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Nutritional Support of Critically ill Neonates in Post-Gastrointestinal Surgery State: Adequacy and Barriers

Abbas Boskabady[1*], Zahra Dehnavi[2*], Gholamreza Khademi[1], Mohsen Nematy[2], Habibollah Esmaily[4], Fatemeh Roudi[2, 3]**

1. Department of Pediatrics, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
2. Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
3. Student Research Committee, Mashhad University of Medical Sciences, Mashhad, Iran
4. Social Determinants of Health Research Center, School of Health, Mashhad University of Medical Sciences, Mashhad, Iran

ABSTRACT

Background: The optimum nutritional support of critically ill neonates is considered an essential aspect of their medical management since they are susceptible to rapid nutritional depletion, loss of fat-free mass, organ failure, delayed wound healing, and diminished immune function in the post-gastrointestinal surgery state. Providing appropriate nutritional support for these high-risk patients is a very complex and critical process accompanied by many potential errors. To the best of our knowledge, this study has been the first attempt investigating the energy and protein adequacy and probable barriers to the achievement of nutritional goals in such patients.
Methods: The present study was carried out at Akbar Children's Hospital in Mashhad, Khorasan Razavi province, Iran, during 8 months in 2019. All the gastrointestinal surgical patients admitted to the neonatal intensive care unit (NICU) for at least 72 h were eligible for enrollment in the study. The information on age, gender, primary surgical diagnosis, route of nutritional support, adequacy of received energy and protein, probable barriers to the achievement of nutritional goals, and clinical outcomes were collected in this study.
Results: Totally, 59 eligible neonates were included in the study 59.3% (n=35) of whom were male. Among different methods of nutritional support, enteral nutrition (47.5%) was the most frequently used feeding route. Energy and protein adequacy was observed in 35.5% and 79.7% of the patients, respectively. The fluid restriction was the major barrier to the provision of optimum nutritional support, affecting 38.9% of the patients. Finally, nutritional adequacy was observed to be significantly associated with decreased infection rate and length of hospital stay.
Conclusion: While 64.5% of the studied neonates did not receive adequate energy, almost 80% of them had adequate protein intake during their post-gastrointestinal surgery state. The awareness of the fluid restriction and non-availability of calorie-dense solutions as the most frequent barriers to the achievement of nutritional goals may lead to making reasonable and realistic decisions on the customized protocols of the NICU patients as well as medical management and insurance coverage of required nutritional products.

Keywords: Gastrointestinal surgeries, Neonatal intensive care units (NICUs), Nutrition support, Nutritional adequacy

Introduction

Malnutrition is among the main causes of death in neonates, infants, and children, leading to the death of more than one-third of under-five children worldwide (1). Especially, critical illnesses in neonates are highly associated with malnutrition and deterioration of the clinical condition. On the other hand, the synergic effect of malnutrition and acute phase response to stress may aggravate the negative energy balance and loss of fat-free mass (FFM) associated with increased mortality, multi-organ dysfunction, prolonged mechanical ventilation, and intensive care unit (ICU) stay (2-4).

Neonatal physiology is markedly different from that of adults and pediatric patients because the neonates' metabolic pathways are immature,

* *First author:* Abbas Boskabady, Zahra Dehnavi
** *Corresponding author*: Fatemeh Roudi, Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran. Tel: +985138002423; Fax: +985138002421; Email: RoudiF951@mums.ac.ir

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and nutrient stores are limited (5). Therefore, critically ill neonates are susceptible to rapid nutritional depletion, contributing to the muscle wasting, disruption of vital organ function, delayed wound healing, and diminished immune function (6-8).

Moreover, insufficient nutritional support is associated with neurodevelopmental and neurocognitive delays, contributing to parental frustration, anxiety, and disappointment (9, 10). Therefore, the optimum nutritional support of critically ill neonates is of especial importance due to their growth and development in this period (11, 12). Providing appropriate nutritional support for high-risk neonates admitted to a neonatal intensive care unit (NICU) is a very complex and critical process accompanied by several potential challenges due to the necessity of individualized nutritional support of such patients (13).

