Temporal Trends in the Use of Parenteral Nutrition in Critically Ill Patients

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Background: Clinical practice guidelines recommend enteral over parenteral nutrition in critical illness and do not recommend early initiation. Few data are available on parenteral nutrition use or timing of initiation in the ICU or how this use may have changed over time.

Methods: We used the Project IMPACT database to evaluate temporal trends in parenteral nutrition use (total and partial parenteral nutrition and lipid supplementation) and timing of initiation in adult ICU admissions from 2001 to 2008. We used χ^2 tests and analysis of variance to examine characteristics of patients receiving parenteral nutrition and multilevel multivariate logistic regression models to assess parenteral nutrition use over time, in all patients and in specific subgroups.

Results: Of 337,442 patients, 20,913 (6.2%) received parenteral nutrition. Adjusting for patient characteristics, the use of parenteral nutrition decreased modestly over time (adjusted probability, 7.2% in 2001-2002 vs 5.5% in 2007-2008, $P < .001$). Enteral nutrition use increased simultaneously (adjusted probability, 11.5% in 2001-2002 vs 15.3% in 2007-2008, $P < .001$). Use of parenteral nutrition declined most rapidly in emergent surgical patients, patients with moderate illness severity, patients in the surgical ICU, and patients admitted to an academic facility ($P \leq .01$ for all interactions with year). When used, parenteral nutrition was initiated a median of 2 days (interquartile range, 1-3), after ICU admission and $>90\%$ of patients had parenteral nutrition initiated within 7 days; timing of initiation of parenteral nutrition did not change from 2001 to 2008.

Conclusions: Use of parenteral nutrition in US ICUs declined from 2001 through 2008 in all patients and in all examined subgroups, with the majority of parenteral nutrition initiated within the first 7 days in ICU; enteral nutrition use coincidentally increased over the same time period.

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Abbreviations: MPM₀-III = mortality probability model III score at ICU admission; PPN = partial parenteral nutrition; TPN = total parenteral nutrition

Critical illness often results in impaired nutritional intake, either due to anorexia or an inability to eat secondary to altered mental status,¹ the need for invasive mechanical ventilation,² or disease processes that disrupt normal GI function.³ Lack of adequate nutrition may lead to nosocomial infections, poor wound healing, and delayed recovery.⁴⁻⁷ Therefore, guidelines recommend early institution of nutritional support, within 24 to 48 h of presentation, as part of the care of critically ill patients who are unable to eat.^{8,9}

Parenteral nutrition is one option to meet these nutritional goals. Use of parenteral nutrition may result in higher caloric intake than enteral nutrition alone^{10,11}; but is also associated with mucosal atrophy, overfeeding, hypervolemia, hyperglycemia, and infection.¹² Results of studies investigating the utility of parenteral nutrition in patients who cannot tolerate full

enteral feeds are inconsistent, suggesting, in turn, both benefit and harm.^{11,13,14} In reconciling these studies, clinical practice guidelines published over the past decade emphasize that use of enteral nutrition is preferable to parenteral nutrition whenever possible in the critically ill patient with a functional GI tract.^{8,9,15} Some experts even suggest abandoning parental nutrition in critically ill patients altogether, except in rare circumstances, such as for patients with anatomic abnormalities of the GI tract in whom enteral nutrition is not possible.¹⁶ American guidelines recommend initiation of parenteral nutrition only after 7 days without nourishment in previously healthy patients.⁹

In the context of this debate, information on the actual frequency of use and timing of initiation of parenteral nutrition in the care of critically ill patients is lacking. Therefore, we sought to characterize the

epidemiology of parenteral nutrition use in critically ill patients in the United States using a large, multi-center database. Given increased advocacy in support of early enteral nutrition and increased awareness of the risks of parental nutrition,¹⁷ we hypothesized that the use of parenteral nutrition declined and the time to initiation increased over time.

MATERIALS AND METHODS

We performed a retrospective cohort study of adult ICU admissions using the Project IMPACT database. Project IMPACT is a voluntary, fee-based ICU registry that, when in operation, provided regular performance audits and feedback to participating ICUs. Data were collected at each institution by on-site data collectors who were certified in advance by Project IMPACT to assure standardization and uniformity in data definitions and entry.¹⁸ We used data from 2001 to 2008, the last full year of data available.

