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Evaluation of Nutritional Status in a Neonatal Intensive Care Unit at a Teaching Hospital

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ABSTRACT

Background: Extrauterine growth restriction remains a common and serious condition in neonates, particularly small, immature, and critically ill infants. Overall, 97% and 40% of very low birth weight (VLBW) infants experience growth failure at 36 weeks and 18-22 months post-conceptual age, respectively. The postnatal development of premature infants is highly dependent on an adequate nutritional intake that mimics a similar gestational stage. Deficient protein or amino acid administration over an extended period may lead to significant growth delays or morbidity in VLBW infants. The purpose of this study was to evaluate the nutritional status of infants in a neonatal intensive care unit (NICU) at a teaching hospital.

Methods: In this prospective observational study, the nutritional status of 100 consecutive critically ill neonates was evaluated, using anthropometric and biochemical parameters in a tertiary NICU. Infants' demographic characteristics (weight, height, and head circumference), energy source (dextrose and lipids), and protein level were recorded on the 1st, 5th, 10th, 15th, and 20th days of admission. Blood samples were obtained to measure serum albumin and prealbumin. Calorie and protein levels were calculated for all preterm and term neonates and were separately compared with the standard mean values.

Results: Calorie and amino acid level were not similar among the majority of preterm and term neonates, and the mean daily parenteral calorie intake was ≤ 30% less than the daily requirements, based on neonatal weight. Mortality rate was significantly higher in neonates with lower serum albumin level and severe malnutrition; however, no association was found between mortality rate and serum prealbumin concentration.

Conclusion: In the evaluated infants, the whole daily calorie and protein requirements were not met. Therefore, timely and adequate administration of calorie sources (dextrose and lipids) and amino acids is highly recommended. Compared to albumin, prealbumin was a more effective biochemical parameter for evaluating neonates' short-term nutritional status, particularly in critically ill patients.

Keywords: Albumin, Infants, Malnutrition, NICU, Prealbumin

Introduction

Malnutrition, as a common problem at hospital admission, tends to increase during hospital stay. In Europe and North America, 40-50% of hospitalized patients may be at risk of malnutrition. The incidence of malnutrition in critically ill children varies between 25% and 70%, depending on the examined series (1, 2-6). According to a previous study, 15–20% of children, admitted to neonatal intensive care units (NICUs), were acutely or chronically malnourished (7).

After birth, preterm infants lose weight and take variable periods to regain birth weight. The postnatal development of premature infants is critically dependent on an adequate nutritional intake that mimics a similar gestational stage to which the fetus would be exposed if still in the uterus (8). Deficient protein or amino acid administration over an extended period may cause significant growth delays or morbidity in very low birth weight (VLBW) infants (9).

More aggressive parenteral nutrition (PN) with higher energy and protein intake might lead to reduced energy and protein deficit. However, early total PN is limited by glucose and lipid intolerance as well as by concerns regarding amino acid metabolism. Abnormal neurodevelopment in preterm infants has been associated with inadequate nutrition during the early postnatal period (10, 11).

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Table1. Demographic characteristic of neonates

	Variables	Male infants (mean±SD)	Female infants (mean±SD)
Demographic characteristics	Sex (%)	49	51
At birth	Weight (g)	2568±745	2215±969
	Height (cm)	45.8±4.2	43.4±5.9
	Head circumference (cm)	32.2±3.1	30.7±3.5
at NICU admission time	Weight (g)	2535±768	2200±943
	Height (cm)	46.3±4.2	43.9±6.1
	Head circumference (cm)	32.7±3.2	30.9±3.7
	Age (day)	4.8±8.5	5.3±2.8