Enteral nutrition (EN) is the preferred route for nutritional support in the neonates with a functional gastrointestinal tract in the NICU, and human milk is preferred as the recommended source of EN due to its several health benefits (14, 15). In some situations where the application of EN is limited or impossible, parenteral nutrition (PN) is considered a vital treatment (16). Previous studies carried out on the nutritional support of critically ill children reported that several factors may disrupt feeding in the ICU, including feeding intolerance, gastric ileus, several situations of gastrointestinal tract dysfunctions, required fasting state for some diagnostic/therapeutic procedures, and restriction of the fluid intake (17-20).

Critically ill neonates undergoing congenital gastrointestinal surgeries are more susceptible to be underfed in the NICU, and they are considered a high-risk group nutritionally depleted in the NICU stay period. Therefore, this study was conducted to investigate the adequacy of energy and protein delivery and probable barriers to the achievement of nutritional goals in the neonates undergoing gastrointestinal surgeries in the NICU. The awareness of the most frequent barriers to the achievement of nutritional goals may lead to making reasonable and realistic decisions on the customized protocols of NICU patients which in turn results in the improvement of medical management and our intensive care services.

Methods

This cross-sectional study was carried out at Akbar Children's Hospital in Mashhad, Khorasan Razavi province, Iran, a university-affiliated, tertiary-level, pediatric hospital with a 10-bed NICU. All the gastrointestinal surgical patients admitted to the NICU for at least 72 h were eligible for enrollment in the study. Informed written consent was obtained from all the parents of the enrolled infants. The data were collected within February 2018 and August 2019.

The information on age, gender, primary diagnosis, route of nutrition support, mean of delivered energy and protein in the 3rd to 7th days of NICU stay, and probable barriers to the achievement of nutritional goals were retrospectively collected in this study. The Schofield Equation (59.5 [weight in kg]-30 for boys and 58.3 [weight in kg]-31 for girls] was used to determine the basal energy requirement for such patients, and additional stress factors were applied based on the clinical condition of each patient (21).

The European Society for Parenteral and Enteral Nutrition, American Society for Parenteral and Enteral Nutrition, and European Society for Pediatric Gastroenterology, Hepatology, and Nutrition guidelines were used to calculate the adequate intake of the energy and protein based on age, weight, gender, severity of the disease, and route of nutrition. The patients received breast milk or standard neonatal formula by enteral route in the form of 2-hour boluses and standard hospital solutions, including amino acid, intra-lipid, and dextrose solutions (i.e., water-soluble vitamins and trace elements, if needed), were given to them by parenteral route.

Energy and protein adequacy was defined as the achievement of at least two-thirds of the individually determined goals regarding energy and protein requirements at the end of the first week of NICU stay (22). Gastric residual greater than 1.5 times the total two-hour rate of infusion was defined as large gastric residual volume (GRV). Any sudden increase in the fluidity, volume, or frequency of the patients' defecation was defined as diarrhea, and aspiration was considered positive 4 h after feeding. The patients who were limited to receive less than 80% of their daily fluid requirements were considered fluid restricted patients.

Additionally, the clinical outcomes of all the patients, including the length of ICU and hospital stay, 28-day mortality, duration of ventilator dependency, and possible infections (e.g., hospital-acquired and ventilator-associated pneumonia and systemic inflammatory response syndrome), were recorded. Regarding the aforementioned clinical outcomes, if the patients were discharged before the 28th day of the post-operation period, then, they were followed up until the 28th post-operation day; otherwise, they were followed up until the end of the hospitalization period.

