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Factors Influencing the Timing of Enteral Nutrition Tolerance in Pediatric Patients Following Open-Heart Surgery: A Retrospective Study in a Referral Center in Iran

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Abstract

Background: Congenital Heart Disease (CHD) is a leading cause of morbidity and mortality in children, with open-heart surgery being a critical intervention. Early initiation of Enteral Nutrition (EN) after surgery is essential for recovery; however, few studies have explored the factors that influence the timing of EN tolerance. This study aimed to identify the factors affecting the timing of EN tolerance in pediatric patients following open-heart surgery.

Methods: A retrospective study was conducted on pediatric patients who underwent open-heart surgery at Children's Medical Center, Tehran, between July 2018 and March 2019. Medical records were reviewed to assess factors such as patient characteristics, duration of mechanical ventilation, sternum status, and the day EN was tolerated. The statistical analysis was performed in SPSS version 24 using Pearson correlation, independent t-test, One-way analysis of variance (ANOVA), and multiple linear regression analysis. The significance level was set at 0.05.

Results: The medical records of 109 patients were analyzed. EN was tolerated at an average of 8.67 days post-surgery. Univariate analysis showed significant associations between late EN tolerance and lower weight ($p=0.03$), longer mechanical ventilation duration ($p<0.001$), and open sternum status ($p=0.02$). However, multiple linear regression identified duration of mechanical ventilation as the sole significant predictor of EN tolerance time ($p<0.001$).

Conclusion: The results identified prolonged mechanical ventilation as the primary predictor of late EN tolerance in pediatric cardiac surgery patients. Further studies are needed to validate this finding and to explore additional factors influencing EN tolerance.

Keywords: Congenital, Cardiac surgical procedures, Enteral nutrition, Heart defects, Postoperative care

Introduction

Congenital Heart Disease (CHD) refers to a range of structural abnormalities in the heart or great vessels that are present at birth and result from improper development during fetal life (1). CHD is recognized as the most common type of congenital anomaly (2), with an estimated incidence ranging from 8 to 17 cases per 1000 live births across different regions (3). Surgical interventions play a crucial role in the management of CHD (4). Nowadays, open-heart surgery is frequently required to correct or palliate many forms of the disease, particularly in cases diagnosed during infancy or early childhood (5). Advancements in medical management and surgical techniques have markedly enhanced survival outcomes (6), allowing over 97% of children with CHD to reach adulthood (7). While these procedures can be life-saving, they also impose considerable physiological stress on pediatric patients (8,9). The postoperative period of cardiac surgery is often characterized by hemodynamic instability, systemic inflammatory response, and multi-organ dysfunction, which can complicate the management of nutritional support (10-13). Among the various challenges in postoperative care, the initiation and progression of Enteral Nutrition (EN) is of critical importance (14).

EN is defined as the delivery of nutrients directly into the gastrointestinal tract (15). It is the preferred route of nutritional support in critically ill children, including those recovering from cardiac surgery (16,17). EN provides approximately two-thirds of a patient's caloric needs and plays a crucial role in improving outcomes following cardiac surgery (18). A systematic review and meta-analysis found that early EN after pediatric open-heart surgery was associated with shorter hospital and ICU stays, reduced need for mechanical ventilation, and shorter durations of aortic cross-clamping and cardiopulmonary bypass. Additionally, early EN was linked to lower rates of postoperative complications, including infections and mortality (14). Therefore, it is recommended to initiate EN as early as possible (12).

In the context of pediatric cardiac surgery, especially those involving Cardiopulmonary Bypass (CPB), the initiation of EN can be challenging (19,20). Factors such as complications from CPB, postoperative hypotension, the use of vasopressors, gastrointestinal hypoperfusion, and delayed return of bowel motility can contribute to delays in initiating enteral feeds (21-24). Late initiation of EN exacerbates the risk of protein-energy malnutrition, which is associated with poorer outcomes and increased healthcare utilization (25,26). Therefore, timely and appropriate nutritional support is a key component of recovery and should be a clinical priority in the management of pediatric cardiac surgery patients.

Despite the recognized benefits of early EN, the existing literature remains limited—particularly regarding pediatric patients undergoing open-heart surgery, with most studies focusing on outcomes rather than the factors influencing its initiation (27,28). Therefore, this study aimed to examine the timing of EN tolerance in pediatric patients following open-heart surgery and the possible factors influencing it.

