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Early Enteral Nutrition in Pediatric Postoperative Cardiac Patients: Optimizing Recovery and Outcomes

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ABSTRACT
Background: *Congenital heart disease (CHD) affects 8/1000 live births and often causes early feeding difficulties and growth failure, especially in cases with cyanosis or heart failure.*
Aim: *To assess the impact of early enteral nutrition on postoperative outcomes in pediatric cardiac patients and promoted a team-based approach to nutritional care.*
Patients and methods: *This prospective two-phase study was conducted at Cairo University's Pediatric Cardiac Intensive Care Unit, involving 117 pediatric patients with CHD who underwent cardiac surgery. Phase 1 involved 57 patients, while Phase 2 involved 60 patients, including 34 males.*
Results: *Implementation of a structured feeding protocol in the postoperative ICU improved nutritional delivery and clinical outcomes. Enteral feeding was initiated earlier, with median NPO days reduced from 4 to 1, and full caloric intake achieved faster (6.5 vs. 4 days). Feeding success increased from 87.7% to 100%, and full intake from 73.7% to 98.3%. ICU survival improved significantly (70.2% to 91.7%, p = 0.004), with reduced ventilation duration (48 vs. 24 h, p = 0.007) and ICU stay (9 vs. 7 days, p = 0.017). Inflammatory markers (TLC and CRP) declined significantly postoperatively. Subgroup analysis showed early enteral feeding (<48 h) was associated with shorter ventilation (24 vs. 48 h), shorter ICU stay (5 vs. 15 days), and lower mortality (0% vs. 5%), all with significant p-values.*
Conclusion: *Early nutrition is crucial for children's heart surgery recovery.*
Keywords: *CHD, Early feeding, Patients, Clinical outcomes*

INTRODUCTION

Congenital heart disease (CHD) represents a heterogeneous group of malformations, in terms of pathogenesis and clinical significance of the lesion, CHD are among the most frequent congenital anomalies, with a reported incidence of 8/1000 live births, with high impact on neonatal morbidity and mortality (1).
Infants with CHD are usually born full term, with a weight that is appropriate for the gestational age. Nutritional problems often appear shortly after birth, and growth failure becomes apparent in the neonatal period. In some conditions, the delay can be mild, whereas in other cases, the failure to thrive can result in permanent physical or developmental impairment. The degree and type of malnutrition can be related to the CHD characteristics, including the presence of cyanosis, congestive heart failure or pulmonary hypertension (2). Descriptions of growth status in acyanotic and cyanotic lesions have changed over the past 25 years, as surgical intervention now occurs earlier in infancy for children with cyanotic lesions.
Feeding, the most complex task the infant must perform, requires coordination and integration of motor and sensory pathways of the oropharynx. Abnormalities in swallowing in these infants include variability in sucking, an uncoordinated suck, swallow and breathing, and oral transit time. Poor skills in feeding and any dysfunctional swallowing can directly affect the ability to feed, and hence the infant's achievement of an adequate nutritional state and growth (3).
Hence, suboptimal nutrition in CHD patients has been associated with poor clinical outcomes: energy and protein deficiency worsen stress-induced catabolic response, impairs wound healing, affects myocardial and muscle function, and may increase the rate of postoperative complications (4). On the other hand, growth failure in infants with CHD has been specifically associated with long-term cognitive impairment (5).
This study aimed to implement and refine a structured feeding protocol for postoperative pediatric cardiac patients and evaluate the impact of early enteral nutrition on mechanical ventilation

duration, infection rates, ICU stay, and survival. It also sought to support a multidisciplinary approach for individualized nutritional care and improved outcomes.

PATIENTS AND METHODS

This prospective two-phase study was conducted at the Pediatric Cardiac Intensive Care Unit (PCICU), Children's Hospital, Cairo University, from January 2023 to January 2024, and included 117 pediatric patients with congenital heart disease (CHD) who underwent cardiac surgery. Phase 1 (observational) included 57 patients (36 males), while Phase 2 (interventional) included 60 patients (34 males).