SPSS software (version 20) was used for data analysis. The significance value of less than 0.05 and a confidence interval of 95% were considered for all the analyses. The demographic characteristics of the studied patients were presented in the form of appropriate tables using descriptive statistics. The normality of the data was evaluated through the Kolmogorov-Smirnov test. Normally distributed data were described by mean±standard deviation (SD), and non-parametric data were described using the median (i.e., interquartile range [IQR]) for quantitative data. Moreover, qualitative data were described using numbers and percentages. Finally, the Spearman test was used to investigate the correlations between nutritional intake indices (i.e., energy and protein adequacy and intake) and recorded clinical outcomes.

Results

In the present study, 59 patients with a mean age of 6±8.3 days were studied. Among the patients, there were 35 (59.3%) male and 24 (40.7%) female patients. Table 1 shows the baseline characteristics of the studied patients. The mean values of weight and height of the critically ill neonates following gastrointestinal surgeries were 2.9 kg (SD=0.49) and 49.9 cm (SD=2.3), respectively. The patients enrolled in our study were diagnosed as surgical candidates due to several causes, including intestinal atresia (n=22), obstruction (n=14), esophageal atresia (n=9), imperforate anus (n=6), gastroschisis (n=3), malrotation (n=3), and congenital diaphragmatic hernia (n=2).

Among different methods of nutritional support in the NICU, EN (47.5%) was the most frequently used feeding route, followed by the combination of enteral and parenteral (33.9%), and total PN (18.6%). Energy and protein adequacy was observed in 35.5% and 79.7% of the patients, respectively (Table 2).

Table 3 shows the prevalence of different barriers to the achievement of nutritional goals. Among different probable barriers investigated in this study, the fluid restriction was the major barrier to the provision of optimum nutritional support, affecting 38.9% of the patients. The non-availability of calorie-dense solutions was the second major barrier, occurring in 27.1% of the patients. Other barriers to the achievement of determined nutritional goals were prolonged pre- and post-operative fasting, including surgical procedures and imaging, affecting 11.9% and 5.1% of the patients, respectively. Among the gastrointestinal problems leading to a brief interruption of feeding, distention was the most frequent gastrointestinal problem, affecting 10.2% of the patients, followed by vomiting (8.5%), large GRV (6.7%), and diarrhea (5.1%) (Table 3).

As it is shown in Table 4, the obtained results of the present study showed that infection occurred in 5.08% of the patients (n=3), and the frequency of NICU mortality and 28-day mortality was equal to 6.8% (n=4) similarly. The median lengths of the hospital and NICU stay were equal to 12 (IQR=3.5) and 10 (IQR=5) days, respectively. Additionally, the median duration of mechanical ventilation in the patients was equal to 3 days (IQR=3). According to the recorded clinical outcomes, there was no relationship between the energy and protein intake and NICU and 28-day mortality; however, lower energy intake was significantly associated with higher infection rate, longer duration of mechanical ventilation, and longer length of NICU stay (P≤001, P≤0.005, and P≤0.07, respectively). Moreover, protein intake

Table 1. Baseline characteristics of studied patients

Number	Variable	Value
1	Age (day)	6±8.3 [a]
2	Weight (kilogram)	2.9±0.49
3	Height (centimeter)	49.9±2.3
4	Gender (male)	35 (59.3) [b]
5	Surgical disease	
	Esophageal atresia	9 (15.3)
	Congenital diaphragmatic hernia	2 (3.4)
	Intestinal atresia	22 (37.3)
	Malrotation	3 (5.1)
	Obstruction	14 (23.7)
	Gastroschisis	3 (5.1)
	Imperforated anus	6 (10.2)

a: Data expressed as mean±standard deviation; b: Frequency of data expressed as number of patients (%)

Table 2. Nutritional support indices

Number	Variable	Number of patients (%)
1	Feeding route	
	Enteral	28 (47.5)
	Enteral + Parenteral	20 (33.9)
	Parenteral	11 (18.6)
2	Energy adequacy	21 (35.5)
3	Protein adequacy	47 (79.7)

