

Original Research Article

Implications of congenital heart disease on growth and development of paediatric cardiac surgical patients

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Received: 28 June 2021

Accepted: 12 July 2021

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ABSTRACT

Background: To identify the prevalence, predictors and implications of malnutrition and failure to thrive (FTT) in paediatric cardiac surgical patients.

Methods: Observational retrospective analysis of data of paediatric patients presenting for cardiac surgery at Queen Alia heart institute/Amman/Jordan between April 2020 and October 2020. Patients' ages, anthropometric measurements, diagnoses, type of surgical intervention, ICU stay and perioperative outcomes were recorded on a special form designed for the purpose of this study. Prevalence of malnutrition based on world health organization (WHO) and centers for disease control (CDC) growth charts was determined using height-for-age z-score (HAZ) and percentile, weight-for-age z-score (WAZ) and percentile, weight-for-height z-score (WHZ) and percentile. BMI was used for patients above 2 years of age in 109 paediatric cardiac surgical patients. Prevalence of malnutrition and FTT was examined according to age category and cardiac pathology). Patients were divided according to heart pathology into cyanotic and acyanotic CHD.

Results: One hundred and nine pediatric cardiac surgical patients were presented for cardiac surgery (59 males and 50 females). Patients' age ranged from 2 days to 17 years (mean 3.7 years, SD±4.5 years). Patients' body weight ranged from 2.7 to 70 kg (mean 14.98 kg, SD±14.2 kg). Average weight percentile was 19.26 (SD±20.01) and ranged between 0.1 and 88.5 and the average Z-score for weight was -1.274±1.037 (mean±SD). The overall height percentile for the all patients with CHD averaged 18.53±17.1 (mean±SD) and the average Z-score for height was -1.1029±0.743 (mean±SD). Prevalence of isolated malnutrition and FTT was 33.2% and 20.2%. Normal nutritional status was found in 46.78%. Cyanotic type CHD was more commonly associated with FTT (p=0.001), longer cardiopulmonary bypass (p=0.001), higher intraoperative lactate (p=0.012) and aortic cross clamp times (p=0.001). Patients with malnutrition and FTT had average ICU stay of 4.32±2.219 days and averaged 4.772±2.065 days (mean±SD) respectively, which was almost double of the ICU stay of patients who had normal nutritional status 2.32±2.261 days (mean±SD).

Conclusions: Prevalence of malnutrition and FTT is high in paediatric patients with CHD at time of presentation for surgery. Predicting factors for malnutrition and FTT are cyanotic type of CHD and smaller age. Malnutrition was associated with longer ICU stay.

Keywords: Congenital, Cyanotic, FTT, Heart, Intensive care, Malnutrition

INTRODUCTION

Congenital heart disease (CHD) is the most common neonatal congenital malformation afflicting approximately 0.8% to 1.2% of live births worldwide.^{1,2} Poor physical

growth described as being underweight for age and decreased height/length for age is relatively common in children with CHD.^{3,4} Causes of poor growth in children with CHD are low energy intake and high energy expenditure, or both.^{5,6}

The severity of malnutrition in children with CHD can range from mild malnutrition to FTT.⁷ This can have considerable effects on the outcome of surgery, increasing length of intensive care unit stay and hospitalization time.⁸ Different types of CHD can affect nutritional status and growth to varying degrees.⁹

Physical growth assessment is often used to gauge a child's general health and ability to thrive. Generally, FTT has been divided into endogenous (organic) and exogenous (nonorganic). Causes of FTT can be largely grouped into three categories: inadequate caloric intake, malabsorption/caloric defect, and increased metabolic demands.¹

Although the terms malnutrition, FTT and stunted growth are often used interchangeably; they are not exactly the same. FTT is a symptom, not a diagnosis. Malnutrition is a diagnosis that more accurately describes inadequate nutrition and can be determined by clinical assessment. The definition of growth stunting according to the WHO is for the "height for age" value to be less than two standard deviations of the WHO child growth standards median.¹¹

One of the main causes of FTT is CHD.^{1,2} Our study aimed to identify the implications of different types of CHD on physical growth of children at time of presentation for surgery at Queen Alia heart institute in Amman-Jordan.