Table 2. Anthropometric parameter changes in neonates during NICU stay

Variables	Gestational age (w)		At birth	At admission	Day 5	Day 10	Day 15	Day 20
Weight	≤30	Observed	1357±499	1389±478	1354±484	1184±142*	1173±132*	1230±71*
		Standard	1330	1380	1500	1840	2000	2140
	31-34	Observed	1780±616	1784±614	1748±613	17.3±707*	1120±367*	--
		Standard	1850	1920	2060	2250	2410	--
	35-37	Observed	2443±541	2415±540	2360±577	2660±377*	2647±208*	2606±172*
		Standard	2650	2730	2850	3000	3130	3250
	≥38	Observed	3222±525	3219±576	3188±581	3081±518*	3027±553*	2943±445*
		Standard	3370	3400	3500	3600	3720	3850
Height	≤30	Observed	39±4	39±4	39±4	38.3±5	37.5±3*	37±2*
		Standard	39	39.5	40.5	42.9	43.7	44.5
	31-34	Observed	42.5±6.4	42.6±6.2	42.7±6.2	40±5.4*	36.5±0.7*	--
		Standard	42.8	43	44	44.8	45.1	--
	35-37	Observed	45.1±3.1	45.4±3.1	45.4±3.1	47.4±3.7	46±3.9*	45.5±4.4*
		Standard	46.5	46.7	47.4	48.1	48.7	49.3
	≥38	Observed	48±3	49±3.5	49±3.5	48±4	49±4	44±3.5*
		Standard	50	50	50.5	51	51.8	52
Head circumference	≤30	Observed	27±3	27±3	27±3	27.3±2	27.5±2*	28±1*
		Standard	26.5	27	28.3	29.8	30.4	31
	31-34	Observed	294±21	29.4±2.3	29.5±2.4	29.2±2.7	28.8±3.2*	--
		Standard	29	29.2	29.8	30	30.4	--
	35-37	Observed	32.4±1.6	32.5±1.5	32.5±1.5	33.1±1.8	33.2±205	33±3.1
		Standard	32.5	32.6	33	33.5	33.9	34.3
	≥38	Observed	34±2	35±2.5	35±2.5	34±2.5	34±3	34±2.5
		Standard	34.5	34.5	35	35.2	35.5	35.8

* These variables had meaningful differences with normal values.

Furthermore, in the short run, suboptimal nutrition is associated with adverse outcomes including increased susceptibility to infections, greater need for mechanical ventilation, and development of chronic lung diseases (12). Recommended intakes are commonly interrupted for clinical reasons, and VLBW infants, during their initial hospital stay, develop major calorie deficits, which are not compensated for by the time of hospital discharge (8).

It is estimated that 1% of endogenous proteins may be lost each day if the preterm infant is provided with only glucose after birth (13, 14). Therefore, there is an urgent need for optimal nutrition at the time of birth. Moreover, the incidence rates of head circumference and length < 10th percentile have been reported to be 34% and 16% at discharge, respectively (15). Dusick et al. reported that 97% and 40% of VLBW infants experience growth failure at 36 weeks and 18-22 months post-conceptual age, respectively (13).

A number of national committees have recommended a daily energy intake of 110-130 kcal/kg/day for healthy premature infants to allow a growth rate similar to that of intrauterine growth rate (16). There are diverse practices with regard to neonatal PN in the United Kingdom. The current neonatal PN practice entails a significant calorie and protein deficit during the early postnatal life and warrants further review. The purpose of this study was to evaluate the nutritional status of infants in the NICU of a teaching hospital.

Material and Method

We conducted this prospective observational study to determine the nutritional status of critically ill neonates by evaluating their anthropometric and biochemical parameters in a tertiary NICU. Overall, 100 consecutive neonates, admitted to NICU, were evaluated.

The neonates' demographic characteristics (age, weight, and height), energy source (dextrose and lipids), and protein level on the 1st, 5th, 10th, 15th, and 20th days of admission were recorded, and blood samples were obtained to measure

Table 3. Serum albumin, prealbumin, and parenteral calorie intake in neonates during NICU stay

Variables		Day 1	Day 5	Day 10	Day 15	Day 20
Preterm	Albumin	4.0±1.8	3.9±1.5	3.6±1.4	3.3±0.8*	2.8±0.5*
	Prealbumin	10.5±4.8*	9.6±3.7*	10.2±3.4*	9.8±3.3*	8.5±3.1*
Term	Albumin	4.0±1.2	3.6±1.3	4.0±1.9	3.5±1.2	3.4±1
	Prealbumin	10.3±3.4*	11±4.3	13.2±8	9.6±3.9*	9.5±4.9*
Calorie (Cal/kg)	Received	28.4*	31.2*	30.5*	36.5*	34*
	Required	110	110	105	105	110

* These variables had meaningful differences with normal values.

Table 4. The relationship between NPO duration and patients' outcomes

NPO duration	Outcomes		Patients (No.)
	Discharge	Death	
<3 days	36	6	42
4-6 days	35	2	37
7-9 days	8	9	17
>10 days	2	2	4
Total	81	19	100
P-value=0.008			

albumin and prealbumin. The calorie and protein levels were calculated for all preterm and term neonates and separately compared with the recommended mean values. The patients were classified as severely, moderately, and mildly malnourished, based on serum prealbumin and albumin levels.

