table 6). By contrast, only 86% of class III and IV patients received any nutritional support, with only 61% receiving enteral nutrition alone and 25% receiving parenteral nutrition alone (p = 0.02). There were no significant differences in the time to initiate feeding or the percentage of the caloric target received on day 4 between the two groups. Class I and II patients had a shorter ICU LOS (p = 0.05), a shorter hospital LOS (p = 0.02), and a lower risk of death (p = 0.01) compared with class III and IV patients.

Overall, compared with surgical patients, medical patients were sicker than surgical patients (SAPS II score, 60.5 ± 16.2 vs 48.7 ± 12.2, respectively; p < 0.0001) and were more severely malnourished at baseline (nutritional class III/IV: medical patients, 89.4%; surgical patients, 72.4%; p = 0.003). There were no demographic differences between medical and surgical patients in terms of their age, gender, requirement for mechanical ventilation, or caloric and protein targets. Surgical patients were more likely to receive TPN (surgical patients, 34%; medical patients, 18%; p = 0.009) and were fed later than medical patients (days to initiate feeding: surgical patients, 3.6 days; medical patients, 2.9; p = 0.01), although there was no significant difference in the percentage of the caloric target administered to medical and surgical patients on day 4 of nutritional support. Medical patients underwent fewer days of mechanical ventilation (11.8 ± 13.3 vs 21.7 ± 43.5 days, respectively; p = 0.03), had shorter ICU LOSs (12.2 ± 11.6 vs 20 ± 28.2 days, respectively; p = 0.007), and shorter hospital LOSs (26.2 ± 26.7 vs 39.6 ± 45.6 days, respectively; p = 0.01) compared with surgical patients. Finally, medical patients had higher mortality rates than surgical patients (33.1% vs 17.5%, respectively; p = 0.03).

Discussion

Adequate nutritional support of critically ill patients helps to prevent malnutrition and its related complications.[8] Eight-five percent of the patients (170) that we studied were moderately to severely malnourished with a high acuity of illness on admission to the ICU, and 72% of the patients (144) required mechanical ventilation, making them particularly vulnerable to developing malnutrition-

Table 6—*Outcomes by Baseline Nutritional Class**

Outcome	Nutritional Class		p Value
	I/II (n = 31)	III/IV (n = 169)	
Enteral nutrition only	28 (90)	103 (61)	
Parenteral nutrition only	2 (7)	28 (16)	
Enteral and parenteral nutrition	0 (0)	15 (9)	
No nutrition	1 (3)	23 (14)	
Nutritional support (nutritional class I/II vs III/IV)			0.02†
Time until feeding, d	2.9 ± 1.5	3.1 ± 1.9	0.64‡
Caloric target, %	79.5 ± 33.6	68.8 ± 39.5	0.29‡
ICU LOS, d	8.6 ± 5.0	15.6 ± 19.7	0.05‡
Hospital LOS, d	17.0 ± 11.7	32.5 ± 2.8	0.02‡
Vent duration, d	7.0 ± 5.4	16.0 ± 28.3	0.12‡
Death	3 (10)	54 (32)	0.01§

*Values given as No. (%) or mean ± SD, unless otherwise indicated.
†A 4 × 2 χ^2 analysis of nutritional support by nutritional class (results reported ascount [%]).
‡Student *t* test (results reported as mean ± SD).
§Fisher exact test (results reported as count [%]).

related complications (Table 1). The use of enteral nutrition and the institution of nutritional support within 48 to 72 h of ICU admission improve clinical outcomes in critically ill patients.[11,12,17–26,32] Despite its documented benefits, not all eligible ICU patients receive early enteral nutrition, and nutritional support of ICU patients is often inadequate because of delayed physician ordering, delayed feeding tube or central line placement, the underestimation of caloric requirements, and the frequent interruption of feeds.[3,9,10]

Nutritional management protocols may improve the nutritional support of ICU patients. Chapman et al[38] found that using standardized enteral nutrition orders in the ICU shortened the time to reach caloric targets in patients by 3 days. Spain et al[37] showed that a tube feed infusion protocol improved the delivery of enteral tube feeds in ICU patients through improved physician ordering and more rapid advancement of tube feeds. However, the nutritional protocols used in these two studies were designed to improve the delivery of enteral feeds in patients whose physicians had previously ordered enteral nutritional support. The primary purpose of our study was to determine whether the implementation of a more comprehensive evidence-based nutritional management protocol in the ICU would improve the nutritional support of all critically ill patients who were unable to take adequate oral nutrition.

