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Deterioration of nutritional status at discharge in critically ill children with appropriate BMI and its association with clinical outcomes: a prospective observational study

Somayeh Dayer[1], Seyedeh Masumeh Hashemi[2], Melika Hajimohammadebrahim-Ketabforoush[1] and Zahra Vahdat Shariatpanahi[1*]

Abstract

Background To determine how nutritional status changes during critical illness in children with age-appropriate BMI at admission and evaluate its impact on clinical outcomes.

Methods 70 subjects with age-appropriate BMI between 2 and 12 years were included in the study. The Z-scores (weight, height, BMI) MUMC, Subjective Global Nutritional Assessment (SGNA), and nutritional intake were calculated on admission and discharge. The relationship between changes in nutritional status with clinical outcomes were assessed.

Results This study includes samples that all were well-nourished based on Z-scores of BMI and weight. However, based on the SGNA 45% were undernourished. All anthropometric variables decreased significantly at the time of discharge. Regression analysis adjusted by age, number of Number of organs with dysfunction at PICU admission, PIM2, and hospital days before ICU admission showed that reduced BMI-for-age was significantly associated with prolonged PICU stay (B = 2.883; CI: 1.813–3.952) and an increased duration of mechanical ventilation (B = 1.541; CI: 0.493–2.588). Every 1 cm decrease in MUAC was associated with a 3.5-fold increase in mortality risk (OR = 3.527; CI: 1.518–9.972). Delayed initiation of nutrition was significantly correlated with a prolonged PICU stay (B = 1.395; CI: 0.518–2.271) and increased duration of mechanical ventilation (B = 0.861; CI: 0.132–1.589). Malnutrition at admission, as assessed by SGNA, was also associated with longer PICU stay (B = 1.739; CI: -0.154- 2.294). Furthermore, increased protein intake during the first week was significantly associated with decrease in the need to mechanical ventilation (OR = 0.824; CI: 0.682–0.995).

Conclusion A comprehensive nutritional assessment should be performed for children admitted with an appropriate BMI, feeding should not be delayed, adequate protein intake should be ensured, and indicators such as MUAC and SGNA should be considered in addition to BMI. These measures can improve clinical outcomes and reduce complications during the PICU stay.

*Correspondence:
Zahra Vahdat Shariatpanahi
nutritiondata@yahoo.com

Full list of author information is available at the end of the article

Keywords Nutritional status, Mortality, Underfeeding, PIM2, SGNA

Introduction

Malnutrition in the Pediatric Intensive Care Unit (PICU) complicates and prolongs the medical treatment of children. Malnutrition increases both mortality and morbidity [1]. More importantly, many children who are admitted with adequate nutritional status become under-nourished during their stay in the ICU and are discharged with malnutrition [2]. This issue can lead to long-term sequelae and increased mortality after discharge, as well as a higher likelihood of readmission [3].

The prevalence of under-nutrition in PICU has been reported to range from 8.1 to 71.7%, depending on the population studied, comorbidities, age, and severity of illness [4–6]. A number of studies have investigated the nutritional status of critically ill children at the time of discharge by measuring body mass index and weight [7–12]. These studies have shown that the nutritional status of 10.2–22% of children deteriorates upon discharge [7–11]. However, the lack of standardization in the cut-off points used to determine nutritional status deterioration makes it challenging to ascertain the true prevalence of this issue.

There are several factors contributing to the deterioration of the nutritional status of a critically ill child. These factors include the disease itself and its associated catabolic state, additional infections, dysfunction of the digestive system, and inadequate nutrition [9]. In the present study, we selected children with age-appropriate Body Mass Index (BMI) at the time of admission to investigate how their nutritional status changed during critical illness. Consequently, we measured anthropometric indices and conducted a Subjective Global Nutritional Assessment (SGNA) at both admission and discharge. SGNA is a comprehensive tool for evaluating nutritional status in children, incorporating clinical history, dietary intake, and physical examination. Unlike BMI, which is primarily calculated based on weight and height and may not adequately reflect functional or clinical signs of malnutrition, SGNA provides a broader perspective on nutritional risk. Its multidimensional nature makes it especially valuable in detecting malnutrition in critically ill patients and serves as an important complement to anthropometric indicators in this study. Additionally, we recorded and analyzed caloric intake, protein intake, feeding methods, and the timing of feeding initiation throughout their stay in the PICU. Other outcomes included examining the impact of changes in nutritional variables on clinical outcomes.