METHODS

This study is a retrospective analysis of data of paediatric patients presenting for cardiac surgery at Queen Alia heart institute/Amman/Jordan between April 2020 and October 2020. Patients' ages (and age categories), anthropometric data, cardiac diagnoses, surgical intervention, intra-operative variables (duration of cardiopulmonary bypass (CPB), duration of aortic cross-clamp, serum lactate, use of haemo-filtration) and post-operative ICU stay were recorded on a special form designed for the purpose of this study. Data was tabulated and statistical analysis performed. Prevalence of malnutrition and FTT was examined according to age category and cardiac pathology). Patients were divided according to heart pathology into cyanotic and acyanotic CHD and subsequently compared according to perioperative parameters. Ethical committee approval obtained from the institutional review board (IRB) of the Jordan royal medical services (JRMS).

Definitions

Malnutrition based on WHO and centers for disease control (CDC) growth charts was determined using height-for-age z-score (HAZ) and percentile, weight-for-age z-score (WAZ) and percentile, weight-for-height z-score (WHZ) and percentile for paediatric cardiac surgical patients whom age is less than 2 years. Body mass index (BMI) was used for paediatric cardiac surgical patients above 2 years of age.¹³⁻¹⁵

For measurement electronic scale was used to measure body weight. For children below 2 years length was measured in recumbent position using measuring tape while for children above 2 years of age height (stature) was measured using a stadiometer or an anthropometric rod. Measurements were performed by trained personnel with significant prior experience with these different instruments for height assessment across varying age groups.

Inclusion criteria

Paediatric cardiac surgical patients presented for cardiac surgery since birth up to 18 years of age were included in the study.

Exclusion criteria

Adult congenital cardiac surgical patients presenting for cardiac surgery, paediatric patients with other congenital anomaly that may cause malnutrition or FTT (maxillofacial, neurological, gastro-intestinal or other), and patients with missing perioperative data were excluded from the study.

Statistical analysis

The mean and standard deviation were used to describe continuous measured variables and the frequency and percentages were used for categorically measured variables. The histogram and the statistical Kolmogorov-Smirnov K-S test was used to assess the Normality assumption of continuous variables and the Levene's test of homogeneity of variance for testing the equality of variance statistical assumption. The Chi-squared (χ^2) test of association was used to assess the associations between categorically measured variables; however, a continuity Adjusted and Likelihood ratio chi-squared tests and associated p were quoted when the statistical assumptions of observed counts below expected were noted for contingency tables and the independent samples t-test was used to assess the statistical mean differences on metric variables across levels of binary categorically measured variables levels. The multiple response dichotomies analysis was used to describe the variables with more than option (e.g., etiology and surgical procedures for cardiac disease). The multivariate binary Regression analysis was used to assess the statistical significance of the predictors of patients' odds of having been treated for cyanotic heart defects, association between patients sociodemographic and disease related factors with cyanotic heart lesions was expressed as an odds ratio with associated 95% CI. The alpha significance level was considered at 0.050 levels and the commercially available SPSS IBM statistical analysis program was used for the data analysis.

RESULTS

One hundred and nine pediatric patients with congenital cardiac disease presented for cardiac surgical repair

included 59 males (54.1%) and 50 females (45.9%). Patients' age ranged from 2 days to 17 years (mean 3.69 years, SD±4.51 years). Patients' body weight ranged from 2.7 to 70 kg (mean 14.98 kg, SD±14.2 kg). Average weight percentile was 19.26 (SD±20.01) and ranged between 0.1 and 88.5. Descriptive analysis of paediatric cardiac surgical patients and their sociodemographic data is presented in Table 1. The study population comprises 39 infants (<1 year of age) (35.8%), 33 toddlers (1-3 years) (30.3%), 16 pre-school age patients (3-6 years) (14.7%), 8 school age patients (7-9 years) (7.3%) and 13 teenage

patients (11.9%). Overall, 73 patients had normal weight for age (67%), 33 patients were underweight for age (30.3%) and 3 patients were at risk of overweight (2.8%). 81 patients had normal height for age (74.3%) and 28 patients were short for age (25.7%). The incidence of malnutrition was 33.2% and the incidence of FTT was 20.2%. Patients with malnutrition had average ICU stay of 4.32±2.219 days (mean±SD), and patients who had FTT had an ICU stay that averaged 4.772±2.065 days (mean±SD) whereas patients who had normal nutritional status ICU stay averaged 2.32±2.261 days (mean±SD).