Nutritional Outcomes

Seventy-eight percent of patients in the postimplementation group received enteral nutrition, vs 68% in the preimplementation group (Table 2). Although these differences were not statistically significant, adjusting for age, gender, severity of illness, admitting diagnosis, and nutritional class, patients in the postimplementation group were significantly more likely to receive enteral nutrition than were patients in the preimplementation group (Table 3). The lack of statistical significance in the simple comparisons of enteral feeding in the preimplementation and postimplementation groups may in part be due to the relatively high incidence of enteral feeding (68%) in the preimplementation group. Surgical patents and patients with higher SAPS II scores were less likely to receive enteral nutrition. For each 1-point increase in a patient's SAPS II score, the likelihood of receiving enteral nutrition decreased by 4%. This may reflect the greater use of sedatives, opioids, and catecholamine infusions in sicker patients, which have been shown to significantly decrease GI motility and absorption in critically ill patients.[45–47] On the other hand, medical patients were more than twice as likely as surgical patients to receive enteral nutrition, despite the fact that they had higher SAPS II scores on average. This observed difference in enteral feeding patterns between medical and surgical patients perhaps reflects a bias against the use of enteral tube feeds in surgical patients because of general concerns regarding reduced gut motility after surgery. The traditional surgical approach to feeding patients postoperatively is to keep them from taking oral nutrition and to give IV fluids until they develop, for example, bowel sounds, flatulence, and hunger.[48,49] These are late findings of GI motility, and waiting for them to occur before initiating enteral nutrition may significantly delay the nutritional support of surgical ICU patients.[4,50] Although delayed gastric emptying occurs commonly in both medical and surgical ICU patients, the incidence of GI intolerance of enteral tube feeds is similar between medical and surgical ICU patients.[51] Patients who have undergone GI surgery with anastomoses often remain unable to take oral nutrition because of surgeons' concerns about anastomotic dehiscence. The use of early enteral nutrition may actually decrease the risk of anastomotic dehiscence in these patients.[52]

Initiating nutritional support in ICU patients within 48 to 72 h of ICU admission results in better clinical outcomes than if nutritional support is delayed.[32,52,53] Although the mean time to initiate feeding in our study was shorter in the postimplementation group than in the preimplementation group (2.9 vs 3.2 days, respectively), this difference did not achieve statistical significance (Table 2). This suggests that although the protocol heightened clinician awareness of the benefits of enteral nutrition (resulting in more patients being enterally fed), there were barriers to implementing nutritional support sooner in these patients. Although the causes of delayed nutritional support were not documented in this study, the most likely explanations include the following: (1) the absence of a standardized protocol for feeding tube placement, with multiple blind attempts at nasoduodenal feeding tube placement over several days; (2) a reluctance to start TPN in patients early on; and (3) physician expectations that most ICU patients (especially surgical patients) would be taking nutrition by mouth within 48 h of admission.

