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Original Article

Intended versus delivered parenteral nutrition in the pediatric intensive care units: A multi-center survey

Zeynelabidin Öztürk[1], Sevgi Topal[2], Ebru Kaçmaz[3], Dinçer Yıldızdaş[4], Murat Kanğın[5], Mustafa Çolak[2], Ener Çağrı Dinleyici[3], Benan Bayrakcı[6]

[1]University of Health Sciences, Dr. Sami Ulus Obstetrics and Gynecology, Pediatric Health and Disease Training and Research Hospital, Department of Pediatric Intensive Care Medicine, Ankara, Türkiye
[2]University of Health Sciences, Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital, Department of Pediatric Intensive Care Medicine, İzmir, Türkiye
[3]Eskişehir Osmangazi University, Faculty of Medicine, Department of Pediatric Intensive Care Medicine, Eskişehir, Türkiye
[4]Çukurova University, Faculty of Medicine, Department of Pediatric Intensive Care Medicine, Adana, Türkiye
[5]Gazi Yaşargil Training and Research Hospital, Department of Pediatric Intensive Care Medicine, Diyarbakır, Türkiye
[6]Hacettepe University, Center for Life Support Practice and Research, Department of Pediatric Intensive Care Medicine, Ankara, Türkiye

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ABSTRACT

Objective: Prevention and management of malnutrition are important in critically ill children. Parenteral nutrition (PN) is considered for patients who cannot tolerate enteral feeding. There are many reasons why PN cannot be delivered in the prescribed amount. We aimed to evaluate whether PN is delivered as prescribed in the pediatric intensive care units and to reveal the reasons for failure.

Method: Demographics, pediatric risk of mortality (PRISM) III scores, predicted death rates (PDR), indications for PN, duration of PN, vascular access site, daily amount of prescribed and delivered PN, reasons for not receiving PN as prescribed, and whether renal replacement therapy (RRT) was received were noted. The delivered/prescribed PN volume ratio was compared by gender, age, PRISM III score, PDR, indications for PN, duration of PN, and vascular access site.

Results: The most common indication for PN was failing to meet the targeted energy enterally (n=51, 69.9%). The duration of PN was ≤ 7 days in 40 (54.8%) patients and the type of vascular access was jugular venous catheter in 46 (63%) patients. 16 (21.9%) patients received RRT. PN was administered for 906 PN-days and the patients received the prescribed volume on 698 PN-days (77%). The most common reasons for not receiving the PN volume as prescribed were volume restrictions (n= 29, 39.7%) and electrolyte imbalance (n=13, 17.8%). Age, gender, weight, duration of PN, vascular access site, receiving RRT, PRISM III score, and PDR were not associated with receiving more than 0.8 of the prescribed PN volume. All gastrointestinal surgery patients received more than 0.8 of the prescribed amount.

Conclusion: In about a quarter of PN-days, the prescribed volume could not be delivered, often due to volume restrictions in the pediatric intensive care units. Setting the correct nutritional targets, individualizing nutritional support, and preventing and overcoming obstacles on the way to the targets may improve outcomes.

Keywords: Critically ill, malnutrition, outcomes, parenteral nutrition, pediatric intensive care

Correspondence: Zeynelabidin Öztürk **E-mail:** zeynelabidin_ozturk@hotmail.com
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INTRODUCTION

Prevention, early detection, and management of malnutrition are important issues in critically ill children.[1] Malnutrition is associated with prolonged duration of ventilation, prolonged hospital stay, and increased risk of infection and mortality.[1-3] All pediatric intensive care unit patients should have a nutrition plan, which include the nutrition route and administration time, the amount of the macro and micronutrients, and the energy to be provided, and it should be updated according to the changing clinical conditions.[1] Parenteral nutrition (PN) can be total PN or supplemental PN. Enteral nutrition (EN) is a priority for critically ill children.[1] In these patients, EN is frequently delayed or interrupted due to gastrointestinal dysfunction, so PN is considered since the resulting nutritional deficiency is associated with adverse outcomes.[1,4] Optimizing energy provision with supplemental PN in critically ill patients receiving inadequate EN has been associated with fewer hospital infections, antibiotic use, and shorter duration of mechanical ventilation.[5] There is no consensus on the timing of initiating PN.[4,6-11] According to current guidelines, PN is not recommended in the first 24 hours, and the waiting period may be extended in children in whom EN can be started and gradually increased.[1] The waiting period can be extended up to one week for patients with a good nutritional status, but it is recommended to start PN in the first week in patients with malnutrition.[1]