Sample size: The sample size was calculated using "Clinical Sample size calculator" considering the primary outcome: the mean of pre intervention length of ICU stay is 12.49 days with standard deviation 24.12 days compared to postintervention length of ICU stay days is 7.7days with standard deviation 9.5 days (6) with alpha error 0.05 and the power of the study is 80%. So, the sample size included 50 patients in each group.

Inclusion criteria: Age range: from birth till 10 years of age, patients who underwent cardiac surgery and were admitted to the pediatric intensive care unit (PICU) postoperatively.

Exclusion criteria: Patients who are admitted in the PCICU but not planned for surgery, patients who are readmitted to the PICU and Patients who are known or suspected syndrome, patients with multiple congenital anomalies, patients who have Inborn Error of Metabolism and patients with non-cardiac surgeries.

METHODS

PHASE 1- Observational phase: (6 months duration): Pre-operative Assessment: Medical history included demographic data, baseline nutritional status using 24-hour recall, caloric intake compared to daily requirements (FAO/WHO/UNU 2004), surgical details, and RACHS score. Clinical examination included preoperative anthropometric measurements with z-scores plotted on WHO charts (2009). full systemic assessment and investigation. **Intraoperative data:** Preoperative echocardiography was performed. Intraoperative data were documented, including bypass time, ischemic time, type of procedure (closed or open-heart surgery, palliative or total repair), and any events that could affect postoperative nutrition such as cardiac arrest. **Follow up Postoperative:** Documentation of daily inotropic support, including type and dose, was performed, and the Vasoactive Inotropic Score (VIS) was calculated. Resting energy expenditure (REE) was estimated using the Schofield formula as recommended by the European Society of Pediatric and Neonatal Intensive Care (7). Postoperative nutritional data were collected, including timing of feeding initiation, route of administration (oral, nasogastric, nasoduodenal, gastrostomy), type of nutrition (trophic feeds, full enteral feeds, parenteral nutrition), type of milk (breastmilk, standard formula, high-caloric formula), use of semisolid food if applicable, calculation of actual daily caloric intake, number of Nil Per Os (NPO) days before feeding started, any feeding interruptions or intolerance, and time to reach full caloric intake. Postoperative echocardiography was performed. Clinical outcomes were documented, including length of PICU stay, duration of mechanical ventilation in hours, infection rates based on positive cultures or wound infection, with serial postoperative total leukocyte count (TLC) and C-reactive protein (CRP) measured on days 3, 7, 10, and at discharge (6), and mortality rate. **PHASE 2– Intervention phase: (6 months duration):** Data documentation was done as in Phase 1. Educational sessions were provided to ICU staff to support protocol implementation. A standardized nutritional plan was applied, starting trophic feeds within 24–48 hours postoperatively for stable patients, with gradual advancement based on tolerance. Parenteral nutrition was used when enteral feeding was not tolerated, with transition as feasible. Fluids were adjusted individually. Outcomes were compared between both phases, including PICU stay, ventilation duration, infection rates, and mortality.

Outcome: The primary outcome was the relationship between early enteral nutrition and postoperative clinical outcome; the secondary outcome was to assess the correlation between the preoperative nutritional state and the postoperative clinical outcome.

Statistical Analysis

Statistical analysis was performed using SPSS version 27. Normality was assessed with the Shapiro-Wilk test. Skewed data were presented as median and interquartile range and compared using the

Mann-Whitney U-test. Categorical variables were expressed as counts and percentages and compared using Fisher's or Fisher-Freeman-Halton's exact test. Correlations were assessed using rank-biserial or point-biserial methods. Kaplan-Meier analysis and log-rank tests were used for survival comparisons. A p-value <0.05 was considered statistically significant.