Postpyloric feeding is preferred over intragastric feeding in ICU patients in order to reduce the risk of GI intolerance, regurgitation, and aspiration of tube feeds.[54,55] The blind placement of nasoduodenal feeding tubes has a reported success rate of $< 35\%$.[56] Insufflation of 10 mL/kg air (in adults) into the stomach via nasogastric (NG) tube just prior to feeding tube placement, the use of prokinetic agents such as metoclopramide and erythromycin, and the use of weighted feeding tubes can increase the success rate of blind nasoduodenal feeding tube placement.[56–62] Endoscopic, fluoroscopic, and ultrasound-guided techniques have a 85 to 95% success rate for postpyloric tube placement, but these require coordinated scheduling that can further delay placement, unless a system is in place to ensure a rapid response time to requests for feeding tube placement.[63–67] Feeding jejunostomy or gastrostomy tubes may be placed preemptively in surgical ICU patients, but this practice is not widespread among surgeons. Regardless of the technique used, the use of standardized protocols for the postpyloric placement of feeding tubes in ICU patients can shorten the time to initiate enteral tube feeding in these patients.

The early use of TPN in ICU patients who cannot tolerate enteral nutrition is not a routine practice, because of the potential side effects of TPN (*eg*, higher infection rates, and fluid and electrolyte disturbances) and the unclear benefit of short-term TPN as a bridge to enteral nutrition.[68] Although there is no clear benefit to starting TPN early in ICU patients with mild malnutrition, the early administration of TPN to severely malnourished ICU patients significantly reduces their risk of complications.[69] Most physicians are overly optimistic about ICU patients' ability to take oral nutrition in a timely fashion. Friedman and Still[70] showed that the ability of physicians to predict which ICU patients will be taking oral or enteral nutrition within 2 to 7 days of admission is only 41%, which could lead to further delays in initiating nutritional support.

In this study, the implementation of a nutritional management protocol had no impact on the rate at which feeds were advanced in patients in our study. The percentage of the caloric target administered on day 4 of nutritional support actually decreased from 73% in the preimplementation group to 67% in the postimplementation group (Table 2). This may be due to the fact that a greater percentage of patients in the postimplementation group received enteral nutrition. Previous studies[18] have shown that ICU patients receiving enteral nutrition are less likely to achieve and maintain their caloric and protein targets than were patients receiving TPN, primarily due to GI intolerance of tube feeds. Strategies to improve the GI tolerance of tube feeds in these patients include the following: (1) postpyloric feeding in conjunction with NG decompression; (2) standardized strategies for stopping and restarting tube feeds; and (3) the administration of promotility agents, such as metoclopramide or erythromycin.[52,71–73]

Enteral feeding protocols can improve the delivery of tube feeds by limiting the criteria and the duration for holding tube feeds. McClave et al[5] found that tube feedings were held in ICU patients for a wide variety of reasons including the following: invasive procedures and diagnostic tests (66%); "high" gastric residuals, which were variably defined (45%); feeding tube displacement (41%); and routine nursing care (*eg*, bathing, dressing changes, and bedding changes; 30%). As a result, patients received an average of only 52% of their daily caloric requirements. Overall, 66% of these tube-feeding interruptions were deemed to be avoidable. Adam and Batson[72] found that ICUs that follow well-defined enteral tube feeding protocols delivered greater volumes of enteral tube feeds to patients. But poor compliance with ICU feeding tube protocols can limit their effectiveness. In the study by Spain et al,[37] a tube-feeding protocol reduced the amount of time that tube feeds were held because of GI intolerance, procedures, tests, and nursing activities, but these effects were not statistically significant. This was likely due to poor compliance (only 42%) with the protocol by clinicians in this study. The protocol implementation strategy employed by Spain et al[37] was similar to that used in our study; adherence to the protocol was not mandatory, and protocol adherence and the reasons for noncompliance with the protocol were not measured. Clinicians are more likely to follow clinical protocols given the following conditions: (1) clinicians have ongoing input as to how to improve the protocol after it is implemented (*ie*, "stakeholder ownership"), (2) protocol performance and clinician adherence to the protocol are frequently measured and assessed, and (3) if clinician-specific feedback about their compliance with the protocol and related patient outcomes is given to them in a timely and constructive fashion.[74–76] As we saw in our study, one-time protocol educational efforts alone are unlikely to result in the full implementation of even an evidence-based protocol in the ICU.

