

Parenteral versus enteral nutrition in children with post-surgical congenital heart disease

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ABSTRACT

Objective: The association of malnutrition with congenital heart disease (CHD) is well documented. Studies comparing the effects of parenteral nutrition (PN) and enteral feeding (EF) on the post-surgical correction of CHD are not available. We compared the effects of PN with EF on the nutritional status of children post-cardiac surgery.

Methods: A retrospective cohort study was conducted with 72 children aged ≤ 6 years who had at least one heart surgery between 2010 and 2016. Malnutrition was defined as a weight for height Z-score (WHZ) below -2 . The primary endpoint was the change in the mean WHZ Z-score from the baseline. All statistical analyses were performed using SPSS 21.0 [Release 21.0.0.0, IBM, USA].

Results: The sample size realized as 72 ($n = 72$). The overall prevalence of malnutrition was 48%. The change in height of the PN group was significantly higher than the EF group (14.2 ± 7.6 cm vs. 7.4 ± 6.3 , $P = 0.010$), but the weight change was not significantly different ($P = 0.28$). The post-surgery Z-scores were significantly lower in the PN group and the Z-score change was marginally smaller ($P = 0.086$), indicating lower growth levels post-surgery. The PN group had a significantly higher incidence of post-surgical malnutrition ($P = 0.046$). Patients who received PN had significantly less improvement (more negative change) in the Z-score levels compared to the EF group (PE = -1.42 , 95% confidence interval [CI] = $[-2.48, -0.35]$; $P = 0.011$).

Conclusion: Malnutrition occurs frequently with CHD. PN does not add any nutritional benefits compared with EF. EF should always be the preferred method of nutrition unless contraindicated.

Keywords: Cardiac surgery, congenital heart disease, enteral feeding, malnutrition, parenteral nutrition

Introduction

Congenital heart diseases (CHDs) are relatively rare. At birth, the prevalence of CHD in 2017 was estimated as 1.8/100 live births globally.^[1] The number steadily increased with 10% every 5 years since 1970, probably due to the advances in detecting milder lesions such as ventricular septal defect and patent ductus arteriosus.^[2] The management of CHD varies widely based on the type and extent of the cardiac lesion. In addition to medical management, most children with CHD require extensive surgical intervention (either curative or palliative), which is in most cases, done before the age of 6 years. Such types of surgeries, in addition to CHD *per se*, cause several unwanted neurological, developmental, and cognitive consequences.^[3] Malnutrition, associated with CHD and its management, is well documented. Literature reports a wide range in the prevalence (17–76%) of malnutrition in

children with CHD.^[4–8] Using different anthropometric indices to define malnutrition,^[8] in addition to deriving the samples from different countries could be an explanation for such large discrepancies in reported prevalence.^[4–8]

The etiology of malnutrition in children with CHD is multifactorial. However, there are three mechanisms, which could explain the association with CHD. The mechanisms include a decreased caloric intake due to delayed feeding, an increased energy expenditure, and a hypermetabolic status post-surgical correction of the cardiac lesion as well as insufficient nutritional absorption, secondary to the reduced cardiac output.^[9,10] In general, any child with CHD may present with one or more of these three mechanisms which predispose the child to malnutrition complicating the overall management. Several factors are linked with the poorer malnutrition status in children with CHD. These include the cyanotic type CHD, younger age, presence of left to right shunting, heart

failure, pulmonary hypertension, pre-operative malnutrition, prolonged intubation and sedation, and feeding intolerance.^[9-12]

The association of malnutrition in CHD with poorer clinical outcomes is well known. Prolonged intensive care unit^[13] and hospital length of stay,^[13,14] longer duration of mechanical ventilation and inotropic support,^[14] and a higher rate of serious infections and delayed wound healing,^[15] in addition to a failure to thrive,^[16,17] have been reported as immediate consequences. Reported long-term outcomes include reduced physical and cognitive development,^[3] delayed puberty,^[16] and higher mortality (odds ratio [OR] 13.5 95% confidence interval [CI] 3.6–51.0).^[14,18]