Table 1: Descriptive analysis of the cardiac surgical children's sociodemographic characteristics and anthropometric measures (n=109).

Variables	Frequency	Percentage (%)
Sex		
Female	50	45.9
Male	59	54.1
Age (years), mean (SD)		3.69 (4.51)
Age groups (years)		
Infant (age<1)	39	35.8
Toddler 1-3	33	30.3
Pre-schooler (age>3 to 6)	16	14.7
School age 7-9	8	7.3
Teenager≥10	13	11.9
Weight (kg), mean (SD)	14.97 (14.26)	
Weight percentile, mean (SD)	19.26 (20.10)	
Weight percentile categories		
5 th percentile	36	33
10 th percentile	13	11.9
25 th percentile	26	23.9
50 th percentile	24	22
75 th percentile	8	7.3
90 th percentile	2	1.8
Weight for age (kg)		
Normal	73	67
Underweight	33	30.3
At risk of overweight	3	2.8
Height (cm), mean (SD)		88.35 (32.50)
Height percentile, mean (SD)		18.51 (17.2)
Height percentile categories		
5 th percentile	28	25.7
10 th percentile	15	13.8
25 th percentile	35	32.1
50 th percentile	25	22.9
75 th percentile	5	4.6
>90 th percentile	1	0.9
Height for age (cm)		
Normal	81	74.3
Short	28	25.7
BMI (children aged >2 years), mean (SD)		16.31 (2.99)
Nutritional status		
Normal	51	46.788
Malnourished	36	33.02
Failure to thrive		
No	87	79.8
Yes	22	20.2

The overall height percentile for the all patients with CHD averaged 18.53 ± 17.1 (mean \pm SD) and the average Z score for height was -1.1029 ± 0.743 (mean \pm SD). Weight percentile for all CHD patients averaged 19.255 ± 20.01 (mean \pm SD) and the average Z score for weight was -1.274 ± 1.037 (mean \pm SD). For patients below 2 years of age Z score for weight for length averaged -0.75 ± 1.344 . For patients above 2 years BMI was used and averaged 16.31 ± 2.99 kg/m².

Descriptive analysis of the cardiac surgical indications for surgery, physiological classifications and perioperative outcomes are described in Table 2. Regarding the physiological classification of the children's diagnoses, 18.3% were found to have left heart obstructive lesions, most of them 45% had been with left to right heart shunting, and 11% had mixing lesions, but 16.5% of the children were found to have right heart obstructive lesions, 0.9% had right to left heart shunting and 8.3% had single ventricles. Regarding classification based on cyanosis, most of the children had acyanotic congenital heart disease and 29.4% of them had cyanotic CHD. The mean aortic cross-clamp time (ACCT) for sample of children was equal to 49.69 min, SD=23.31 min and the overall total cardiopulmonary bypass time CPBT was measured with 85.42 min, SD=39.28 min. Mean intraoperative serum lactate was 1.53 mmol/L, SD=0.82 mmol/L and 12.8% had required the use of haemo-filtration therapy during CPB. The length of ICU stay had an average of 2.89 days, SD=2.44 days.

Comparison between paediatric patients with cyanotic and acyanotic CHD is presented in Table 3. The Bivariate analysis in the table-3 was used to compare the cyanotic and acyanotic CHD children with respect to their sociodemographic, growth and surgical outcomes. The yielded findings showed that cardiac surgical children's sex did not correlate significantly with their likelihood of having cyanotic CHD. However, an independent samples t-test showed that the cyanotic children in the sample were significantly younger (Mean age=1.01 years) than the acyanotic children (mean age=4.81), $p < 0.001$, also the chi-squared test showed that the infants in the sample were found to be significantly more predicted to have cyanotic CHD compared to the other children, $p < 0.001$. Nonetheless, the cyanotic children measured significantly lower mean weight (M=6.76) compared to the acyanotic children (M=18.40), $p < 0.001$ according to an independent samples t-test, also the weight percentile for the cyanotic children was significantly lower than for the acyanotic children, $p < 0.001$, according to another independent samples t test. The yielded analysis findings suggested that there were significantly more children with weights falling within the 5th percentile among the cyanotic group compared to the acyanotic, $p < 0.001$ according to the chi-squared test of independence and the cyanotic CHD children were found to be significantly less predicted to fall within the 50th weight percentile. However, according to a likelihood ratio corrected chi-squared test of association, the age standardized weight for the children