Clinical Outcomes

The implementation of the nutritional management protocol significantly shorted the duration of mechanical ventilation in the patients studied. After adjusting for age, gender, severity of illness, type of ICU admission (*ie*, medical vs surgical), nutritional status, and type of nutritional support, patients in the postprotocol implementation group were mechanically ventilated an average of 9.5 days less than patients in the preimplementation group (Table 4). This difference is not explained by differences in mortality rates since mortality was similar in both groups (Table 2). Rather, this may be explained by the fact that patients in the postimplementation group were more likely to receive enteral nutrition, which is associated with a lower incidence of complications in ICU patients that might prolong their duration of mechanical ventilation.[18,52] There was a trend toward a shorter duration of mechanical ventilation with enteral nutrition, but this did not achieve statistical significance (Table 4). Medical patients were also mechanically ventilated for significantly shorter periods than were surgical patients and had shorter ICU LOS, although these differences may be explained by the higher observed mortality rates in medical patients, particularly if they died early on in their ICU stay. The shorter duration of mechanical ventilation observed in medical patients also may be explained by the fact that medical patients were more likely to receive enteral nutrition than were surgical patients (Table 3).

Although the implementation of the nutritional management protocol itself had no impact on mortality rates, patients receiving enteral nutrition had a 56% reduction in their risk of death, independent of their severity of illness, nutritional class, age, gender, or admitting diagnosis (Table 5). To our knowledge, this is the first study to demonstrate an association between enteral nutrition and in-hospital survival.[32,52] Although the nutritional management protocol itself was not an independent predictor of mortality in this study, it increased the likelihood of patients receiving enteral nutrition (Table 3). Other predictors of in-hospital mortality in this study included age, severity of illness, and medical admission diagnosis, which are expected risk factors for death in ICU patients (Table 5).

Baseline nutritional status influenced both the nutritional management and the clinical outcomes of patients in this study. ICU patients with moderate-to-severe malnutrition were less likely to receive any nutrition, were less likely to receive enteral nutrition, and were more likely to receive parenteral nutrition when they were fed, compared to patients who were better nourished at baseline (Table 6). These differences in nutritional management may be explained in part by the fact that malnourished patients had higher SAPS II score (class I/II SAPS II, 46.7 [SD, 9.4]; class III/IV SAPS II, 59 [SD, 16.3]; $p < 0.0001$), which was a negative predictor of patients receiving enteral nutrition (Table 3).

ICU and hospital LOSs were twice as long, and mortality rates were three times higher in ICU patients with moderate-to-severe malnutrition (Table 6). Adjusting for other variables, baseline nutritional status was an independent predictor of the duration of mechanical ventilation, with class III and IV patients mechanically ventilated an average of 12 days longer than class I and II patients (Table 4). This is consistent with previous studies showing that moderate-to-severe malnutrition in ICU patients is associated with higher morbidity and mortality rates in these patients. Focused efforts should be made to improve the nutritional management of severely malnourished patients in particular.

Conclusions

The early institution of nutritional support and the use of enteral nutrition improve clinical outcomes in critically ill patients. We demonstrated that the implementation of an evidence-based nutritional management protocol increases the likelihood of ICU patients receiving enteral nutrition, and reduces their duration of mechanical ventilation. Patients receiving enteral nutrition had a 56% reduction in their risk of death when compared to patients receiving parenteral nutrition or no nutritional support. Surgical patients and patients with significant baseline malnutrition were less likely to receive enteral nutrition, and were ventilated for longer periods. The protocol did not hasten the onset of nutritional support or shorten the time to achieve caloric targets in patients. The use of a standardized approach for postpyloric feeding tube placement and tube-feeding management, the mandatory use of NG tubes for gastric decompression, and the administration of promotility agents in patients with high gastric residuals may have improved the delivery of enteral nutrition in these patients. Future research should focus on strategies for improving the nutritional management of surgical ICU patients and ICU patients with moderate-to-severe malnutrition at baseline, and focus on strategies for improving compliance with nutritional management protocols in an ICU setting.

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