There are many reasons why PN cannot be delivered in the targeted and prescribed amount in pediatric intensive care units. Lack of appropriate vascular access, interactions with other drugs, electrolyte disturbances, abnormalities in kidney and liver tests, and volume restrictions are some of these reasons. In the presented study, we aimed to evaluate whether PN was delivered as planned and prescribed in the pediatric intensive care units participating in the study and to reveal the reasons for failure.

MATERIAL AND METHODS

Study design

The data of 5 tertiary hospitals in Türkiye that agreed to participate in this multi-center retrospective study were evaluated. All patients aged between 1 month and 18 years, who were hospitalized in the pediatric intensive care units and received total or supplemental PN between July 2018 and January 2019, were included. The characteristics of the pediatric intensive care units participating in the study are described in Figure 1.

Variables and measurements

Demographics, pediatric risk of mortality (PRISM) III scores, predicted death rates (PDR), indications for PN, duration of PN,

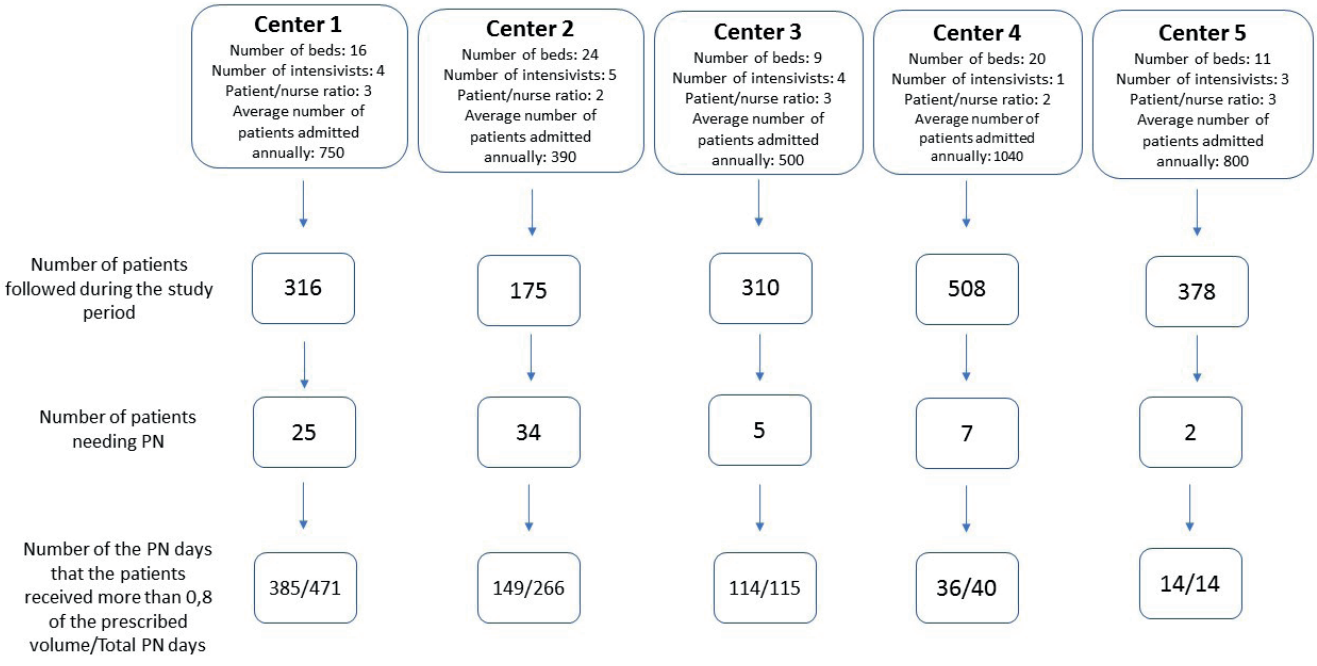

Figure 1. Characteristics and patient numbers of the pediatric intensive care units participating in the study.
PN: Parenteral nutrition