Materials & methods

Study design and ethics

This prospective observational study was conducted in a mixed Pediatric Intensive Care Unit (PICU) at a university-affiliated hospital from March 2024 to September 2024. Informed consent was obtained from the parents of the patients. The study received approval from the ethics committee and was carried out in accordance with the ethical standards outlined in the 1964 Declaration of Helsinki and its subsequent amendments.

Study population

We included consecutive children who were enrolled within 24 h of their admission to the ICU. The inclusion criteria consisted of critically ill children aged 2 to 12 years with an appropriate BMI for their age, defined as a BMI-for-age z-score greater than −2. Furthermore, these children had not participated in any interventional studies in the 30 days prior to enrollment. The exclusion criteria included discharge or death occurring within 48 h of admission.

Data collection

Demographic information was obtained from the patients' medical records. Anthropometric data, including height, weight, BMI at both admission and discharge from the PICU, along with their corresponding Z-scores, were extracted and documented from patient files. All measurements were performed by a trained staff member to ensure consistency throughout the data collection process. A single calibrated SECA scale was used for both admission and discharge weights. Mid-upper arm circumference (MUAC) was measured at both admission and discharge from the PICU. MUAC was assessed using a calibrated tape on the non-dominant arm (typically the left) at the midpoint between the shoulder and the elbow. The tape was gently wrapped around the arm, and the measurement was recorded to the nearest 0.1 cm. Each measurement was taken twice, and the average of the two values was reported as the final result.

Standard scores for weight, height, and BMI-for-age were calculated using the CDC growth charts. In this study, undernutrition was defined as a Z-score < -2 BMI-for-age. The severity of illness was estimated using the Pediatric Index of Mortality 2 (PIM2), which was measured within the first 24 h of admission. The PIM2 score was calculated using the Medscape online tool.

The Subjective Global Nutritional Assessment (SGNA) questionnaire was first introduced in 1982 by Baker et al. In 1987 [13], Detsky et al. refined and presented the method in a more comprehensive manner [14, 15]. Later, in 2007, Secker et al. developed a version of this tool specifically for pediatric populations [16]. Nutritional status was also assessed using the SGNA questionnaire at both admission and discharge. During the hospital stay, we recorded the intake of calories and protein, the method of feeding (enteral, parenteral, oral, or mixed), and the day feeding was initiated.

The daily dietary intake of the children was recorded and compared with their basal energy requirements, which were estimated using the Schofield equation. Additionally, according to established guidelines, the minimum protein requirement for children in the PICU is 1.5 g/kg of body weight. The average protein intake of the children was compared to this benchmark value [17]. The timing of feeding initiation and the method of feeding were also documented. Throughout their hospital stay, patients were monitored for various outcomes.

Outcomes

The primary outcome was the change in nutritional status during the PICU stay. The secondary outcomes included the relationship between changes in nutritional status and clinical outcomes, such as length of PICU stay, dependence on ventilation, duration of ventilation dependence, mortality, 28-day mortality, occurrence of Multi organ dysfunction, and readmission within one month. Multi organ dysfunction was defined as the presence of dysfunction in two or more organ systems, according to the criteria proposed by Goldstein et al. [18].

Statistical analysis

SPSS software (Chicago, IL, USA) was used for data analysis. All hypothesis tests were two-tailed, with a significance level set at $P < 0.05$. Quantitative variables are presented as mean ± standard deviation, while qualitative variables are expressed as frequency (percentage). To compare qualitative variables between two groups, the Chi-square test was employed. For quantitative variables, the Paired T-test was used. Logistic and linear regression analyses, while controlling for potential confounding variables, were utilized to assess the relationship between nutritional status and binary outcomes. A linear regression analysis, controlling for potential confounding variables, was conducted to evaluate the relationship between nutritional status and quantitative clinical outcomes.