Table 4. Clinical outcomes

Variable	Value
Infection	3 (5.08)
Intensive care unit mortality [a]	4 (6.8)
28-day mortality [a]	4 (6.8)
Length of ventilator dependency [b]	3 (3)
Length of intensive care unit stay [b]	10 (5)
Length of hospital stay [b]	12 (3.5)

a: Frequency of data expressed as number of patients (%):
b: Data expressed as median (i.e., interquartile range)

Table 3. Barriers to achievement of nutritional goals

Barrier	Frequency (%)
Fluid restriction	23 (38.9)
Non-availability of calorie-dense solutions	16 (27.1)
Vomiting	5 (8.5)
Large gastric residual volume	4 (6.7)
Distention	6 (10.2)
Diarrhea	3 (5.1)
Imaging	3 (5.1)
Surgical procedures	7 (11.9)
Other	2 (3.4)

was inversely associated with the infection rate, duration of mechanical ventilation, and length of hospital and NICU stay (P=0.004, P=0.02, P=0.009, and P=0.03, respectively).

Discussion

Optimal nutritional support is considered a pivotal component of neonatal intensive care to achieve an acceptable status for the delivery of the nutrients, especially adequate energy and protein, to maintain a positive nitrogen balance ameliorating the organ function and disease recovery in the NICU patients (23). Minimizing the morbidities and growth retardation in addition to maintaining FFM in critically ill neonates is of particular importance highlighting the special attention to the early and optimum delivery of energy and nutrients in such patients (24). Failure to provide adequate nutritional support during a prolonged course of critical illness in the neonates or infants may contribute to further deterioration of nutritional indices, malnutrition, and poor clinical outcomes (25).

There are numerous barriers to provide optimal nutritional support for critically ill neonates following major gastrointestinal surgeries, impeding the adequate delivery of nutrients and contributing to malnutrition and other related complications (26). To the best of our knowledge, this study has been the first attempt investigating the adequacy of energy and protein delivery and probable barriers to the achievement of nutritional goals in critically ill neonates who underwent gastrointestinal surgeries in the NICU.

Our results showed that 35.5% and 79.7% of the patients received adequate calorie and protein, respectively. On the contrary, in a study carried out by Judith et al. on the critically ill children, it was reported that only 24.2% and 13.0% of the patients received adequate calorie and protein, respectively (27). The aforementioned values were lower than the calorie and protein adequacy obtained in our study in critically ill neonates who underwent gastrointestinal surgeries. The higher nutritional adequacy of critically ill neonates in comparison to that reported for the critically ill children may be probably due to the special attention of neonatologists to provide energy and protein for their patients because of the particular dramatic effect of this issue on the clinical outcomes.

On the other hand, our results demonstrated that suboptimal energy delivery was greater than suboptimal protein delivery in the studied neonates. According to the literature, no similar study was found investigating the nutritional adequacy in the critically ill neonates following gastrointestinal surgeries and even critically ill neonates admitted to the NICU due to internal diseases.

However, our findings are inconsistent with the results of previous studies on critically ill children in the pediatric intensive care units (PICUs) showing that insufficient protein delivery was significantly greater than suboptimal energy delivery (27, 28). In this regard, it has been reported that the development of critical illness is related to higher basal metabolic rate and protein break down, and the patients in the neonatal period are susceptible to loss of lean body mass, including cardiac, respiratory, and skeletal muscles, contributing to delayed recovery and post-discharge poor clinical outcomes. Therefore, adequate energy and protein delivery are important to prevent these stress-induced changes (3, 26, 29).

Various treatments and interventions implemented in the ICUs often barricade adequate delivery of the nutrients in the critically ill neonates and children (26). Among different probable barriers investigated in this study, the fluid restriction was identified as the major barrier to the provision of optimal nutritional support, affecting 38.9% of the patients. Other important barriers to the provision of optimum nutrient delivery were the non-availability of calorie-dense solutions (mostly due to the non-coverage of the insurances), medical procedures, and some gastrointestinal problems. Among gastrointestinal problems leading to a brief interruption of feeding, distention was the most frequent gastrointestinal problem in this study.