Patients and Variables

For each ICU, data were collected from either consecutive admissions or a random sample of admissions. Sites using the latter method collected information on either 50% or 75% of patients; the percentage was determined quarterly before data collection commenced. We excluded patients < 18 years of age. We also excluded patients admitted to neurologic ICUs, neurosurgical ICUs, or cardiac surgery ICUs, as these units were few and highly specialized, with patient populations that do not generalize to other study ICUs. Only the initial ICU admission for a given hospital stay was included.

For each ICU admission, Project IMPACT collected patient-level data on demographics (age, race, sex), chronic comorbidities from a predefined set of up to 16 conditions, severity of illness on admission as assessed by the mortality probability model at ICU admission (MPM₀-III),¹⁹ admission diagnosis, admission type (medical, emergent surgical, elective surgical), and location prior to ICU admission (ED, operating room/postanesthesia care unit, general ward, other). Project IMPACT also collected ICU- and hospital-level data including the type of ICU (surgical, including trauma/burn ICUs; medical, including coronary care units; and mixed medical-surgical), ICU structure ("closed model" physician staffing and/or required mandatory critical care consultation for all admissions vs those that did not), hospital teaching status (academic vs nonacademic [community or government run]), and hospital location (urban, suburban, or rural).

Project IMPACT contains data on the start and stop dates for each of various categories of supplemental feeding for individual patients. Categories included total parenteral nutrition (TPN), TPN with lipids, partial parenteral nutrition (PPN), PPN with lipids, PPN that was a fat emulsion only, and enteral nutrition. We defined receipt of parenteral nutrition as having received TPN, PPN, lipids, or any combination for at least 1 day during the ICU stay. We considered parental nutrition as intended to be supplemental to enteral feeding when a patient was receiving enteral nutrition on the day of initiation of parenteral nutrition; for patients receiving parental nutrition for > 1 day, it was considered supplemental parental nutrition only if enteral feeding was provided on both days 1 and 2 (as patients with only 1 day of overlap may represent a switch from enteral to parenteral nutrition rather than use as supplementation).

Analysis

We described the hospital and ICU characteristics of the cohort using standard summary statistics. To assess trends in parenteral nutrition use over time, we first examined the unadjusted percentage of patients who received parenteral nutrition in 2-year time periods: 2001 to 2002, 2003 to 2004, 2005 to 2006, and 2007 to 2008. Two-year time periods were used to increase group size and power to detect statistically significant differences. We then assessed differences in patient-, ICU-, and hospital-level characteristics of patients receiving parenteral nutrition in each time period, using χ^2 tests and analysis of variance, as appropriate. To account for possible changes in the case mix of patients over time, we built a multilevel multivariable logistic regression model to determine the adjusted odds of receiving parenteral nutrition over time. We converted the coefficients of these models into predicted probabilities using marginal standardization.²⁰ All available patient-, ICU-, and hospital-level variables were included in a base model without interaction terms. To understand the degree to which temporal trends in parenteral nutrition were potentially related to trends in enteral nutrition use, we fit a similar multivariable model using receipt of enteral nutrition as the dependent variable.

We then assessed whether trends in parenteral nutrition use over time varied for specific subgroups of interest. The subgroups were selected based on the medical literature to be stratified based on factors that may either impact parenteral nutrition use or cessation in use of ICU therapies.^{10,21-23} Patient-level subgroups of interest included patient type (medical, elective surgical, emergent surgical), age (grouped as < 50, 50-64, 65-84, $\geq$ 85 years), severity of illness (MPM₀-III $\leq$ 5%, 6%-25%, 26%-50%, > 50%), and admission diagnosis (categorized by level of baseline use of < 2%, 2%-15%, or > 15% during the 2001-2002 study period) (Table 1). ICU- and hospital-level subgroups of interest included ICU type (medical, surgical, or combined), ICU structure (closed or mandatory critical care consultation vs possible or no critical care consultation), and academic affiliation of the hospital. For these analyses, we constructed separate multilevel models that included an interaction term between each of the subgroups of interest and admission year to determine whether there was variation by group in changes over time. We assessed statistical significance of the interaction term using the likelihood ratio test.