RESULTS

Table (1): Demographic characteristics of patients during both study phases

Variable	Phase 1 (N=57)	Phase 2 (N=60)	P value†
Sex (M/F), n/n	36/21	34/26	0.572‡
Age (months), median (IQR)	12.0 (6.0 - 36.0)	12.0 (6.0 - 30.0)	0.576
Weight (kg), median (IQR)	7.5 (5.5 - 12.0)	8.0 (5.0 - 11.0)	0.741
Height (cm), median (IQR)	70 (62 - 90)	72 (60 - 84)	0.713
BMI (kg/m2), median (IQR)	14.1 (12.8 - 15.3)	14.1 (12.5 - 15.7)	0.887

†. Mann-Whitney test unless otherwise indicated.
‡. Fisher's exact test.
IQR = interquartile range, n/n = ratio.

Table 1 showed that, the median age in both phases was 12 months. Median weight, height, and BMI in Phase 1 were 7.5 kg, 70 cm, and 14.1 kg/m^2, respectively, and in Phase 2 were 8.0 kg, 72 cm, and 14.1 kg/m^2. There was no significant difference in demographic data between the two phases.

Table (2): Anthropometric measurements of patients during both study phases

Variable	Phase 1 (N=57)		Phase 2 (N=60)		P value†
	n	%	n	%	
Weight Z-score					0.540
<-3	13	22.8%	9	15.0%	
-3	5	8.8%	9	15.0%	
-2.5	5	8.8%	2	3.3%	
-2	7	12.3%	9	15.0%	
-1.75	1	1.8%	0	0.0%	
-1.5	4	7.0%	2	3.3%	
-1	6	10.5%	9	15.0%	
-0.5	1	1.8%	2	3.3%	
0	4	7.0%	7	11.7%	
0.5	3	5.3%	2	3.3%	
1	6	10.5%	7	11.7%	
1.5	0	0.0%	2	3.3%	
2	2	3.5%	0	0.0%	
Height Z-score					0.241
<-3	5	8.8%	3	5.0%	
-3	7	12.3%	9	15.0%	
-2.5	3	5.3%	0	0.0%	
-2	13	22.8%	13	21.7%	
-1.75	1	1.8%	0	0.0%	
-1	9	15.8%	5	8.3%	
-0.5	0	0.0%	1	1.7%	
0	11	19.3%	19	31.7%	
0.5	0	0.0%	1	1.7%	
1	4	7.0%	4	6.7%	
2	4	7.0%	4	6.7%	
3	0	0.0%	1	1.7%	
Weight/Height Z-score					0.729
<-3	6	10.5%	5	8.3%	

-3	5	8.8%	9	15.0%	
-2.5	1	1.8%	0	0.0%	
-2	5	8.8%	9	15.0%	
-1.5	2	3.5%	0	0.0%	
-1	15	26.3%	12	20.0%	
0	13	22.8%	9	15.0%	
0.5	2	3.5%	0	0.0%	
1	5	8.8%	8	13.3%	
2	2	3.5%	5	8.3%	
2.5	0	0.0%	1	1.7%	
3	1	1.8%	2	3.3%	
BMI Z-score					0.496
<-3	14	24.6%	13	21.7%	
-3	2	3.5%	3	5.0%	
-2.75	0	0.0%	1	1.7%	
-2.5	6	10.5%	7	11.7%	
-2.25	0	0.0%	1	1.7%	

Table 2 showed that, anthropometric measures were plotted and represented in z -scores. Results shows that 52.7% of patients with WAZ ≤ −2 in phase 1, 48.3 % in phase 2, 49.2% with HAZ ≤ −2 in phase 1 & 41.7 % in phase 2. BMI Z-score ≤ −2 in phase 1 is 50.9% & 46.8 % in phase 2.