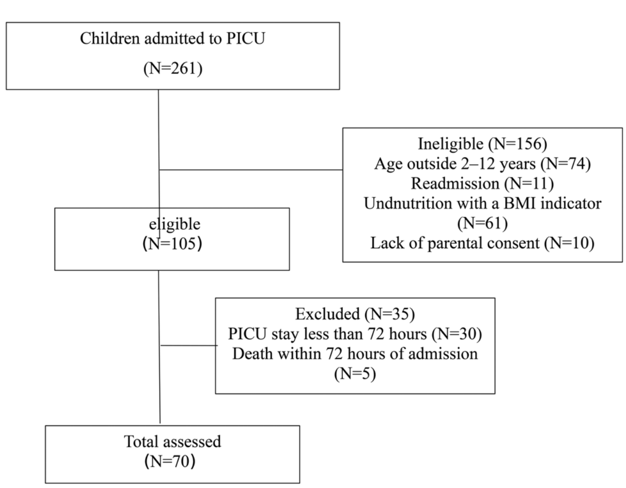

Fig. 1 Flowchart of patients

Results

A total of 261 children admitted to the ICU were screened, of whom 105 met the inclusion criteria. After further exclusions, 70 patients were included in the final analysis, as shown in Fig. 1. The baseline characteristics and general information of the children are presented in Table 1. At admission, participants were in good nutritional condition based on BMI-for-age and weight-for-age Z-scores. However, based on the SGNA, 55% of the participants were identified as not malnourished, while 45% exhibited moderate malnutrition. All anthropometric variables decreased significantly at the time of discharge (Table 2).

Anthropometric data and clinical outcomes

The primary and main results of this study relate to anthropometric data and their association with clinical outcomes. All anthropometric variables, including weight, Z-score weight, BMI, Z-score BMI, and MUAC, significantly decreased at the time of discharge (Table 2).

Changes in anthropometric variables were analyzed in relation to binary and quantitative clinical outcomes. MUAC change was the only anthropometric parameter that significantly predicted ICU mortality, where each 1 cm decrease in MUAC was associated with a 3.5-fold increase in mortality risk (OR = 3.527; 95% CI: 1.518–9.972; $p = 0.038$). Additionally, increased days of hospitalization prior to ICU admission was significantly associated with a higher likelihood of mechanical ventilation (OR = 1.298; 95% CI = 1.046–1.610; $p = 0.018$), and higher PIM2 scores were associated with greater odds of one-month readmission (OR = 1.137; 95% CI = 1.013–1.277; $p = 0.029$) (Table 3).

Regarding quantitative clinical outcomes, BMI change emerged as the only anthropometric predictor significantly associated with both the length of PICU stay and duration of mechanical ventilation. Each 1 unit decrease in BMI was associated with a 2.8-day increase in PICU stay (B = 2.883; 95% CI = 1.813–3.952; $p < 0.001$) and a 1.5-day increase in mechanical ventilation duration (B = 1.541; 95% CI = 0.493–2.588; $p = 0.006$). Number of organs with dysfunction at PICU admission and PIM2 were also significant predictors for length of PICU stay and duration of mechanical ventilation, respectively (Table 4).

Table 1 Characteristics of subjects ($n = 70$)

Age, months	70.96 ± 34.11
Sex, male	42(60)
Height, cm	99.70 ± 16.17
Weight, kg	19.91 ± 6.13
MUAC, cm	16.53 ± 2.79
Calorie intake - week1,kcal/day	521.10 ± 199.01
Protein intake - week1,gr/day	14.84 ± 7.10
Energy intake Ratio - week1,%	72.02 ± 29.25
Protein intake Ratio - week 1,%	52.27 ± 21.91
Time of start feeding	
<72 h	60 (85.7)
>72 h	10 (14.3)
Nutritional route	
EN	11(15.7)
PO	5 (7.1)
EN + PN	23(32.9)
PO + PN	30(42.9)
PO + PN + EN	1(1.4)
Disease category	
Respiratory	22(31.4)
GI	8(11.4)
Sepsis	1(1.4)
Neurologic	17(24.3)
Heart	1(1.4)
Cancer	17(24.3)
Other	4(5.7)
PIM2	10.32 ± 10.38
CRP	16.95 ± 18.00
Albumin (g/dL)	3.10 ± 0.54
Days to ICU admission	4.41 ± 4.78
Multi-organ dysfunction	35(50)
Number of organs with dysfunction	1.77(1.119)
Type of organdysfunction	
Heart	7(10)
Neurologic	36(51.4)
Respiratory	41(58.6)
Hematologic	8(11.4)
Liver	16(22.9)
Kidney	12(17.1)
Mechanical ventilation need	28(40)
Mechanical ventilation duration (Day)	4.00 ± 2.94
PICU length of stay (Day)	6.57 ± 4.29
Mortality	9(12.9)
1 month readmission	10(14.3)

MUAC, Mid-upper arm circumference; EN, Entral Nutrition; PO, Per oral; PN, Parenteral Nutrition; GI, Gastrointestinal; PIM2, Pediatric Index of Mortality 2; PICU, Pediatric intensive care unit;

Data are presented as Mean(SD) or n(%)