We defined the timing of parenteral nutrition as the number of days between ICU admission and initiation of the first episode of parenteral nutrition administration. For the patients who received parenteral nutrition, we used Kaplan-Meier analysis and the log-rank test for equality to compare changes in length of time until initiation of parental nutrition over time. We then assessed whether trends in timing of initiation of parenteral nutrition varied over time for the whole cohort and the subgroups (both patient level and ICU/hospital level) using Cox proportional-hazard regression with interaction terms; shared frailty was used to allow for

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Table 1—Parenteral Nutrition Use in 2001 to 2002 by APACHE II Diagnostic Category

Low Use (<2%)	Moderate Use (2%-15%)	High Use (>15%)
Specific categories		
Asthma/allergy	Aspiration/poisoning/toxic	GI bleeding (not in shock; surgical)
Coronary artery disease	Cardiogenic shock	GI perforation/obstruction
Craniotomy for neoplasm	Chronic cardiovascular disease	GI surgery for neoplasm
Diabetic ketoacidosis	Congestive heart failure	Hemorrhagic shock/hypovolemia (surgical)
Drug overdose	COPD	Respiratory insufficiency
Heart valve surgery	Craniotomy for ICH/SDH/SAH	Sepsis
Hypertension	Dissecting thoracic/abdominal aneurysm	
Laminectomy and other spinal cord surgery	GI bleeding (not in shock; medical)	
Renal transplant	Head trauma (medical and surgical)	
	Hemorrhagic shock/hypovolemia (medical)	
	ICH/SDH/SAH	
	Multiple trauma (medical and surgical)	
	Peripheral vascular surgery	
	Postcardiac arrest	
	Postrespiratory arrest	
	Pulmonary edema (noncardiogenic)	
	Pulmonary embolus	
	Renal surgery for neoplasm	
	Respiratory (medical)	
	Respiratory infection	
	Respiratory neoplasm	
	Rhythm disturbance	
	Seizure disorder	
	Thoracic surgery for neoplasm	
General categories		
Neurologic (surgical)	Cardiovascular (medical and surgical)	GI (medical and surgical)
	Metabolic/renal (medical and surgical)	
	Neurologic (medical)	
	Respiratory (surgical)	

APACHE = Acute Physiology and Chronic Health Evaluation; ICH = intracerebral hemorrhage; SAH = subarachnoid hemorrhage; SDH = subdural hemorrhage.

clustering in individual ICUs. The likelihood ratio test was used again to assess the statistical significance of the interaction term.

Database management and statistical analysis were performed using Excel (Microsoft Corp) and Stata, version 11.0 (StataCorp LP). Human subjects approval was obtained from Beth Israel Medical Center institutional review board (IRB# 200-10).

RESULTS

The final cohort consisted of 337,442 adults admitted to 176 ICUs in 125 hospitals (Table 2). A total of 20,913 (6.2%) received parenteral nutrition during their ICU admission. The majority of parenteral use was TPN (95.1%). Enteral nutrition was provided to 15.6% of the cohort, with 84.6% of these patients receiving enteral nutrition as the sole source of supplemental feeds.

Temporal Trends in Overall Use of Parenteral Nutrition

The percentage of patients receiving parenteral nutrition decreased from 6.9% in 2001 to 2002 to 5.7% in 2007 to 2008 ($P < .001$) (Table 3²⁴). Of patients receiving parenteral nutrition, 6.4% received it as supplement

to enteral nutrition; there was no change in this proportion over time (6.4% in 2001-2002, 6.0% in 2003-2004, 6.5% in 2005-2006, and 6.7% in 2007-2008, $P = .50$). Throughout the study period, $\geq 94\%$ of all patients receiving parenteral nutrition received it as TPN with or without lipids; the use of lipid supplementation to

Table 2—Characteristics of ICUs in the Cohort

Characteristics	No. (%)
Hospital organization	
Nonacademic	141 (80.1)
Academic	35 (19.9)
Hospital community ^a	
Urban	96 (54.5)
Suburban	61 (34.7)
Rural	18 (10.2)
ICU specialty	
Medical ICU	39 (22.2)
Surgical ICU	42 (23.9)
Combined	95 (54.0)
ICU structure ^b	
Open	129 (73.3)
Closed/mandatory consultation	45 (25.6)

^aData missing on one of 176 units.