vascular access site, daily amount of prescribed and delivered PN, reasons for not receiving PN as prescribed, and whether patients received renal replacement therapy (RRT) and/or extracorporeal membrane oxygenation (ECMO) support were noted. The patients were divided into two groups: those who received the prescribed PN volume on more than 0.8 of PN days and those who did not. The received/prescribed PN volume ratio was compared by gender, age, PRISM III score, PDR, indications for PN, duration of PN, and vascular access site.

Indications for parenteral nutrition

Indications for PN include failure to meet the targeted energy enterally, gastrointestinal surgery/bleeding, and inborn errors of metabolism/metabolic crisis.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics (version 22.0.0; IBM Co., Armonk, NY, USA), and p-values <0.05 were considered statistically significant. The normal distribution of variables was analyzed visually (histogram and probability graphs) and statistically (Kolmogorov-Smirnov test). Data were presented as medians (25th-75th percentiles) for continuous variables and as numbers of cases and percentages (%) for categorical variables that did not fit a normal distribution. Chi-square or Fisher's exact test was used to compare differences between frequencies. The Mann-Whitney U test was used to compare numerical variables without normal distribution.

Ethical approval

Ethical approval was obtained from the ethics committee of the hospital where the study was conducted (Approval number: E-21/11-237). The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

RESULTS

Seventy-three patients (41 males, 56.2%) were included in the study. The median age was 17 (5-66) months, and the median body weight was 10 (5.3-17.2) kg.

PN was given to patients with sepsis/multi-organ failure (26%), gastrointestinal surgery/bleeding/obstruction (21.9%), inborn errors of metabolism/chronic diarrhea (16.4%), respiratory diseases/infections (15.1%), congenital heart disease (8.2%), malignancy (6.8%), and immunodeficiency (5.5%).

The most common indication for PN was failing to meet the targeted energy enterally (n=51, 69.9%) (Table 1). The duration of PN was ≤ 7 days in 40 (54.8%) patients and the vascular access type was jugular venous catheter in 46 (63%) patients (Table 1). 16 (21.9%) patients received RRT and 5 (6.8%) received ECMO (Table 1). PN was administered for 906 PN-days and the patients received the prescribed volume only on 698 PN-days (77%) (Fig. 1). The most common reasons for not receiving the PN

Table 1. Demographic and clinical characteristics of the patients

Demographic Characteristics	n (%)
Gender	
Male	41 (56.2)
Female	32 (43.8)
Age, months	17 (5-66)
Body weight, kg	10 (5.3-17.2)
Indications for PN	
Failure to meet the targeted energy enterally	51 (69.9)
Gastrointestinal surgery	9 (12.3)
Inborn errors of metabolism/metabolic crisis	8 (11.0)
Gastrointestinal bleeding	5 (6.8)
Duration of PN (days)	
≤7	40 (54.8)
8-30	26 (35.6)
>30	7 (9.6)
Vascular access site	
Jugular	46 (63.0)
Femoral	16 (21.9)
Subclavian	5 (6.8)
Peripheral	6 (8.2)
RRT	16 (21.9)
CRRT	14 (19.2)
IHD	2 (2.7)
ECMO	5 (6.8)
Reason for not receiving PN as prescribed	
Volume restriction	29 (39.7)
Electrolyte imbalance	13 (17.8)
Delay for preparing the PN solution	3 (4.1)
Cholestasis	1 (1.4)
PRISM III (n=66)	12.0 (7.8-18.0)
PDR (n=66)	8.00 (4.2-21.3)

Data are presented as n (%) or median (25^{th} and 75^{th} percentiles).
CRRT: continuous renal replacement therapy, ECMO: extracorporeal membrane oxygenation, IHD: intermittent hemodialysis, PDR: predicted death rate, PN: parenteral nutrition, RRT: renal replacement therapy.

volume as prescribed were volume restrictions (n= 29, 39.7%) and electrolyte imbalance (n=13, 17.8%) (Table 1).