Studies provide evidence that correctional surgeries of CHD have significantly improved the child's nutritional status,^[16,19,20] and that most children will regain weight and height within 6- and 12-month post-surgery, respectively.^[21,22] However, a poor preoperative nutritional status is strongly correlated with worse clinical outcomes such as longer ventilation days ($P < 0.0001$) and death at 1 year ($P = 0.001$).^[23]

The normal growth of a child with CHD can be achieved with adequate perioperative nutritional support. Providing aggressive nutritional supplementation equal to 170 kcal/kg of daily calories and a protein of 3–4 g/kg/day may be necessary to improve the growth and accelerate wound healing.^[24] This quantity of feeding can be delivered through an oral, enteral, or a parenteral route. To optimize feeding and mitigate complications, many pediatric cardiology centers develop a successful protocolized approach to initiate, advance, and maintain nutrition.^[25-28] The central concept of these protocols is optimizing early enteral feeding (EF) to reduce the need for parenteral nutrition (PN). The superiority of the early administration of PN in critically ill children is not supported in some literature,^[29] and an enteral route of feeding is usually the preferred mode of administration because of its convenience, reduced price, fewer infectious complications, and preservation of gut function.^[30] However, PN is indicated in many situations where using the gastrointestinal tract is contraindicated, or when the caloric needs of the child cannot be met through EF.^[31] Studies comparing the effects of PN and EF on the nutritional status of the child post-cardiac surgery are not available. The current study was conducted to investigate the difference between EF and PN to improve malnutrition in a child with CHD. We hypothesized that using PN perioperatively would be more effective in improving the nutritional status of the child requiring CHD correctional surgery.

Methods

Setting

The study was conducted at the Pediatric Cardiology Department, Cardiac Center, King Abdulaziz Medical City, Riyadh, Saudi Arabia. In addition to academic, training, and

research services, the pediatric cardiology section provides a tertiary level of care for children with complex congenital and acquired heart disease. The section performs as many as 500 cardiac surgeries annually, in addition to advanced cardiac imaging, catheterization, and echocardiography. An interdisciplinary team of physicians, clinical pharmacists, nurses, and dietitians participates in providing a high standard of care for an admitted child. The dietitian supports the team in providing appropriate EF, but PN is provided by the clinical pharmacist, based on a departmentally approved guideline.

Design and patients selection

This retrospective cohort study ($n = 72$) was conducted to assess the effectiveness of PN versus EF in improving the nutritional status of pediatric patients with CHD who had correctional surgeries. We screened the records of all patients admitted to the pediatric cardiac intensive care unit in the electronic medical systems Quadramed[®] and BestCare[®] between 2010 and 2016. In total, 107 patient records were identified, which met the following inclusion criteria: Children with CHD, aged 6 years or younger, and had at least one correctional heart surgery. Of this group, we excluded children who were premature (<37 weeks gestation age), on PN for <2 weeks, hospitalized for non-cardiac surgeries, having incomplete information (weight, height, and feeding method), or have a condition that may contribute to poor growth or interfere with feeding, such as necrotizing enterocolitis, chylothorax, pulmonary disease, congenital abnormalities other than cardiac, known genetic disease, global development delay, and malignancy.

Outcome measures

The following baseline characteristics were recorded: Date of birth, age, gender, weight, height, date of admission, date of discharge, date of heart surgery, post-surgical sedation and duration, post-surgical methods of feeding (EF vs. PN), and post-surgical PN and duration. The information required to determine the nutritional status and the state of malnutrition were also collected. The nutritional status was assessed based on the World Health Organization 1995 standardized growth charts and Z-score for weight-for-height (WHZ). Malnutrition was defined as a Z-score of at least two points below (Z scores < -2) the mean standard value in WHZ.^[32]

The primary endpoint was the change in the mean Z-score for WHZ from the baseline (pre-surgery), for both the PN and EF groups. The overall prevalence of malnutrition in the cohort, the effects of the patient's demographic information (age and gender), and the sedation on the post-operative WHZ were the secondary endpoints.