Materials and Methods

Study design and setting

This retrospective study was conducted through the analysis of medical records of pediatric patients who underwent open-heart surgery at Children's Medical Center Hospital, affiliated with Tehran University of Medical Sciences, Tehran, Iran, between July 23, 2018, and March 20, 2019. Children's Medical Center Hospital is a tertiary referral center and one of the three pediatric heart surgery centers in Iran. The hospital admits patients from all regions of the country, providing a diverse and representative sample of the pediatric population with CHD, thereby enhancing the generalizability of the study findings.

Participants

The study population consisted of pediatric patients with confirmed congenital heart disease (as diagnosed by a pediatric cardiologist) who were admitted to the ICU-OH ward of Children's Medical Center Hospital. Children were included in the study if they had a diagnosis of congenital heart disease, underwent open-heart surgery during the study period, were admitted to the ICU-OH after surgery, and had complete medical records related to nutritional management. Patients were excluded if they required reoperation during the same admission, had incomplete or missing nutritional data, or had pre-existing gastrointestinal conditions that could affect EN. These exclusion criteria ensured that the correlations observed in the data would more accurately reflect the true relationships between patient-related factors and EN initiation and tolerance, without the confounding influence of additional surgical stress or pre-surgery gastrointestinal conditions.

Data collection

After obtaining ethical approval and the necessary permissions to access medical records, two researchers (SH and BG) reviewed all medical records to identify eligible patients. Once the eligible cases were selected, data extraction for the study began. A structured checklist was used to ensure the consistency and completeness of the collected data. The checklist included variables such as age, gender, weight, congenital heart disease diagnosis, Risk Adjustment for Congenital Heart Surgery (RACHS-1) score, duration of ventilation, whether the sternum was closed or open after surgery, and the day on which EN was tolerated. In case of any disagreements or discrepancies between the researchers regarding the data extraction, a third researcher (MRM) was consulted to resolve the issue and ensure accuracy in the final dataset.

Definitions

In this study, weight refers to the patient's weight measured one day before surgery. The day of tolerating EN refers to the specific post-surgery day when the patient is successfully administered EN without complications such as vomiting more than twice or abdominal distension, with the volume gradually increased as tolerated. Regarding the acceptable amount of administered EN, there is no consensus among specialists (29). However, to enhance the validity of our findings, we adopted the definition provided by Hamilton *et al*, which considers EN to be tolerated if there are no signs of intolerance—including gastric residual volumes greater than 3 *ml/kg* and other evidence of EN intolerance—after 4 *hr* of feeding (30). EN refers to the delivery of nutrients directly into the gastrointestinal tract, for example, through a feeding tube (29).

One of the clinical variables assessed in this study was the RACHS score. The RACHS score is a classification system used to assign congenital cardiac surgeries into categories based on their complexity and expected risk of mortality. A higher RACHS score indicates a more complex surgical procedure and a greater expected risk (31). Ventilation duration is the period of time a patient requires mechanical ventilation to support breathing after surgery. Another clinical variable assessed in this study was the status of the sternum after surgery. Closed sternum refers to the sternum being closed after surgery, while open sternum indicates the sternum was left open post-surgery, often due to complications and unstable hemodynamics.

Ethics approval

Ethical approval for this study was granted by the Ethics Committee of Tehran University of Medical Sciences (Approval No. IR.TUMS.CHMC.REC.1398.062). The study adhered to the ethical principles outlined in the Declaration of Helsinki. Informed consent was waived by the Ethics Committee due to the retrospective nature of the study. All patient data were anonymized to ensure confidentiality.

Data analysis

Data were analyzed using SPSS version 24. The normal distribution of the data was assessed and confirmed using the Kolmogorov-Smirnov test. Continuous variables were reported using the mean and standard deviation. Categorical variables were reported using frequency and percentage. To assess the relationship between continuous variables, Pearson correlation was used. For comparing the differences in continuous variables between two groups, an independent t-test was applied. When comparing more than two groups, one-way analysis of variance (ANOVA), and multiple linear regression analysis was used. A significance level of 0.05 was considered for all statistical tests.

Results

Demographic and clinical characteristics of the patients

A total of 109 pediatric patients who underwent open-heart surgery were included in the analysis. The mean age of the patients was 84.39±73.59 days, and the mean weight was 4.02±1.04 *kg*. The average duration of mechanical ventilation was 135.24±82.31 *hr*.