^bData missing on two of 176 units.

TPN decreased from 72.8% of patients in 2001 to 2002 to 62.6% of patients in 2007 to 2008 ($P < 0.001$). More than one-half of patients receiving parenteral nutrition in all time periods had moderate severities of illness (MPM₀-III, 6%-25%). Patients with sepsis represented a larger percentage of patients receiving parenteral nutrition over time, while patients

with respiratory diagnoses represented a smaller percentage.

After multivariate adjustment for other factors, the probability of receiving parenteral nutrition remained associated with the year of ICU admission (Fig 1); use of parenteral nutrition decreased from 2001 to 2002 to 2007 to 2008 (adjusted probability in 2001-2002,

Table 3—Characteristics of Patients Receiving Parenteral Nutrition by Time Period^a

Years	2001-2002	2003-2004	2005-2006	2007-2008	P Value
Patients receiving parenteral nutrition, No. (% of cohort)	5,352 (6.9)	6,331 (6.1)	5,636 (6.1)	3,594 (5.7)	< .001
Types of parenteral nutrition					< .001
TPN + lipids	3,894 (72.8)	4,255 (67.2)	3,617 (64.2)	2,242 (62.4)	
TPN only	1,139 (21.3)	1,542 (24.4)	1,486 (26.4)	1,089 (30.3)	
Other ^b	319 (6.0)	534 (8.4)	533 (9.4)	263 (7.4)	
Parenteral nutrition used as supplement to enteral nutrition	343 (6.4)	379 (6.0)	365 (6.5)	241 (6.7)	.50
Days from ICU admission to initiation of parenteral nutrition, median (IQR)	2 (1-3)	2 (0-3)	2 (0-4)	2 (1-4)	< .001
Patient factors					
Age, mean $\pm$ SD, y	63.6 $\pm$ 16.9	63.1 $\pm$ 17.1	61.8 $\pm$ 17.1	61.7 $\pm$ 17.4	< .001
Severity of acute illness, MPM ₀ -III, %					.50
≤ 5	1,044 (20.6)	1,277 (21.4)	1,136 (21.5)	680 (20.4)	
6-25	2,824 (55.8)	3,317 (55.5)	2,968 (56.2)	1,876 (56.3)	
26-50	833 (16.5)	1,006 (16.8)	844 (16.0)	569 (17.1)	
> 50	359 (7.1)	375 (6.3)	329 (6.2)	207 (6.2)	
Race					< .001
White	4,378 (83.1)	5,086 (82.8)	4,480 (80.6)	2,904 (81.4)	
Black	686 (13.0)	728 (11.9)	731 (13.1)	477 (13.4)	
Other	203 (3.9)	328 (5.3)	348 (6.3)	187 (5.2)	
Sex					.07
Male	2,772 (51.8)	3,285 (51.9)	3,038 (53.9)	1,916 (53.3)	
Female	2,578 (48.2)	3,045 (48.1)	2,597 (46.1)	1,678 (46.7)	
Insurance					< .001
Private insurance	1,482 (27.9)	1,717 (27.3)	1,547 (27.6)	1,061 (29.6)	
Medicare	3,073 (57.9)	3,604 (57.4)	3,009 (53.7)	1,837 (51.3)	
Medicaid	339 (6.4)	461 (7.3)	475 (8.5)	355 (9.9)	
Self pay	283 (5.3)	355 (5.6)	400 (7.1)	214 (6.0)	
Other	126 (2.4)	147 (2.3)	172 (3.1)	115 (3.2)	
Patient type					< .001
Medical	2,636 (49.3)	3,247 (51.3)	2,853 (50.6)	1,769 (49.2)	
Elective surgical	1,307 (24.4)	1,482 (23.4)	1,185 (21.0)	778 (21.6)	
Emergent surgical	1,409 (26.3)	1,602 (25.3)	1,598 (28.4)	1,047 (29.1)	
Location prior to ICU					< .001
ED	1,145 (21.4)	1,439 (22.7)	1,304 (23.1)	793 (22.1)	
Operating room/postanesthesia care unit	2,249 (42.0)	2,497 (39.4)	2,277 (40.4)	1,497 (41.7)	
General ward	1,458 (27.2)	1,775 (28.0)	1,401 (24.9)	883 (24.6)	
Other	499 (9.3)	620 (9.8)	654 (11.6)	421 (11.7)	
Category of admitting diagnosis					< .001
Respiratory	1,433 (26.8)	1,543 (24.4)	1,172 (20.8)	704 (19.6)	
Cardiovascular	792 (14.8)	931 (14.7)	818 (14.5)	493 (13.7)	
Sepsis	710 (13.3)	1,059 (16.7)	1,049 (18.6)	817 (22.7)	
Trauma	299 (5.6)	468 (7.4)	494 (8.8)	279 (7.8)	
Neurologic (nontrauma)	240 (4.5)	304 (4.8)	310 (5.5)	193 (5.4)	
Metabolic/renal	219 (4.1)	241 (3.8)	174 (3.1)	108 (3.0)	
GI	1,658 (31.0)	1,784 (28.2)	1,619 (28.7)	1,000 (27.8)	
Chronic illnesses ^c					< .001
0	3,891 (72.7)	4,386 (69.3)	3,878 (68.8)	2,450 (68.2)	
1	1,169 (21.8)	1,639 (25.9)	1,497 (26.6)	999 (27.8)	
2+	292 (5.5)	306 (4.9)	261 (4.6)	145 (4.0)	