Statistical analysis

The initial analyses were based on unadjusted comparisons between patients on PN versus EF in terms of demographic and clinical factors using the Chi-square test for categorical

variables and a t-test for the continuous variables. The average change in the WHZ pre- and post-surgery was compared in the two groups using a *t*-test. A multivariate linear regression model was employed to predict the average change in the Z-score for each group. Adjustments were made for the patient's demographic information and clinical factors, including age (per 10-month period), gender, and the baseline Z-score (pre-surgery). Through a regression analysis, this set of variables was analyzed to understand the nature and source of the change in the Z-score and the relationship to PN and other demographic characteristics. Statistical significance was considered as $P < 0.05$. All statistical analyses were performed using SPSS 21.0 (Release 21.0.0.0, IBM, USA).

Results

In total, 72 patients were included in the study. The descriptive statistics of the sample are displayed in Table 1. The age mean \pm SD was 34.8 ± 14.9 months and the median (IQR range) = 29 (25–38.5) with 54% of female. The mean \pm SD baseline (pre-surgery) height was 67.8 ± 17.0 cm and the median (IQR range) 65 (57–75). The mean \pm SD baseline (pre-surgery) weight was 6.9 ± 4.4 Kg and the median (IQR range) 5.7 (3.5–9.2). Overall, the average baseline Z-score = -1.8 (SD = 2.4) and the median (IQR) = -1.9 (-3.1 – 0.6).

Significant differences were observed between the PN and EF groups in terms of age and baseline height and weight [Table 1]. The PN group was significantly younger and had a

Table 1: Baseline demographic and clinical factors, overall and by PN status, $n=72$

Factor	Group			P-value ^a
	All patients ($n=72$)	EF ($n=63$, 87.5%)	PN ($n=9$, 12.5%)	
Age (months) mean \pm SD	34.8 \pm 14.9	36.2 \pm 15.4	24.9 \pm 2.1	0.032
Median (IQR)	29 (25–38.5)	30 (26–42)	24 (23–26.5)	
Gender				0.93
Male	33 (45.8%)	29 (87.9%)	4 (12.1%)	
Female	39 (54.2%)	34 (87.2%)	5 (12.8%)	
Height (cm) mean \pm SD	67.8 \pm 17.0	70.3 \pm 16.6	50.3 \pm 6.2	<0.001
Median (IQR)	65 (57–75)	67 (59–80)	49 (46.3–55.5)	
Weight (kg) mean \pm SD	6.9 \pm 4.4	7.4 \pm 4.4	3.0 \pm 0.6	<0.001
Median (IQR)	5.7 (3.5–9.2)	6.1 (4.3–10)	3.1 (2.3–3.5)	
Baseline Z-score mean \pm SD	-1.8 \pm 2.4	-1.7 \pm 2.3	-2.1 \pm 3.0	0.68
median (IQR)	-1.9 (-3.1–0.6)	-2.0 (-3.0–0.6)	-1.0 (-5.1–0.9)	
Malnutrition ^b at baseline n (%)	32 (47.6%)	29 (48.3%)	3 (42.9%)	0.78

^aBased on the Chi-square test or T-test. ^bIndicated by Z-score < -2

lower height and weight pre-surgery ($P = 0.032$ and $P < 0.001$, respectively). The Z-score at baseline was not significantly different by PN status ($P = 0.68$). The two groups were significantly different in terms of height pre-surgery ($P < 0.001$) and weight pre-surgery ($P < 0.001$).

Descriptive statistics for the pre-, post-surgery and change in height, weight, and Z-score, overall and by PN status are displayed in Table 2. Patients receiving PN had lower

Table 2: Descriptive statistics for pre-, post-surgery and change in height, weight, and z-score, overall and by PN status, $n=72$