Data were analyzed by SPSS version 16, and P-value ≤ 0.05 was considered statistically significant.

Results

Table 1 shows the characteristics of 100 enrolled neonates at birth and admission time. The subjects were followed-up on the 1st, 5th, 10th, 15th, and 20th days of admission. Changes in anthropometric parameters are shown in Table 2. Table 3 shows the patients' biochemical parameters (albumin and prealbumin levels) and calorie intake during the NICU stay. Moreover, the relationships between patients' outcomes and 'no oral intake' (NPO) duration, serum albumin level, and prealbumin concentration are reported in Tables 4-6.

Discussion

The aim of this study was to investigate the nutritional status of neonates at the NICU of a teaching hospital. Our data revealed that growth in terms of weight, height, and head circumference was not adequate in patients, particularly on day 10 of admission and later. Based on neonatal weight, the mean daily parenteral calorie intake was ≤ 30% lower than the daily requirements.

Serum prealbumin concentration was meaningfully different from the normal value since the first day until the 20th day of hospitalization in preterm and the majority of term infants, whereas serum albumin level was lower than the normal value in preterm infants only on days 15 and 20. There was a positive relationship between NPO duration and patients' mortality. Moreover, serum albumin had a significant negative relationship with mortality rate, whereas prealbumin level was not significantly correlated with patient outcomes.

Extrauterine growth restriction remains a common and serious problem in premature neonates, especially small, immature, and critically ill infants (15). The ultimate goal of neonatal nutrition is to replicate *in utero* growth patterns. Fetal growth is at a minimum rate of 15 g/kg/day during the mid-trimester, decreasing to 10 g/kg/day at full term (17). The American Academy of Pediatrics recommends that the postnatal growth of preterm infants in terms of both anthropometric indices and body composition should be the same as the normal fetus with the same gestational age (18).

The risk of developing malnutrition during the infant's stay at NICU can only be minimized by standardized nutritional assessment upon admission, which should enable identifying children at higher risk and optimize their nutritional support (7). The major nutritional components for preterm infants include

Table 5. The relationship between serum albumin and patients' outcomes

Albumin level at the time of admission (g/dL)	Outcomes		Patients (No.)
	Discharge N (%)	Death N (%)	
Severe malnutrition (<2)	3 (50)	3 (50)	6
Moderate malnutrition (2-2.5)	12 (66.7)	6 (33.3)	18
Mild malnutrition (2.5-3)	16 (76.2)	5 (23.8)	21
Normal (3-4.5)	22 (88)	3 (12)	25
Upper normal (>4.5)	17 (94.4)	1 (5.6)	18
Total	70 (79.5)	18 (20.5)	88
P-value=0.004			

Table 6. The relationship between serum prealbumin and patients' outcomes

Prealbumin level at the time of admission (mg/dL)	Outcomes		Patients (No.)
	Discharge No. (%)	Death No. (%)	
Severe malnutrition (<5)	1 (50)	1 (50)	2
Moderate malnutrition (5-10.5)	51 (81)	12 (19)	63
Mild malnutrition (10.6-15.9)	20 (80)	5 (20)	25
Normal (16-40)	9 (100)	0 (0)	9
Total	81 (81.8)	18 (18.2)	99
P-value=0.19			

appropriate amounts of essential nutrients (mainly glucose, lipids, and amino acids), received via parenteral routes.

Carbohydrates are the main energy source for neonates, receiving PN in form of glucose. Glucose synthetic rates in preterm infants are much higher at 6-8 mg/kg/min, compared to term infants, who synthesize glucose with a rate of 3-5 mg/kg/min. Maintaining normal glucose concentrations that match those of a normally growing fetus (> 50 mg/dl) is important for neurodevelopment (19). In the present study, although dextrose was the main source of energy, most of the neonates did not receive adequate daily calories, and only 30% or less met the daily needs.

The ideal energy ratio provides 65% of energy as carbohydrates and 35% as lipids. Most infants require 100-120 cal/kg/day for adequate growth, whereas some neonates need up to 160-180 cal/kg/day (e.g., infants with bronchopulmonary dysplasia). In fact, the primary goal is to provide energy and nutrients in sufficient quantities to allow normal growth and development (20).