Similarly, Elizabeth et al. have introduced the fluid restriction as the major barrier to the achievement of Estimated Energy Requirement in the critically ill children and infants, which affected almost all the patients undergoing cardiac surgeries and almost half of the non-cardiac patients. Additionally, procedures and gastrointestinal intolerance were other causes of the interruption of feeding in this study (20). However, previous studies have shown that other barriers leading to undernutrition in the PICU and NICU include problems related to the feeding tubes, prolonged pre- and post-operative fasting, delayed or inaccurate monitoring of nutritional requirements, and use of vasoactive medications and muscle relaxants (30, 31).

The results of the studies carried out on critically ill children demonstrated that higher nutritional adequacy is associated with improved clinical outcomes, including infection, duration of ventilator dependency, and length of NICU and hospital stay (4, 32). In line with the results of previous studies, the findings of the current study indicated that calorie intake was significantly inversely associated with the duration of ventilator dependency, NICU stay, and infection rate. Additionally, the higher intake of protein was associated with a lower infection rate, lower duration of ventilator dependency, and shorter NICU and hospital stay.

The results of the present study highlighted the importance of the role of optimal nutritional support in minimizing the infection rate in the NICUs where the infection is considered a major cause of morbidity and mortality in critically ill neonates (33). Additionally, our findings are similar to the results of a recent study carried out by Larsen et al. on the neonatal patients who underwent open-heart surgeries. The results of the aforementioned study indicated that the neonates with lower calorie intake showed a longer time of ventilator dependency, longer time of PN support, and longer length of PICU and hospital stay (34).

On the other hand, the results of previous studies on critically ill children showed that energy and protein adequacy was significantly associated with lower 60-day mortality (4, 27, 32). On the contrary, our findings demonstrated no association between the calorie and protein adequacy and mortality rate in critically ill neonates following the surgeries. This inconsistency between the results may be due to the different nutritional conditions of the patients on admission and different inclusion criteria determined in our study.

There were some limitations in the present study. Firstly, the results of our study as a single-center study might not be generalized to all other centers. On the other hand, this study was carried out only on the neonates undergoing gastrointestinal surgeries; therefore, our findings might not be extrapolated to all other critically ill neonates. Also, in the present study, the energy expenditure was calculated using the prediction equations instead of indirect calorimetry.

In addition, as the measurement of anthropometric parameters is difficult in critically ill neonates, inaccurate measurements are likely to obtain. It is required to carry out larger multicenter studies to assess the nutritional adequacy and barriers to the achievement of nutritional goals in critically ill neonates with different internal and surgical diseases to modify the customized nutritional support protocols in the NICUs.

Conclusion

According to the obtained results of our study, while almost 80% of the studied patients received adequate protein during their post-gastrointestinal surgery state, only 35.5% of them had adequate energy intake. The fluid restriction was observed as the major barrier to adequate nutritional support, and nutritional adequacy was significantly associated with decreased infection rate and length of hospital stay. Consequently, it is required to perform further prospective studies to find appropriate feeding protocols in order to prevent nutritional inadequacy and overcome the probable barriers to the delivery of adequate nutrition in the NICUs.

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Conflicts of interest

Abbas Boskabady, Zahra Dehnavi, Gholamreza Khademi, Mohsen Nematy, Habibollah Esmaily, and Fatemeh Roudi declare that they have no competing interest to report.

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Ethics approval and consent to participate

The current study was approved by the Ethics Committee of Mashhad University of Medical Sciences (ethical code: IR.MUMS.MEDICAL.REC. 1397.553).

Author's Contributions

The authors' responsibilities were as follows:

FR, AB, MN, and GK designed the research; FR, GK, ZD, and AB conducted the library search, collected the data, and wrote the manuscript; FR and HE were involved in data analysis; FR designed tables. All of the authors read and approved the final manuscript.

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