Nutritional data and clinical outcomes

In addition to the main outcomes, this study also evaluated nutritional data and related clinical outcomes as secondary results. Nutritional variables included the timing of feeding initiation, average energy and protein intake

Table 2 Anthropometric & nutritional data comparisons based on admission and discharge values

Anthropometric & Nutritional Data	Admission	Discharge	*P*-value
Weight, kg	19.917 ± 6.133	18.625 ± 5.992	< 0.001*
Z-score weight	-0.229 ± 1.139	-0.724 ± 1.341	< 0.001*
BMI, kg/m^2	16.168 ± 1.926	15.332 ± 2.134	< 0.001*
Z-score BMI	0.056 ± 1.120	-0.762 ± 1.870	< 0.001*
MUAC, cm	16.538 ± 2.794	15.254 ± 1.763	< 0.001*
SGNA, n(%)			< 0.001**
Well-nourished	38 (54.3)	20 (28.6)	
Mild to moderate malnourished	32 (45.7)	36 (51.4)	
Severe malnourished	0 (0)	14 (20)	

BMI, body mass index; MUAC, Mid-upper arm circumference; SGNA, Subjective Global Nutritional Assessment

* Paired t- test. ** Chi-square test

Table 3 Predictive value of anthropometric data for binary clinical outcomes in the unadjusted & adjusted logistic regression model

Predictor	Unadjusted analysis		Adjusted analysis	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Weight change[a]	1.344 (0.573–3.150)	0.497	2.871 (0.485–6.998)	0.497
Weight change[b]	1.110 (0.505–2.439)	0.795	5.490 (0.005–10.771)	0.996
BMI change[c]	2.892 (0.459–8.222)	0.258	1.284 (0.124–3.306)	0.834
Z-score BMI change[c]	1.434 (0.625–3.288)	0.394	1.373 (0.401–4.705)	0.614
Weight change[c]	1.220 (0.395–3.771)	0.730	1.795 (0.305–5.556)	0.518
MUAC change[d]	2.949 (3.548–7.618)	0.008	3.527 (1.518–9.972)	0.038

BMI, body mass index; MUAC, Mid-upper arm circumference

Model had been full adjusted for the following variables: age, Number of organs with dysfunction at PICU admission, PIM2, and hospital days before admission to ICU

[a] Dependent variable was mechanical ventilation need

[b] Dependent variable was occurrence of multi-organdysfunction

[c] Dependent variable was one month's readmission after discharge

[d] Dependent variable was mortality

Table 4 Predictive value of anthropometric data for quantitative clinical outcomes in the linear regression models

Predictor	Unadjusted analysis		Adjusted analysis	
	B (95% CI)	*p*-value	B (95% CI)	*p*-value
BMI change[a]	2.885 (1.812–3.957)	< 0.001	2.883 (1.813–3.952)	< 0.001
BMI change[b]	1.933 (0.927–2.938)	0.001	1.541 (0.493–2.588)	0.006

BMI, body mass index

Model had been full adjusted for the following variables: age, Number of organs with dysfunction at PICU admission, PIM2, and hospital days before admission to ICU _ results have been reported in the stepwise method

[a] dependent variable was the length of ICU stay

[b] dependent viable was the mechanical ventilation duration

during the first week of PICU admission, nutritional route, and SGNA classification at both admission and discharge.

In logistic regression analyses, average protein intake during the first week was significantly associated with the need for mechanical ventilation. While this relationship was not significant in the unadjusted model, it became significant in the adjusted model, where each 1 g/day increase in protein intake reduced the odds of requiring mechanical ventilation by 18% (OR = 0.824; 95% CI = 0.682–0.995; $p = 0.044$).

Regarding quantitative outcomes, delayed initiation of feeding (greater than 72 h) was significantly associated with prolonged PICU stay (B = 1.395; 95% CI = 0.518–2.271; $p = 0.002$) and increased duration of mechanical ventilation (B = 0.861; 95% CI = 0.132–1.589; $p = 0.023$). SGNA score at admission showed a marginal association with prolonged PICU stay in the unadjusted model ($p = 0.051$), but this effect was attenuated after adjustment ($p = 0.131$).