Factor	Group			P-value ^a
	All patients ($n=72$)	EF ($n=63$, 87.5%)	PN ($n=9$, 12.5%)	
Height (cm)				
Baseline (pre-surgery)	67.8 \pm 17.0	70.3 \pm 16.6	50.3 \pm 6.2	<0.001
	65 (57–75)	67 (59–80)	49 (46.3–55.5)	
Post-surgery	76.6 \pm 14.3	78.4 \pm 14.3	64.5 \pm 6.9	0.002
	75.7 (67.3–82.7)	76.7 (71–84.7)	64.8 (60.6–69.6)	
Change (post-pre-surgery)	8.3 \pm 6.9	7.4 \pm 6.3	14.2 \pm 7.6	0.010
	8.6 (3.9–12.5)	7.8 (3.1–11.1)	14.9 (8.6–21.3)	
Weight (kg)				
Baseline (pre-surgery)	6.9 \pm 4.4	7.4 \pm 4.4	3.0 \pm 0.6	<0.001
	5.7 (3.5–9.2)	6.1 (4.3–10)	3.1 (2.3–3.5)	
Post-surgery	9.5 \pm 4.4	10.0 \pm 4.4	6.1 \pm 1.7	0.001
	8.8 (7.0–10.7)	9.2 (7.6–11.7)	6.4 (5.4–7.5)	
Change (post-pre-surgery)	2.6 \pm 1.6	2.5 \pm 1.7	3.1 \pm 1.4	0.28
	2.7 (1.3–4.1)	2.6 (1.0–4.0)	3.8 (2.3–4.1)	
Z-score				
Baseline (pre-surgery)	-1.8 \pm 2.4	-1.7 \pm 2.3	-2.1 \pm 3.0	0.68
	-1.9 (-3.1–0.6)	-2.0 (-3.0–0.6)	-1.0 (-5.1–0.9)	
Post-surgery	-1.3 \pm 5.9	-1.2 \pm 6.3	-2.0 \pm 1.4	0.008
	-0.6 (-1.5–0.03)	-0.5 (-1.3–0.2)	-1.8 (-2.6–0.9)	
Change (post-pre-surgery)	1.3 \pm 2.0	1.5 \pm 1.9	0.1 \pm 2.5	0.086
	1.1 (0–2.6)	1.3 (0.1–2.6)	-0.03 (-1.7–2.9)	
Malnutrition ^b n (%)				
Baseline (pre-surgery)	32 (47.6)	29 (48.3)	3 (42.9)	0.78
Post-surgery	11 (15.9)	8 (13.3)	3 (42.9)	0.046

^aBased on the T-test or Mann-Whitney U-test. ^bIndicated by Z-score < -2 .

height levels pre- and post-surgery and their height change was significantly more than the EF group [14.2 ± 7.6 cm vs. 7.4 ± 6.3 , $p = 0.010$]. The PN group also had significantly decreased weight pre-surgery, but their weight change was not significantly different from the EF group ($p = 0.28$).

Descriptive statistics for the pre-, post-surgery and change in height, weight, and Z-score, overall and by PN status are displayed in Table 2. Patients receiving PN had lower height levels pre-and post-surgery and their height change was significantly more than the EF group (14.2 ± 7.6 cm vs. 7.4 ± 6.3 , $P = 0.010$). The PN group also had significantly decreased weight pre-surgery, but their weight change was not significantly different from the EF group ($P = 0.28$).

Although the baseline Z-score was not different in the two groups ($P = 0.68$), the post-surgery Z-scores were significantly lower in the PN group and their Z-score change was marginally smaller ($P = 0.086$), indicating less improvement or lower growth levels post-surgery. Almost half (47.6%) of the patients had malnutrition (defined Z-score < -2). The PN group had a significantly higher incidence of post-surgical malnutrition compared to the EF group ($P = 0.046$). No significant differences were observed between the PN and EF groups in terms of pre-surgical malnutrition ($P = 0.78$).

The mean and 95% CI change in the Z-score, overall and by PN status are shown in Figure 1. The figure clearly demonstrates the significantly smaller change in the Z-scores of the PN group compared to the EF group.

The results from the fitting the multivariate linear regression model for the Z-score change are shown in Table 3. The results show that the PN group had significantly less improvement (more negative change) in the Z-score levels compared to the EF group (parameter estimate [PE] = -1.42 , 95% CI = $(-2.48, -0.35)$; $P = 0.011$). The significantly lower improvement in the Z-score levels was also related to higher Z-score levels pre-surgery [PE = -0.66 , 95% CI = $(-0.8, -0.51)$; $P < 0.001$]. Age and gender were not related to change in Z-score levels ($P > 0.05$).