The mean RACHS-1 score was 2.76±0.98. Among the patients, 65 (59.6%) were male and 44 (40.4%) were female. Regarding sternum status, 35 patients (32.1%) had an open sternum postoperatively, while 74 (67.9%) had a closed sternum. In terms of CHD diagnoses, the most frequent condition was Ventricular Septal Defect (VSD), observed in 28 patients (25.7%), followed by dextro-Transposition of the Great Arteries (d-TGA) in 22 patients (20.2%) and coarctation of the aorta in 16 cases (14.7%). On average, patients tolerated EN at 8.67±5.28 days after surgery (Table 1).

The relationship between patient characteristics and the day of EN tolerance

A significant negative correlation was observed between weight and the day of EN tolerance (p=0.03). Additionally, a strong positive correlation was found between the duration of mechanical ventilation and the day of EN tolerance (p<0.001). No significant associations were observed between age (p=0.13) or RACHS score (p=0.06) and the day of EN tolerance. Additionally, there was no statistically significant difference in EN tolerance between male and female patients (p=0.17). The status of the sternum (open or closed) was also significantly associated with the time to initiation of EN tolerance (p=0.02). The type of CHD diagnosis was not significantly associated with the day of EN tolerance (p=0.76) (Table 2).

Predictors of time to EN tolerance

A multiple linear regression analysis was conducted to examine the predictors of time to EN tolerance. The model included variables that were significantly associated in the univariate analysis, including weight at admission, sternum status (open or closed), and duration of mechanical ventilation as independent variables. The results revealed that only the duration of mechanical ventilation was a significant predictor of EN tolerance time (p<0.001) (Table 3).

Table 1. Demographic and clinical characteristics of the patients

Variable	Mean ± SD
Age (days)	84.39±73.59
Weight (*kg*)	4.02±1.04
Duration of ventilation (*hr*)	135.24±82.31
RACHS-1 score	2.76±0.98
Day of EN tolerance (days)	8.67±5.28
Sex	N (%)
Female	44(40.4%)
Male	65(59.6%)
Sternum status	
Open	35(32.1%)
Closed	74(67.9%)
CHD diagnosis	
Atrial septal defect	6(5.5%)
Coarctation of the aorta	16(14.7%)
Dextro-transposition of the great arteries	22(20.2%)
Patent ductus arteriosus	5(4.6%)
Single ventricle	3(2.8%)
Total anomalous pulmonary venous connections	6(5.5%)
Tetralogy of fallot	6(5.5%)
Ventricular septal defect	28(25.7%)
Others	17(15.6%)

Table 2. Association between patient characteristics and day of enteral nutrition tolerance

Variable	Test statistic	p-value
Age (days)	r=-0.14	p=0.13 *
Weight (*kg*)	r=-0.20	p=0.03 *
Duration of ventilation (*hr*)	r=0.82	p<0.001 *
RACHS score	r=0.18	p=0.06 *
Sex	t=1.368	p=0.17 **
Sternum status	t=2.294	p=0.02 **
CHD diagnosis	F=0.617	p=0.76 ***

*Pearson correlation **Independent t-test ***ANOVA.

Discussion

This retrospective study investigated the factors influencing the initiation of EN in pediatric patients following open-heart surgery. The study found that patient sex, age, CHD diagnosis, and RACHS score were not significantly associated with the timing of EN tolerance. The present results revealed that lower body weight and longer mechanical ventilation duration were significantly associated with late EN

Table 3. Multiple Linear Regression Analysis for Predictors of Tolerance to Enteral Nutrition

Predictor	B (unstandardized coefficient)	Std. Error	Beta (standardized coefficient)	t	p-value
(Constant)	-1.157	2.099	-	-0.551	0.583
Admission weight (*kg*)	0.547	0.495	0.066	1.105	0.272
Sternum status (Closed *vs.* Open)	-0.317	1.080	-0.017	-0.293	0.770
Duration of ventilation (*hr*)	0.054	0.004	0.845	14.549	<0.001

tolerance. Additionally, an open sternum status was linked to postponed initiation of EN.