Table (3): Postoperative feeding intake

	Phase 1 (N=57)		Phase 2 (N=60)	
	n	%	n	%
Breastmilk	0	0%	0	0%
Standard Formula	27	47%	31	51%
High caloric Formula	9	15.7%	10	16%
Cow milk & semisolid	20	35%	15	25%
Monogen	0	0%	4	6.6%

Table 3 showed that, the documented postoperative feeding intake shows that patients who received standard formula was 47% and 51% in phase 1 and 2 respectively. while patients who received high caloric formula was 15.7% and 16% in phase 1 and 2 respectively. Cow milk and semisolid intake counted to be 35 % and 25% in phase 1 & 2 respectively. Monogen intake was documented only in phase 2 representing 6.6% of this phase.

Table (4): Median of NPO Days, Time to Start Enteral Feeds, Time to Reach Full Caloric Intake, and Number/Percentage of Patients Successfully Achieving Full Caloric Intake in Both Study Phases"

Variable	Phase 1 (N=57)		Phase 2 (N=60)		P value†
	Median	IQR	Median	IQR	
NPO days	4	2.00 - 6.00	1	1.00 - 2.00	<0.001
Time to start enteral feeding(days)	4	2.25-5.75	2	2.00-2.00	0.005
Time to reach full caloric intake (days)	6.5	5.00-10.00	4	4.00-5.00	<0.001
Starting enteral feeding	50	87.7%	60	100.0%	0.005
Reaching target caloric intake	42	73.7%	59	98.3%	<0.001

Table 4 showed that, implementation of the feeding protocol in the postoperative ICU led to earlier initiation and faster progression of enteral nutrition. Median NPO days decreased from 4 in Phase 1 to 1 in Phase 2; enteral feeding started earlier (day 4 vs. day 2), and full caloric intake was achieved sooner (6.5 vs. 4 days). The number of patients who started enteral feeding increased from 87.7% to

100% (p = 0.005), and those who reached full caloric intake rose from 73.7% to 98.3% (p < 0.001).

Table (1): Incidence of Main Clinical Endpoints Including Mechanical Ventilation Duration, NPO Days, and ICU Length of Stay in Both Study Phases

Outcome	Phase 1 (N=57)		Phase 2 (N=60)		P value†
	n	%	n	%	
Weaning from MV	56	98.2%	60	100.0%	0.487
Survival to ICU discharge	40	70.2%	55	91.7%	0.004
Variable					
Duration of MV (hr.)	48	24 - 96	24	24 - 48	0.070
ICU length of stay (days)	9	6 - 14	7	5 - 11	0.017

Table 5 showed that, implementation of the nutritional protocol led to a significant improvement in ICU survival, increasing from 70.2% in Phase 1 to 91.7% in Phase 2 (p = 0.004). While no significant difference was observed in weaning from mechanical ventilation, the median ventilation duration decreased from 48 to 24 hours (p = 0.007), and ICU stay was reduced from 9 to 7 days (p = 0.017).

Table (6): Incidence of infective complications and change in TLC and CRP levels during both study phases.

Variable	Phase 1 (N=57	Phase 2 (N=60)	P value†
Positive microbiological culture, n (%)	21 (42.0%)	8 (22.2%)	0.067‡
Wound infection, n (%)	2 (3.5%)	7 (11.7%)	0.164‡
TLC (k/mm3), median (IQR)			
Day 1	20.0 (15.0 - 22.0)	15.0 (10.7 - 22.0)	0.137
Day 3	18.0 (14.0 - 21.0)	15.0 (12.0 - 19.0)	0.029
Day 5	13.5 (10.0 - 18.0)	12.0 (10.0 - 15.0)	0.144
Day 7	11.3 (10.0 - 14.0)	11.3 (10.0 - 15.0)	0.879
CRP (mg/l), median (IQR)			
Day 1	121 (79 - 170)	109 (83 - 147)	0.208
Day 3	123 (63 - 180)	90 (39 - 140)	0.023
Day 5	90 (52 - 157)	56 (27 - 90)	0.012
Day 7	66 (33 - 100)	49 (22 - 111)	0.738