The results from the fitting a multivariate logistic regression model for malnutrition post-surgery are displayed in Table 4. The results show that the PN group had higher odds of malnutrition compared to the EF group (OR = 3.77), however, this result was not statistically significant ($P = 0.17$). None of the other factors listed in the model were related to malnutrition ($P > 0.05$). Additional results (not shown) showed that there were no significant differences in post-surgical malnutrition between the patients who were or were not sedated postoperatively (15% vs. 21%; $P = 0.59$).

Discussion

The WHO recommends using anthropometric indices, weight-for-age, height-for-age, and weight-for-height, to qualify and

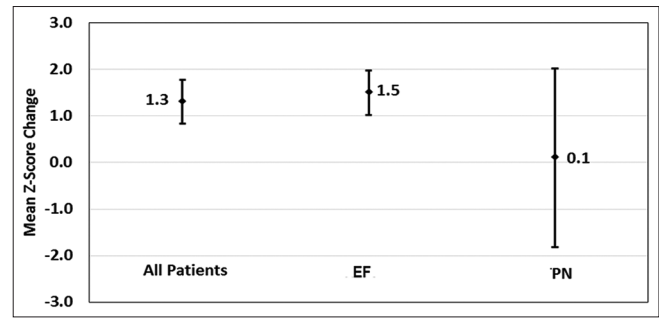


Figure 1: Z-score change = post-pre-surgery Z-score

Table 3: Multivariate linear regression model for Z-score change, $n=72$

Factor	Mean or %	Beta	95% CI	P-value
Constant		-0.26	(-1.37, 0.85)	
Group				
PN	12.5%	-1.42	(-2.48, -0.35)	0.011
EF	87.5%	0.00	Ref.	
Age (per 10 months)	34.8	0.19	(-0.04, 0.42)	0.12
Gender (male vs. female)	45.8%	-0.34	(-0.98, 0.31)	0.31
Baseline Z-score (per 1 unit)	-1.79	-0.66	(-0.8, -0.51)	<0.001

CI: Confidence interval

Table 4: Multivariate logistic regression model for malnutrition post-surgery, $n=72$

Factor	Mean or %	OR	95% CI	P-value
Group				
PN	12.5%	3.77	(0.58, 24.62)	0.17
EF	87.5%	1.00	Ref.	
Age (per 10 months)	34.8	0.44	(0.12, 1.54)	0.20
Gender (male vs. female)	45.8%	0.98	(0.23, 4.13)	0.98
Baseline malnutrition (yes vs. no)	47.6%	3.54	(0.74, 17.03)	0.11

CI: Confidence interval, OR: Odds ratio

define nutrition disorders. Malnutrition is characterized by a significant deficit in one or more of these indices. In our study, we used weight-for-height to classify malnutrition, as this index is more accurate in describing the term “wasting,” which is widely used when the malnutrition is secondary to starvation or severe illness. Consequently, we classified the patient as malnourished if the child had a WHZ $< (-2)$.^[32]

Due to physiologic differences between parenteral and enteral delivery of nutrients, an accurate comparison of the two methods is difficult. However, most clinicians report that feeding through the enteral route should always be the preferred method. A randomized clinical trial^[29] reported that early initiation of PN was associated with longer duration of ICU stay, longer duration of mechanical ventilation, and increased rate of new infections. Based on these findings,

the Society of Critical Care Medicine and the American Society for Parenteral and Enteral Nutrition recommended against early initiation of PN after admission to the pediatric intensive care unit (PICU). In contrast, early initiation and advancement of EF as tolerated was recommended after PICU admission.^[33]