Lipid is a good source of energy, given its high energy density; in fact, 1 gram of fat provides 9 kcal or 37.8 Joules of energy, and 1 gram of carbohydrate and protein provide about 4 kcal or 16.8 Joules, each. Essential fatty acid deficiency may develop within the first 72 hours of life and can be avoided by giving at least 0.5-1 g/kg/day of intravenous lipids. Suboptimal nutrition during sensitive stages in early brain development may have long-term effects on cognitive function (21). Early lipid administration by day two of life is safe and well tolerated (22).

Proteins are essential for normal growth and development. Growth of lean body mass is particularly dependent on protein intake in organs such as the brain. As a number of studies have reported, failure to provide dietary proteins of at least 1 g/kg/day would result in protein breakdown, presenting as negative nitrogen balance (9, 23, 24). Protein is a building block for new tissues rather than an ideal source of energy. Therefore, even if energy intake from proteins is included in calculations of total energy intake, not all protein-derived calories are available for energy expenditure.

Protein administration should be started on the first day of life or as soon as the fluid and electrolyte requirements have been met. In fact, a non-protein-to-protein calorie ratio of at least 25-30:1 should be maintained. Term infants need 1.8-2.2 g/kg/day along with adequate non-protein energy for growth, whereas preterm VLBW infants need 3-3.5 g/kg/day, along with adequate non-protein energy for growth; usually, providing more than 4 g/kg/day of protein is not advisable (25, 26)

In consistence with our findings, Grover et al. reported that in only 26 NICUs (54%) in England (from 52 NICUs), PN was initiated on day 1, and full PN was achieved by the median duration of 6 days. Twelve units (25%) achieved full PN only by day 7 or later; maximum median amino acid was 2.9 g/kg/day. Only 13 units (27%) prescribed 3 g/kg/day, and 2 prescribed more than 3.5 g/kg/day. Nineteen units (39%) initiated lipids on day 1, 11 units (23%) delayed lipids until day 3, and 2 units delayed lipids until day 4. In comparison with the recommended intake of calories and amino acids, the current median prescription would result in a cumulative deficit of 420 kcal/kg and 11.9 g/kg over the first 10 days, respectively (27).

Albumin is a parameter that is widely used in nutritional evaluation due to its high specificity. However, it has a low sensitivity as a nutritional marker, given its long plasma half-life (20 days); therefore, it is not a good parameter for monitoring nutritional status, due to its low sensitivity to acute changes (28). Other body proteins with shorter half-lives are better alternatives for the evaluation of protein status in critically ill patients. Prealbumin, with a short half-life of two days and limited distribution, is very sensitive and specific to changes in the nutritional status. Variations in prealbumin concentration can be observed in less than 7 days after diet changes.

Some studies have reported a good correlation between prealbumin level and nitrogen balance (29-32). Prealbumin is a useful parameter for monitoring the nutritional status, re-nutrition, and changes in nutritional patterns in seriously ill patients; in fact, it is the only valid parameter for the evaluation of nutritional status in patients with renal failure (28). In the present research, in agreement with the results of previously conducted studies, prealbumin was a better biochemical parameter for evaluating nutritional status, compared to albumin, although patients did not receive the recommended daily calorie and protein requirements.

Delgado et al. reported that during standardized metabolic support, serum albumin did not significantly change, but the mean value of prealbumin increased significantly from the 1st to the 10th day (33). In consistence with previous studies (34-38), we also found that patients with lower serum albumin level had a significantly higher mortality rate, whereas there was no significant relationship between low prealbumin level and mortality rate.

In adult patients, hypoalbuminemia was shown to be a strong independent predictor of poor outcomes, and each 1 g/dL decline in albumin significantly elevated the risk of mortality and morbidity and increased the length of hospital stay (34). Several pediatric studies have suggested an association between low serum albumin and adverse clinical sequelae such as necrotizing enterocolitis, poor surgical outcomes, prolonged length of NICU stay, and mortality (35-38). Unfortunately, in these studies, amino acid and intralipid formulae for neonates were not available to be prescribed as calorie and protein sources.

Conclusion

Similar to many previous studies, the evaluated infants did not receive their whole daily calorie and protein requirements. Based on numerous studies, timely and adequate administration of suitable calorie sources (dextrose and lipids) and amino acids is recommended. Prealbumin was a better biochemical parameter, compared to albumin for evaluating patients' short-term nutritional status, particularly in critically ill patients. This study was funded by Mazandaran University of Medical Sciences.

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