The results revealed that longer durations of mechanical ventilation were associated with late EN tolerance. Furthermore, multivariate analysis identified the duration of mechanical ventilation as the sole independent predictor of the timing of EN tolerance. This finding suggests the interrelationship between respiratory support needs and nutritional recovery. In line with our findings, Yang *et al* demonstrated that mechanical ventilation is a risk factor for late EN tolerance in adults (32). The results of a systematic review and meta-analysis found that the duration of mechanical ventilation can significantly influence EN tolerance, supporting our findings (33). Additionally, this finding aligns with previous studies indicating that prolonged mechanical ventilation often reflects greater illness severity (34), and hemodynamic instability (35) that also delay gastrointestinal recovery and feeding readiness.

The authors found that lower weight was associated with late EN tolerance. This finding suggests that reduced gastrointestinal function in underweight infants may predispose them to feeding intolerance and delayed gastric emptying. Previous literature identified younger age as a risk factor for feeding intolerance, which aligns with our findings (36,37).

The presence of an open sternum postoperatively emerged as a significant factor influencing EN tolerance. This finding is consistent with existing literature suggesting that an open sternum is a marker of severe postoperative instability, often necessitated by intractable hemodynamic compromise or myocardial edema (38,39). This condition can delay EN due to concerns about mesenteric perfusion and gastrointestinal motility. The present results reinforce the need for cautious nutritional planning in this high-risk subgroup.

The lack of association between CHD diagnosis and EN tolerance suggests that postoperative nutritional trajectories may be more influenced by procedural factors than by the underlying anatomical lesion. The RACHS score was not significantly associated with EN tolerance, although the p-value was close to the significance threshold. This may be attributed to the small sample size in our study. Conducting similar studies with a larger sample size is recommended to better clarify the potential impact of the RACHS score and CHD diagnosis on EN tolerance.

The identification of weight, ventilation duration, and sternum status as key factors affecting EN tolerance can guide risk stratification and early nutritional planning. Notably, the duration of mechanical ventilation stands out as the most critical factor, as it was the only significant predictor in the multiple linear regression analysis. Clinicians should closely monitor patients with extended mechanical ventilation, implementing early nutritional strategies such as slow and incremental feeding advancements and the use of trophic or minimal enteral feeding to maintain gut integrity. Other practical measures may also include regular assessment of gastrointestinal function and collaboration between the critical care team, dietitians, and surgeons to adjust feeding protocols promptly. Such interdisciplinary approaches are essential to reduce feeding-related complications and ensure adequate nutritional support for patients receiving mechanical ventilation.

Strengths of this study include its relatively large and representative sample of pediatric patients undergoing open-heart surgery, drawn from the largest pediatric cardiac center in Iran. The use of a structured data extraction tool and standardized definitions for EN tolerance enhances the internal validity of the findings. However, the study also has several limitations. In this study, the small sample size may reduce statistical power and limit the precision of the findings. As a retrospective analysis, it is subject to potential information bias due to the reliance on documentation quality in medical records. To enhance the accuracy and comprehensiveness of data collection, it is recommended that future research be conducted using a prospective or longitudinal study design, which would allow for real-time monitoring of nutritional variables, clinical parameters, and outcomes. Furthermore, the study did not evaluate inflammatory markers or hemodynamic parameters that could influence gastrointestinal perfusion and feeding tolerance. The lack of information on laboratory test results (such as lactate levels, serum albumin, and markers of inflammation), the use of inotropic agents, the inotropic score, and the duration of CPB represents a further limitation, as these variables are known to affect postoperative recovery and gut perfusion and could significantly influence the timing of EN initiation. Future studies should also incorporate these variables to provide a more comprehensive understanding of the physiological factors influencing feeding tolerance in this population. They should also include larger samples to strengthen the statistical power. Finally, findings from a single center may limit generalizability to other healthcare settings with different practices or patient populations. Future studies should involve multi-center collaborations to enhance external validity.

Conclusion

The present findings showed that lower weight, prolonged mechanical ventilation, and open sternum status are associated with late EN tolerance. Notably, duration of mechanical ventilation was the only significant predictor in the multiple linear regression analysis, highlighting its crucial role in EN tolerance. These factors should be carefully considered in the early postoperative care of pediatric patients to guide nutritional planning and minimize the risk of malnutrition. Despite these valuable insights, the study's limitations—such as its retrospective design and lack of data on key physiological parameters—suggest the need for future prospective, multi-center studies to validate these findings and explore additional determinants of EN tolerance in pediatric cardiac surgery patients.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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