Age, gender, body weight, duration of PN, vascular access site, receiving RRT and ECMO, PRISM III score, and PDR were not associated with receiving more than 0.8 of the prescribed PN volume (Table 2). All gastrointestinal surgery patients received more than 0.8 of the prescribed amounts of PN (Table 2).

DISCUSSION

The nutritional status of critically ill children is associated with the outcomes.[1] The nutritional status of the patients should be evaluated within the first 48 hours after hospitalization and an appropriate nutritional plan should be made.[1] Energy, protein, and other macro- and micronutrient needs should be correctly determined and optimally provided.[1] Interruptions in nutrition for various reasons or failure to deliver the targeted volume are usually ignored, and this adversely affects the outcomes. These patients often receive inadequate nutrition, and their nutritional status gradually deteriorates during their stay in the pediatric intensive care units.[2,8] In an international multicenter study that included 31 pediatric intensive care units in eight countries, 30% of the patients had severe malnutrition, 38% of the daily energy target and 43% of the daily protein target were achieved, and the mortality was lower in children who received more energy via EN.[2]

Only a few studies have evaluated the amount of enteral or parenteral nutrition delivered/prescribed in pediatric intensive care units. Moreover, the appropriate method to assess whether parenteral nutrition is delivered as intended in critically ill children needs to be clarified. A study on enterally fed critically ill children reported that the daily caloric intake was about 60% of the calorie requirement and 85% of the prescribed calories.[12] In another study conducted on pediatric patients admitted to intensive care units, the estimated energy requirement, the prescribed calories, and the delivered calories were 90 kcal/kg/day, 75 kcal/kg/day, and 58 kcal/kg/day, respectively. The ratio of calories delivered/prescribed was 77%.[13] In a prospective survey conducted by De Jonghe et al.[14], 78% of the mean caloric requirement was prescribed, and 71% was actually delivered. The amount of calories actually delivered compared with the amount prescribed was significantly lower in enteral than in

Table 2. Factors associated with the received/prescribed parenteral nutrition volume ratio

Variables	Patients received ≥0.8 of prescribed PN (n=32)	Patients received <0.8 of prescribed PN (n=41)	p value
Age, months	17.5 (4.0-67.5)	16.0 (5.5-71.5)	0.894
Gender, Male	19 (59.4)	22 (53.7)	0.625
Weight, kg	10.0 (5.3-17.3)	10.0 (5.4-17.8)	0.697
Indications for PN			
Failure to meet the targeted energy enterally	25 (78.1)	26 (63.4)	0.174
Gastrointestinal surgery	0 (0.0)	9 (22.0)	0.004
Metabolic crisis	5 (15.6)	3 (7.3)	0.287
Gastrointestinal bleeding	2 (6.3)	3 (7.3)	1.000
Duration of PN, days			
≤7	21 (65.7)	19 (46.3)	0.100
8-30	9 (28.1)	17 (41.5)	0.238
>30	2 (6.3)	5 (12.2)	0.456
RRT (n=16)	9 (28.1)	7 (17.1)	0.257
CRRT	8 (25.0)	6 (14.6)	0.264
IHD	1 (3.1)	1 (2.4)	1.000
ECMO	1 (3.1)	4 (9.8)	0.377
PRISM III (n=66)	11 (7-17)	15 (8-18)	0.382
PDR (n=66)	8.0 (4.9-21.3)	9.4 (2.9-22.5)	0.683

Data are presented as n (%) or median (25^{th} and 75^{th} percentiles).
CRRT: continuous renal replacement therapy, ECMO: extracorporeal membrane oxygenation, IHD: intermittent hemodialysis, PDR: predicted death rate, PN: parenteral nutrition, RRT: renal replacement therapy.

parenteral administration (86.8% vs. 112.4%). In summary, the delivered/prescribed amount of nutrition was 85%, 77%, and 86.8% in these three studies. Based on these studies, we determined a similar cut-off value of 80% and divided patients into two groups: those who received the prescribed volume of PN on more than 80% of PN days and those who did not. Another point worth noting is that the reasons for the interruption of EN were airway management, digestive intolerance, diagnostic procedures, and mechanical problems. Therefore, PN may provide an advantage in patients whose EN is interrupted.