Discussion

Assessment of nutritional status upon admission

The results of the present study indicate that, despite having an normal BMI for age at admission, many children experienced significant decreases in anthropometric indices, including weight, BMI, and MUAC during their hospitalization. The BMI-for-age index is a widely used criterion for assessing nutritional status in children, as recommended by American Society of Parenteral and Enteral Nutrition for evaluating malnutrition in PICU. However, this index primarily reflects current nutritional status and may overlook chronic latent malnutrition. The SGNA questionnaire, which incorporates medical history, physical examinations, and dietary patterns, offers a more comprehensive evaluation and can detect chronic malnutrition that may be overlooked by the BMI-for-age index. Despite favorable anthropometric indices at admission in this study, 45% of children experienced some degree of malnutrition, emphasizing the importance of combining SGNA with anthropometric measures for a more thorough assessment and improved clinical interventions in PICU settings.

Anthropometric data and clinical outcomes

The primary objective of this study was to evaluate the deterioration of nutritional status based on anthropometric indicators and its association with clinical outcomes in PICU patients. The findings demonstrated that in this study, changes in anthropometric indicators such as BMI, MUAC, and weight were significantly associated with specific clinical outcomes in patients admitted to the PICU. Specifically, a decrease in BMI during hospitalization correlated with an extended length of stay in the PICU. Furthermore, a reduction in the Z-score of BMI for age was linked to an increased duration of mechanical ventilation dependence among the patients. Regarding changes in MUAC, the results indicated that a 1 cm decrease in MUAC was associated with a 3.5-fold increase in the risk of mortality. These findings are consistent with similar studies, such as those by Misirlioglu (2023) and Ventura (2020), which identified MUAC as a strong predictor of mortality in the PICU [3, 9]. In terms of weight changes, weight loss was also associated with a longer PICU stay and increased dependence on mechanical ventilation. Additionally, this study provided evidence of a connection between weight loss and readmission, which may be attributed to the 30-day follow-up period used to assess long-term outcomes, potentially yielding more accurate results.

Overall, this study suggests that, in addition to routine anthropometric indicators for evaluating nutritional status and determining nutrition protocols in the PICU, a comprehensive, multidimensional approach using various tools such as MUAC and SGNA should be employed. This recommendation is based on the fact that SGNA is more effective at identifying acute malnutrition than BMI, and that MUAC is instrumental in the early detection of malnutrition in children within the PICU. Furthermore, MUAC provides valuable insights into a child's nutritional status, muscle mass, and fat reserves. This method is simple, quick, non-invasive, and cost-effective, making it suitable not only for assessment but also for monitoring nutritional status, which contributes to improved prognosis and a reduced length of stay in the ICU [19].

Finally, children who are not in optimal nutritional status according to MUAC or SGNA require special attention. For this group, it is recommended that energy and protein intake be rapidly increased to target levels, accompanied by continuous and precise nutritional monitoring, rather than focusing solely on BMI. To achieve the best outcomes in improving health status and prognosis, it is essential to utilize a variety of comprehensive tools for assessing nutritional status and adjusting nutritional protocols.

Nutritional intake and clinical outcomes

Although nutritional intake variables were considered secondary outcomes, their analysis provided valuable insights into factors contributing to adverse clinical outcomes. The nutritional status of children admitted to the PICU was evaluated based on the timing of nutrition initiation, feeding method, and energy and protein intake, along with its association with clinical outcomes. In this study, 85% of children began feeding after 72 h of admission. The timing of nutrition initiation was significantly associated with outcomes such as the length of PICU stay and the duration of mechanical ventilation. Early feeding (within 72 h) is recommended, as it can enhance the patient's nutritional status and prevent muscle wasting. However, challenges such as feeding intolerance may arise in critically ill patients. Mehta et al. (2017) demonstrated that initiating nutrition within 72 h can reduce mortality and hospital-acquired infections [17], while Ventura et al. (2020) reported that delayed feeding leads to a decline in nutritional status and muscle wasting [20]. Although this study found that the timing of feeding initiation and malnutrition status at discharge, based on SGNA are associated with readmission within one month. In the unadjusted model, both factors exhibited a significant relationship with readmission; however, after controlling for confounding variables, the association with feeding initiation was not significant. These results suggest that both the timing of feeding initiation and malnutrition status at discharge may influence readmission within one month. Nevertheless, further research and more precise control of other factors are needed to confirm and better understand these relationships.

Nutritional status at admission, assessed using the SGNA questionnaire, was associated with a prolonged length of stay in the PICU. A study by Jingjing Li (2020) also reported a similar association between nutritional status at PICU admission and extended hospitalization duration [21].