Malnutrition is known to affect morbidity and mortality.^[3,14-18] According to the WHO, 52 million patients, <5 years old, suffer from wasting, 17 million from severe wasting, and 155 million from stunting.^[32] The percentage of malnutrition (wasting) in the current study was 47.6%, similar to the prevalence reported by Okoromah *et al.* (41%) in a case-control study conducted at a tertiary teaching hospital in Lagos, Nigeria.^[34] The prevalence of the current study was higher than the 22% reported by Ratanachu-ek and Pongdara but lower than the 59.9% reported by Vaidyanathan *et al.*^[20,35] The combined proportion of malnutrition for Ratanachu-ek and Pongdara, which included weight-for-height, weight-for-age, and height-for-age Z-scores, was 40%.^[20] In another study, the prevalence (28.2%) was determined based on the weight-for-age Z-score (WAZ) to define malnutrition.^[14]

The dietary intake of a patient plays a major role in determining the nutritional status. Children are continuously developing beings that depend on food as a source for development. The patients who required PN were younger and had a significantly lower height and weight, even after adjusting for their age. PN use was associated with a negative nutritional status. The only positive significant effect of PN on the patients' nutritional status was the height. The Z-score improvement was significantly enhanced for patients receiving EF. Kelleher *et al.* reported that a short time on PN was associated with a reduced weight-for-age Z-score.^[36]

Patients who needed post-surgical PN obviously had a poor nutritional status before the surgery. In addition, their nutritional status development after the surgery was not adequate and most were malnourished. We suggested that post-surgical sedation possibly played a role in affecting the nutritional status, but in this study, it was not affected by the sedation status.

The current study did not show any correlation between age at the time of surgery and the nutritional status. Controversially, Arodiwe *et al.* and Venugopalan *et al.* reported a significant correlation between age at presentation and malnutrition, and they concluded that an older age was a predictor of poor growth.^[8,37]

Of the sample, 32 children were malnourished at the baseline; however, only 11 children maintained their malnourished status after the surgery. We can deduce that more than 60% of the status of the malnourished children improved after the correctional heart surgery. However, patients who received PN did not get any nutritional benefit from the surgery at all. We provided evidence that the weight and height before

surgery, in addition to the need for PN use, are predictors of a poor prognosis.

The findings of the current study could have significant implications for the practice of the team managing the children with CHD. However, a large prospective study investigating the time of initiation, the quantity, and type of EF is required to ensure improved post-surgical child outcomes.

Limitations

We classified the sample based on the presence of malnutrition using only one index, weight-for-height. Although this index has the advantage of requiring no knowledge of age, and one anthropometric index can be used to assess the nutritional status, a single index should never be used as a substitute of others (height-for-age or weight-for-age). Our rationale for using the weight-for-height index in this study is because we were describing malnutrition related to severe cardiac illness. We did not classify the sample according to the specific congenital heart defect, which might have assisted in identifying the relationship between the type of the congenital heart defect and malnutrition.

Information about the feeding habits of the sample was not obtained. Home feeding before hospital admission and surgery may predict good or poor growth. In addition, we did not measure other biochemical parameters used to assess the nutritional status, such as albumin, which may have provided a broad picture of the child's nutritional status.

Conclusion

The post-surgery weight-for-height Z-scores were significantly lower in the PN group, and their Z-score change was marginally smaller ($P = 0.086$), indicating less improvement or lower growth levels post-surgery. This study clearly demonstrates a significantly smaller change in the Z-scores of the PN group compared to the EF group. Feeding through a parenteral route does not add any benefit over feeding through an enteral route. The parenteral method of feeding resulted in a higher incidence of malnutrition in children who had a surgical correction of their cardiac lesion and using PN as nutritional support in a child post-cardiac surgery may negatively affect their growth.

Malnutrition occurs frequently in children with CHD; the prevalence is 48%. There was no correlation between the age at presentation (at surgery) or post-surgical sedation, and the prevalence of post-operative malnutrition. Surgical correction of the defect obviously improves the nutritional status. The baseline weight and height, in addition to the need for PN use, are considered predictors of a poor prognosis. We encourage the use of EF over PN for the child post-cardiac surgery whenever possible.

Authors' Declaration Statements

Ethics approval

Ethical approval for the study was obtained from Institutional Review Board of King Abdullah International Medical Research Center, Riyadh, Saudi Arabia (IRB no. SP16/171).

Availability of data and material

The datasets of the study are available from the corresponding author on reasonable request.

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