We saw that we could not give the targeted volume of PN to a significant proportion of the patients included in the study. This was mainly due to hypervolemia and electrolyte imbalance. The interruption of PN for a single reason also interrupts the provision of all energy, macro, and micronutrients. Therefore, dynamically arranging the PN solution to the current clinical condition without disrupting the overall nutrition can prevent such problems. For patients with volume restriction and/or metabolic imbalance, individually prepared PN solutions in the hospital allow for a more appropriate composition in the proper volume. However, in patients with electrolyte imbalance, preparing and administering electrolytes and minerals separately from PN may prevent interruption of PN due to electrolyte and mineral imbalances. Although all patients in the study used individual PN solutions prepared with a compounder, the patients could not reach the nutritional target.

We think that RRT may be advantageous in patients with volume restriction. The present study included patients receiving intermittent hemodialysis and continuous RRT. Especially in patients receiving CRRT, the amount of ultrafiltration can be dynamically regulated so that volume restriction will not be necessary, so the nutrition of the patient can be brought closer to the optimum level. In the present study, there was no relationship between receiving RRT and receiving the PN volume effectively. This relationship should be investigated in studies with a larger patient population.

In a small number of our patients, the delay in the preparation of the PN solution resulted in the target volume not being delivered to the patients. Although individualized PN solutions prepared in the hospital provide an advantage in patients with metabolic imbalance and volume restriction, the disadvantage is that it takes time to prepare and requires teamwork and appropriate equipment.

Establishing a standard nutrition protocol with a high compliance rate for pediatric intensive care units is difficult. Compliance with the nutritional recommendations was evaluated in a prospective cohort that included 158 adult intensive care units from 20 countries, and although there was a high rate of compliance with some recommendations, such as the priority of EN, it was found that there was no compliance with the recommendations in many subjects.[3] We think it's worth trying to at least ensure that feeding is not interrupted for a preventable reason. As seen in our study, nutrition may not be given as intended in pediatric intensive care units in Turkey. If the composition of PN solutions is regulated appropriately, this problem can be overcome.

Age, gender, body weight, duration of PN, vascular access site, receiving RRT and ECMO, PRISM III score, and PDR were not associated with receiving more than 0.8 of the prescribed PN volume. We think that the heterogeneity in the patient population may have made it difficult to find an associated factor. Interestingly, however, all patients who underwent gastrointestinal surgery received all the prescribed PN volume.

This study has several limitations. It is a retrospective study with a limited number of patients, which was carried out with the participation of 5 hospitals in Türkiye. Therefore, its capacity to represent the whole country is limited. There was no written protocol on enteral and PN in the centers participating in the study. The presence of different nutritional practices in the different hospitals caused difficulties in the evaluation of the results. In the study, we presented the PRISM III and PDR scores; however, organ failure scores were not noted. Given these limitations, we invite readers to interpret the results carefully.

CONCLUSION

The intended and prescribed volume could not be delivered in about a quarter of PN-days, often due to volume restriction in critically ill children. The patient population in pediatric intensive care units is heterogeneous. Setting the correct nutritional targets, individualizing nutritional support, and preventing and overcoming obstacles on the way to the targets may improve outcomes.

Ethical approval

This study has been approved by the Dr. Sami Ulus Gynecology, Child Health and Diseases Training and Research Hospital Clinical Research Ethics Committee (approval date 17/11/2021, number E-21/11-237). Written informed consent was obtained from the participants.

Author conribution

Surgical and Medical Practices: ZÖ, ST, EK, DY, MK, MÇ, EÇD, BB; Concept: ZÖ, BB; Design: ZÖ, BB; Data Collection or Processing: ZÖ, ST, EK, DY, MK, MÇ; Analysis or Interpretation: ZÖ, BB; Literature Search: ZÖ; Writing: ZÖ, BB. All authors reviewed the results and approved the final version of the article.

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Conflict of interest

The authors declare that there is no conflict of interest.

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