Table 6 show that positive microbiological culture in phase 1 was 42% decline to be 22.2% in phase 2 with p value 0.067. Serial TLC count was reported demonstrating decline in day 3 with median count 18 (IQR 14,21) in phase 1 to be 15 (IQR 12, 19) in phase 2 with p value 0.029. Also, the CRP level in phase 1 decline at day 3 with median value 123 (IQR 63,180) to be 90 (IQR 39,140) in phase 2 with p value 0.023. and at day 5 median level 90 (IQR 52,157) in phase 1 to be 56 (IQR 27, 90) in phase 2 with p value 0.012. On the other hand, results don't show any statistical significance between both phases from the point of view of wound infection.

Table (7): Subgroup analysis for comparison of relevant outcomes in patients who started enteral feeding before or after 48 hours during phase 2.

Variable	Time to start enteral feeding in phase 2		P value
	ENN Within 48 hours (N=46)	LEN After 48 hours (N=14)	
Duration of MV (hr.)	24 (12 – 24)	48 (48 – 144)	<.001†
ICU length of stay (days)	5 (5 – 7)	15 (10 – 20)	<.001†
Mortality	0 (0.0%)	5 (35.7%)	<.001‡

Table 7 showed that, subgroup analysis was done in phase 2 comparing between patients who started early enteral nutrition (ENN) before 48h postoperative (n=46) and patients who started late enteral nutrition (LEN) after 48 hours postoperatively (n=14). Results revelated that patient with ENN median duration of mechanical ventilation was 24 (IQR 12,24) h while in LEN was 48 (IQR 48, 144) h. with p value < 0.001. while median ICU length of stay in ENN was 5 (IQR 5,7) days and in LEN is 15 (IQR (10, 20) days with p value 0.001. Mortality rate is 0% in ENN while in LEN was 5% with p value <0.001.

DISCUSSION

Substantial variation in feeding practice still exists despite the American Society for Parenteral and Enteral Nutrition guidelines from 2017. Report of institutional established feeding protocol was associated with increased early feeding and reaching goal feeds by 48 hours postoperative (8).

There were no significant differences in baseline demographics between the two phases, with both groups having a median age of 12 months and similar weight, height, and BMI. Undernutrition was common, as shown by comparable rates of low WAZ, HAZ, and BMI z-scores in both phases. Most patients received standard formula, while smaller percentages received high-caloric formula, cow milk, or semisolid food. Monogen formula was used only in Phase 2 in a small proportion of patients. That reflect on the median NPO days that significantly declines from 4 to 1 days in phase 1 and 2 respectively (p < 0.001). On the other hand, patients who reached the target caloric intake is 73.7% in phase 1 increasing to 98.3% in phase 2 (p < 0.001).

These findings were similar to results examining enteral feeding protocols with neonates with HLHS. Braudis et al., (9) and Del Castillo et al., (10) demonstrated post- operative feeding protocols could decrease the incidence of NEC and help facilitate patients receiving their recommended calories faster.

The results in this study revealed that the median hour of mechanical ventilation decreases from 48 h in phase 1 to 24 h in phase 2 (p = 0.07) and ICU stay median days decrease from 9 days in phase 1 to 7 days in phase 2 (p = 0.017). Survival to ICU discharge 70.2% and 91.7 % in phase 1 and 2 respectively (p= 0.004).

A systematic review and meta-analysis assessing the effectiveness of early enteral nutrition on post-operative outcomes of congenital cardiac surgery in infants. The findings of existing review summarized that early enteral feeding or supplementary nutrition is safe and effective intervention in infants to reduce the post-operative complications, ICU stay and duration of mechanical ventilation (11).