(Continued)

Table 3—Continued

Years	2001-2002	2003-2004	2005-2006	2007-2008	P Value
Mechanical ventilation on ICU admission	2,240 (41.9)	2,727 (43.1)	2,682 (47.6)	1,855 (51.6)	< .001
Hospital mortality	1,621 (30.3)	1,729 (27.3)	1,413 (25.1)	985 (27.4)	< .001
ICU length of stay, median (IQR), d	3 (7-14)	3 (7-13)	3 (7-14)	4 (8-15)	< .001
Hospital length of stay, median (IQR), d	12 (19-30)	12 (19-29)	12 (19-30)	12 (19-30)	.23
Hospital disposition for survivors					< .001
Home	1,657 (47.0)	1,926 (44.7)	1,785 (46.1)	1,088 (45.4)	
SNF/LTAC	1,630 (46.3)	2,107 (48.9)	1,852 (47.8)	1,189 (49.6)	
Other hospital	94 (2.7)	103 (2.4)	118 (3.0)	43 (1.8)	
Hospice	65 (1.8)	135 (3.1)	107 (2.8)	72 (3.0)	
Other	78 (2.2)	34 (0.8)	10 (0.3)	6 (0.3)	

Data given as No. (%) unless otherwise indicated. IQR = interquartile range; LTAC = long-term acute care; MPM₀-III = mortality probability model at ICU admission; PPN = partial parenteral nutrition; SNF = skilled nursing facility; TPN = total parenteral nutrition.

^aData not available for all patients for all variables. Race: missing data for 1.8%; sex: 0.02%; insurance, 0.7%; location prior to ICU, 0.005%; admitting diagnosis, 0.01%; ICU length of stay, 0.02%; hospital length of stay, 0.01%; and hospital disposition for survivors 7.0%. Also, 6.1% of patients were excluded from the MPM₀-III calculation.

^bOther includes PPN, lipids, TPN + PPN, PPN + lipids, and TPN + PPN + lipids.

^cCount of chronic health conditions from Project IMPACT, including severe abnormalities of the (1) GI, (2) cardiovascular, (3) respiratory, and/or (4) renal systems; (5) severely immunocompromised; (6) active malignancy.²⁴

7.2% vs 5.5% in 2007-2008, *P* for trend < .001). In contrast, enteral nutrition use increased over the same time period (Fig 1).