Regarding feeding methods, no significant association was observed between various feeding methods and clinical outcomes. However, enteral nutrition is generally preferred due to its advantages, which include a reduced risk of infections and improved nitrogen balance. Of course, we did not have any cases of total parenteral nutrition in our study. Grippa et al. (2017) demonstrated better clinical outcomes with enteral nutrition compared to parenteral nutrition [22], and Ventura et al. (2020) emphasized the benefits of enteral nutrition in preventing infections [11]. In terms of energy intake, the recommended energy intake during the first week is %70 of the energy derived from the Schofield Eq. (17). Studies have shown that energy intake during the first week varies and falls within the range of 62–84% of the studies have shown that energy intake during the first week varies and falls within the range of 62–84% of the recommended values. In the present study, the mean energy intake during the first week was 70% of the recommended values [23]. Previous studies have also shown that overfeeding can extend the time patients require mechanical ventilation. One possible explanation for this phenomenon is that excessive energy intake increases carbon dioxide (CO_2) production, which can exacerbate ventilator dependency [24]. On the other hand, Li et al. (2020) found that malnutrition and inadequate energy intake are associated with prolonged PICU stays. Grippa et al. (2017) highlighted the importance of optimizing energy intake in critically ill patients [22]. Therefore, in critically ill patients, it is essential to not only address underfeeding, but also to avoid overfeeding to minimize the risks associated with prolonged ventilator dependency.

In terms of protein intake, studies have shown that during the first week of admission to the PICU, protein intake ranges between 55% and 72% of the recommended daily intake (1.5 g/kg/day). This deficiency is associated with a decrease in muscle mass, which can range from 3 to 13.3%. These findings underscore that protein intake consistently falls below the recommended levels. In the present study, the mean protein intake during the first week was only 52.2% of the recommended amount, indicating inadequate protein provision during this critical period. Potential reasons for this deficiency include enteral intolerance, frequent fasting for medical procedures, delayed initiation of feeding, and electrolyte imbalances [23]. Additionally, a significant association was observed between protein intake and the need for mechanical ventilation. Children admitted to the PICU often enter a catabolic phase, leading to a negative protein balance. While increasing protein intake alone may not achieve a positive protein balance, adequate intake can help prevent muscle breakdown, particularly in cardiac and respiratory muscles. The deterioration of these muscles can contribute to increased mortality rates. Mehta et al. (2017) emphasized the importance of sufficient protein intake in preventing muscle loss and improving clinical outcomes [17], while Grippa et al. (2017) linked inadequate protein intake to an increased need for mechanical ventilation [22].

Conclusion

This study demonstrated that a reduction in BMI-for-age was significantly associated with prolonged PICU stay and an increased duration of mechanical ventilation. Every 1 cm decrease in MUAC was associated with a 3.5-fold increase in mortality risk. Delayed initiation of nutrition was significantly correlated with a prolonged PICU stay and an increased duration of mechanical ventilation. Malnutrition at admission, as assessed by SGNA, was also associated with longer PICU stay. Furthermore, increased protein intake during the first week was significantly associated with reduced duration of mechanical ventilation. Although this study recommends that a comprehensive nutritional assessment be conducted for patients admitted with an appropriate BMI, nutrition should not be delayed, adequate protein intake must be ensured, and indicators such as MUAC and SGNA should also be considered alongside BMI. These measures can enhance clinical outcomes and reduce complications during PICU stays.

Abbreviations

BMI Body Mass Index
EN Entral Nutrition
MUAC Mid-Upper Arm Circumference

PICU	Pediatric Intensive Care Unit
PIM2	Pediatric Index of Mortality 2
PO	Per Oral
PN	Parenteral Nutrition
SGNA	Subjective Global Nutritional Assessment

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Author contributions
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by S.D, M.H, M.H, and Z.V. The first draft of the manuscript was written by S.D and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability
Data will not be made available in a public repository as we have not obtained ethical clearance to share data publicly. However, on request from corresponding author data could be provided while maintaining anonymity.

Declarations

Ethics approval and consent to participate
Ethical approval for the study was obtained from the Research Ethics Committee of National Nutrition and Food Technology Research Institute of Shahid Beheshti University of Medical Sciences. it was carried out in accordance with the Declaration of Helsinki of the World Medical Association. Before beginning the intervention, informed consent was obtained from the patients or their legal representative.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Clinical Nutrition and Dietetics, Faculty of Nutrition and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Baran, West Arghavan Farahzadi Blvd., Shahrak Qods, PO Box: 19395-4741, Tehran 1981619573, I. R., Iran
[2]Department of Critical Care, Mofid Children's Hospital, Faculty of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran

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