Recent studies have suggested that early enteral nutrition (EEN) is the most favorable and immediate replacement of nutrients (24-72 hours) following congenital cardiac surgery). There is evidence available that EEN reduces the length of ICU stays, lessens mechanical ventilation, and decreases hospital expenditure (12). Critical illness brings forth numerous hormonal and metabolic derangements, leading to grave micronutrient and macronutrient deficiencies (13). All primary studies reported that EEN continued to be small, increasing gradually to the target volume within 48-72 hours. Enteral nutrition is a simple and often substitute marker for post-operative recovery in routine clinical practice (14).

Incidence of infective complications and change in TLC and CRP levels during both study phases was calculated and the results revealed decline of the infection rate proved by positive microbiological cultures from 42% to 22.2% in phase 1 and phase 2 respectively with (p = 0.067);

17these results was compatible with a study done by Sahu MK and his colleagues, shows the microbiologically confirmed cultures positives (from tracheal aspirates, blood, wound discharge and urine). A total of 28 patients were suspected to have infection in control and interventional group who have early enteral nutrition. the samples from different sources in 17 patients were sent for culture to microbiology laboratory. Of 17 patients, pathogenic microorganisms were isolated from different samples of eight patients and rest of the nine patients produced negative results. Of the eight culture positive patients, five were from control group and three patients were from the intervention group (15).

In the current study there were also decline in the mean of CRP in day 3 and day 5 during phase 2 with early enteral feeding with p value 0.023 and 0.012 respectively. Also, a decline in TLC level between both phases in Day 3 with (p value 0.29).

There is a significant correlation between nutritional status and the prognosis of critically ill children

(16), which was mainly reflected by shorter duration of mechanical ventilation and lower incidence of pneumonia; it is also possible that children with poor nutritional status have a poor inflammatory response and are therefore more susceptible to pneumonia, as other studies have confirmed these results (17).
A significance difference in median mechanical ventilation hours from 24 to 48 hours in ENN and LEN respectively ($p < 0.01$). Also, a significance affection of ICU length of stay median days 6 and 11 in ENN and LEN respectively ($p < 0.01$). Mortality rate in ENN was 0% while in LEN was 37.9 %. ($p < 0.01$).
This was relevant with a pilot study that reported they initiated enteral feeding after 6 hours of cardiac surgery after their initial hemodynamic stabilisation, they found that the ventilation duration, ICU stay and hospital stay was less in intervention group as compared to the control group, and also, they observed that early enteral feeding is feasible in post cardiac surgery children with better convalescence (15).
Another study results revealed that children in the 24-EEN group had shorter duration of MV compared with those in the 24-LEN group ($P = 0.04$). EEN may improve nutrient delivery, reduce time on MV, and prevent constipation in critically ill children (18).
A study; Median time to EN was 29 vs 79 h from admission in the EEN and LEN groups, respectively. There was no significant difference in mortality or hospital LOS between the two nutrition strategies. EEN was associated with shorter ICU LOS, lower need for renal replacement therapy, and lower incidence of electrolyte abnormalities (19).

Limitation

This single-center study is limited by several confounding factors such as surgery complexity, bypass time, residual lesions, and feeding tolerance. Enteral feeding was not always possible, especially in neonates and complex cases with complications like NEC or chylothorax. Data on preoperative status and standardized formula use were lacking. Larger multicenter studies with unified protocols are recommended to reduce bias and improve reliability.

CONCLUSION

Providing adequate nutrition is very much essential for the patients with CHD, Improved strategies for nutritional support and standard feeding regimen have been associated with increased survival and decreased overall morbidity. Preoperative optimization of nutritional status may improve the clinical outcome postoperatively. Enteral nutrition is a simple and often substitute marker for post-operative recovery in routine clinical practice. However, there is high prevalence of nutritional deficits among patients specially neonates and infants after congenital cardiac surgery. Therefore, there is an urgent need for an evidence-based guideline on the specific timing and nutrients to be adopted to decrease post-operative complication following congenital cardiac surgery.

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