Temporal Trends in Use of Parenteral Nutrition for Specific Subgroups

Among subgroups selected for assessment, there were significant interactions between year and two of the three patient-level factors. Adjusted use of parenteral nutrition among patients admitted for emergency surgery decreased at a faster rate over the period studied compared with those admitted for medical and elective surgeries, although the overall use among those admitted for emergency surgery remained high (Table 4). Similarly, patients with an intermediate severity of illness (predicted hospital mortality of 26%-50%) had the highest probability of parenteral nutrition use throughout, as well as one of the steepest declines in probability of use compared with patients at lower and higher risk of death. All age groups experienced similarly declining probabilities of adjusted parenteral nutrition use. Significant interactions were also observed for all three ICU- and hospital-level factors and ICU admission year. Patients admitted to closed/mandatory critical care consultation units (Table 4), surgical or combined specialty units, and teaching units had the highest adjusted probabilities of parenteral nutrition use and steeper declines in adjusted probability of use.

We determined that 16.8% of the cohort had one of the eight APACHE (Acute Physiology and Chronic Health Evaluation) II diagnostic category diagnoses, which we categorized as high use (> 15%); 67.2% were in the moderate-use group (2%-15%), and 16.0% were in the low-use group (< 2%) based on use rates in

2001 to 2002. Over the entire period studied, 18.6% of patients in the high-use group received parenteral nutrition, 4.6% in the moderate-use group, and 1.0% in the low-use group (*P* < .001). Probabilities of parenteral nutrition use declined over time for patients in each of the three utilization groups (Table 4). There was no significant difference in the rates of decline of parenteral nutrition probability dependent on initial use rate.

Temporal Trends in Timing of Initiation of Parenteral Nutrition

Among all patients who received parenteral nutrition from 2001 to 2008, the median time to initiation of parenteral nutrition was 2 days (interquartile range, 1-3 days) after ICU admission. Parenteral nutrition

FIGURE 1. Adjusted probabilities of nutritional support over time. *Includes all patients who received parenteral nutrition at any point during their ICU admission (whether they also received enteral nutrition either simultaneously or at another time) (*P* < .001 for trend). †Includes patients who received enteral nutrition but not parenteral nutrition at any point during their ICU admission (*P* < .001 for trend).

Table 4—Adjusted Probabilities of Parenteral Nutrition Use Over Time Stratified by Patient, ICU, and Hospital Characteristics and Baseline Parenteral Nutrition Use

Characteristics	2001-2002	2003-2004	2005-2006	2007-2008	P Value ^a
Complete cohort	7.2	6.3	6.0	5.5	...
Patient characteristics					
Patient type					.01
Elective surgical	7.2	6.7	6.4	6.3	
Emergent surgical	17.2	15.0	14.0	12.7	
Medical	5.5	4.7	4.4	3.8	
MPM ₀ -III, %					< .001
≤ 5	4.0	3.7	3.6	3.2	
> 5-25	8.2	7.2	6.9	6.3	
> 25-50	12.5	10.6	9.8	8.8	
> 50-100	10.2	7.1	6.9	6.3	
Age, y					.16
< 50	6.0	5.0	5.0	4.5	
50-64	7.1	6.5	6.4	5.7	
65-84	7.8	7.0	6.7	6.1	
≥ 85	8.4	6.6	5.6	6.2	
ICU/hospital characteristics					
ICU structure					.002
Open	7.0	6.2	5.6	5.1	
Closed/mandatory critical care consultation	7.7	6.5	6.7	6.1	
ICU type					< .001
MICU	5.0	4.5	4.2	3.7	
SICU	9.2	8.4	7.9	7.4	
Combined ICU	7.1	6.0	5.7	5.0	
Academic status					< .001
Noneaching hospital	6.9	6.0	5.6	5.4	
Teaching hospital	9.3	7.6	7.1	5.8	
Baseline parenteral nutrition utilization rates ^b					.21
Low-use diagnoses	1.0	1.0	1.0	0.9	
Moderate-use diagnoses	5.1	4.4	4.1	3.5	
High-use diagnoses	21.0	17.5	16.9	14.9	

Data given as % unless otherwise indicated. MICU = medical ICU; SICU = surgical ICU. See Table 1 and 3 legends for expansion of other abbreviations.

^aP value for interaction of each subgroup with ICU admission year.

^bHigh, APACHE II diagnostic categories with > 15% parenteral nutrition use in 2001-2002; moderate, 2-15%; low, < 2% (see Table 1 for complete list of diagnoses).

was initiated before the seventh day of ICU admission in 90.6% of patients. There were no large changes in the time to initiation of parenteral nutrition from 2001 to 2008 (adjusted time to initiation in 2001-2002: 1.43 days vs 1.32 days in 2007-2008; *P* value for trend < .001) (Fig 2). After adjusting for severity of illness, there were no significant interactions between any patient subgroup or ICU/hospital-level subgroup and temporal trends in timing of initiation of parenteral nutrition (Table 5).

DISCUSSION

This large, multicenter, cohort study demonstrates that on average, 5% to 7% of patients admitted to ICUs in the United States receive parenteral nutrition during their stay in the unit. There was a modest decline in the rate of parenteral nutrition use in the US ICU population from 2001 through 2008 that was consis-

tent across all subgroups of patients examined. This decline was coincident with an increase in the probability of enteral nutrition use over the same period. Almost all (> 90%) of parenteral nutrition was initiated prior to a patient's seventh day in the ICU; there was no change in either the timing of initiation of parenteral nutrition or its use as a supplement to enteral nutrition from 2001 to 2008.

We hypothesize that the decline in the use of parenteral nutrition is attributable to changing perceptions about the associated risks and benefits over the period studied. The risks associated with parenteral nutrition, including mucosal atrophy, overfeeding, hypervolemia, hyperglycemia, and infection, are well established.¹² As a consequence, US guidelines first published in 2009 recommend initiation of parenteral nutrition only after 7 days of no nutrition and only if the duration of its use is expected to be at least seven additional days.⁹ European guidelines are less stringent, suggesting administration of parenteral nutrition

FIGURE 2. Time to initiation of parenteral nutrition among the patients who received parenteral nutrition, stratified by year of ICU admission. Log-rank test for equality, $P < 0.001$ for comparison of all groups.

if enteral nutrition will not be possible for 72 h.¹⁵ It is possible that the studies that informed these guidelines may have slowly influenced the overall rates of

use. However, it is important to note that while the studies all predate 2009, the guidelines themselves were published after the period we studied. Moreover, it is notable that although the rate of use has declined, the time to initiation of parenteral nutrition is much shorter than most guidelines recommend, and this aspect of use has not changed over time.

In addition to specific concerns about parenteral nutrition, new data on the risks of general fluid administration may have influenced use. There is a growing body of literature suggesting that excess fluid administration can prolong duration of mechanical ventilation and worsen outcomes in critical illness.²⁵⁻³² As a result, clinicians may opt to avoid parenteral nutrition to help minimize fluid administration and prevent volume overload. Another potential explanation for declining use may be an increasing focus on the costs of therapies, particularly for those without clear evidence of benefit.³³ An economic analysis suggested that use of early parenteral nutrition in the ICU may actually reduce costs, yet its publication postdates the

Table 5—Adjusted Days to Initiation of Parenteral Nutrition Over Time Stratified by Patient, ICU, and Hospital Characteristics and Baseline Parenteral Nutrition Use

Characteristics	2001-2002	2003-2004	2005-2006	2007-2008	P Value ^a
Complete cohort	1.43	1.42	1.34	1.32	...
Patient characteristics					
Patient type					.49
Elective surgical	1.51	1.65	1.57	1.51	
Emergent surgical	1.67	1.59	1.51	1.44	
Medical	1.29	1.27	1.18	1.20	
MPM ₀ -III, %					.99
≤ 5	1.51	1.43	1.40	1.35	
> 5-25	1.42	1.41	1.32	1.28	
> 25-50	1.36	1.36	1.28	1.26	
> 50-100	1.25	1.33	1.18	1.47	
Age, y					.54
< 50	1.29	1.20	1.13	1.10	
50-64	1.29	1.26	1.27	1.21	
65-84	1.38	1.40	1.28	1.30	
≥ 85	1.47	1.58	1.59	1.41	
ICU/hospital characteristics					
ICU structure					.44
Open	1.51	1.46	1.43	1.39	
Closed/mandatory critical care consultation	1.26	1.34	1.22	1.23	
ICU type					.71
MICU	1.19	1.28	1.29	1.31	
SICU	1.40	1.46	1.33	1.37	
Combined ICU	1.60	1.54	1.50	1.44	
Academic status					.61
Nonteaching hospital	1.51	1.49	1.42	1.42	
Teaching hospital	1.26	1.33	1.26	1.21	
Baseline parenteral nutrition utilization rates ^b					.78
Low-use diagnoses	1.26	0.90	1.00	0.86	
Moderate-use diagnoses	1.05	1.03	0.98	0.96	
High-use diagnoses	1.49	1.54	1.40	1.36	

See Table 1, 3, and 4 legends for expansion of abbreviations.

^aP value for interaction of each subgroup with ICU admission year.

^bHigh, APACHE II diagnostic categories with > 15% parenteral nutrition use in 2001-2002; moderate, 2-15%; low, 2% (see Table 1 for complete list of diagnoses).

period of our study.³⁴ Finally, increased awareness of catheter-related bloodstream infections, and the requirement to report such infections,³⁵ could heighten awareness of the risks of parenteral nutrition and deter use.

Even with the declining overall use, many subgroups had extremely high usage rates at baseline. We were able to identify a subset of eight diagnoses (representing > 15% of our cohort) in which patients received parenteral nutrition more frequently than 15% of the time in 2001 to 2002; similarly, in patients admitted for emergency surgery, more than one in six received parenteral nutrition in 2001 to 2002. In these high-use subgroups, relative reductions > 25% were observed. The overall trends in parenteral nutrition use, therefore, may not fully describe the magnitude of use reduction in certain high-use groups.

We also found that enteral nutrition use increased over the study period. A meta-analysis of studies published prior to 2009 demonstrated a mortality benefit associated with initiation of enteral nutrition within 24 h of ICU admission among general critical care populations,³⁶ with similar findings in a variety of subgroups of critically ill patients, including cardiac arrest survivors,³⁷ patients with pancreatitis,^{38,39} and patients with traumatic injury.⁴⁰ The data from the original studies (the majority of which were published before 2005) may be driving the increased use of enteral nutrition we observed. However, a more recent study called into question early, aggressive use of enteral nutrition,⁴¹ and results of randomized controlled trials of early, full nutritional support are equivocal.^{14,42,43} The majority of these studies postdate the time period we investigated, precluding a direct examination of these studies on usage trends.

Our study is limited by several factors. First, we had no information on how and why the decision was made to initiate parenteral nutrition in each patient. Specifically, we were unable to ascertain whether parenteral nutrition was used early when there were expectations that patients would not tolerate enteral nutrition; used later, after patients were actively unable to tolerate enteral nutrition; or used later without any trial of enteral nutrition. We also could not report how long patients received parenteral nutrition or whether parenteral nutrition was used in tandem with enteral nutrition to meet caloric goals, as has been used in a number of trials.^{10,11} We also did not have information on nutrition-related complications, such as central line-associated bloodstream infections, for which critically ill patients are already at high risk.⁴⁴⁻⁴⁷ Finally, due to the cessation of data collection in Project IMPACT, we were unable to assess trends beyond 2008. It is possible that with subsequent studies of enteral and parenteral nutrition,^{10,11,13,43} practices have shifted in unanticipated ways.

Despite these limitations, we demonstrate an overall trend over the last decade toward decreasing use of parenteral nutrition, with a concomitant increase in enteral nutrition use. These trends are consistent with current guidelines.^{8,9,15} However, when it is used, parenteral nutrition is most commonly initiated prior to the seventh ICU day contrary to current guideline recommendations. The decreasing use of parenteral nutrition over time is also consistent with the evolving state-of-the-science in ICU nutrition, which increasingly favors a “less is more” approach to feeding in critical illness.⁴⁸ However, there are clearly some “high-use” subgroups of critically ill patients in whom clinicians still perceive a real need for parenteral nutritional support. Focused study of these more homogeneous subgroups is necessary to determine the validity of this perceived need.

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Dr Gershengorn: contributed to the conception and design of the study, the primary analyses, interpretation of results, and drafting of the manuscript and served as principal author.

Dr Kahn: contributed to the conception and design of the study, interpretation of results, and revisions of the manuscript and approved final version of the manuscript.

Dr Wunsch: contributed to the conception and design of the study, interpretation of results, and revisions of the manuscript and approved final version of the manuscript.

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