had correlated significantly with being cyanotic, the underweight-for-age children were found to be significantly more predicted to be cyanotic however, $p < 0.001$. The yielded bivariate analysis also showed that the cyanotic children's mean height was significantly lower (M=65.7 centimeters) than the acyanotic children (M=97.76 centimeters) on average, $p < 0.001$. Likewise, the cyanotic children's standardized height percentile was significantly lower compared to the acyanotic children, $p < 0.001$ according to the independent t-test. But a likelihood Ratio corrected chi-squared test showed that children with heights falling within their 5th percentile for age and sex were found to be significantly more inclined to be cyanotic than acyanotic, $p < 0.001$, as well the chi-squared test suggested that short-stature for age was correlated significantly and positively with being cyanotic cardiac surgical patient, $p < 0.001$. The mean body mass index of the children did not converge significantly on the cyanosis outcome particularly for the children aged >2 years however, $p = 0.353$. As well, a chi-squared test of association showed that FTT had correlated significantly and positively with cyanosis, FTT children were found to be significantly more predicted to be cyanotic, $p < 0.001$. Cyanotic CHD children required significantly longer aortic cross-clamp time and total cardiopulmonary bypass time intra-operatively compared to acyanotic children on average, $p < 0.001$ each respectively. The cyanotic children also had significantly longer ICU stay on average compared to the acyanotic, p value of < 0.001 . The patients' intra-operative serum lactate and the need for haemo-filtration therapy did not correlate significantly with cyanotic CHD.

The multivariate binary logistic regression analysis of the paediatric cardiac surgical patients with cyanotic CHD, Table 4, showed that the children's age, sex, weight percentile, height percentile and failure to thrive did not converge significantly on cyanotic type of CHD, although the children who had failure to thrive were slightly more predicted (6.25 times more) for being cyanotic. The association between growth parameters and failure to thrive beside malnutrition did not correlate significantly with the patient's odds of having cyanotic type congenital heart disease, well by considering the other predictor variables in the analysis. But, the patient's length of ICU stay had converged significantly on their odds of being cyanotic, children who stayed longer in the ICU were found to be significantly more (3.03 times more) predicted for being with cyanotic congenital heart disease, p value of 0.002. The children's intraoperative aortic cross-clamp time and their total cardiac bypass time did not converge significantly on their odds of cyanosis, but their intraoperative lactate level had converged significantly but negatively on their odds of being with cyanotic congenital heart disease, as the children's intraoperative serum lactate tended to rise by one mmol/L; their corresponding odds of being with cyanotic congenital heart disease later declined by a factor equal to 79.1% times less on average, p value of 0.012, accounting for the other predictor variables in the analysis model nonetheless.

Table 2: Descriptive analysis of the children's cardiac surgical indications and outcomes (n=109).

Variables	Frequency	Percentage (%)
Definitive indications/etiology for the cardiac surgery		
Anomalous pulmonary venous connection (APVC)	5	4.6
Atrial septal defect (ASD)	20	18.3
Aortic stenosis (AS)	15	13.8
Mitral regurgitation (MR)	1	0.9
Pulmonary stenosis (PS)	4	3.7
Double-chambered right ventricle (DCRV)	1	0.9
Ventricular septal defect (VSD)	35	32.1
Double outlet right ventricle (DORV)	2	1.8
Atrioventricular canal (AVC)	6	5.5
Transposition of great vessels (TGV)	6	5.5
Tetralogy of Fallot (TOF)	14	12.8
Mitral stenosis (MS)	4	3.7
Other cardiac disease*	4	3.7
Diagnostic physiologic classification		
Left heart obstructive lesion	20	18.3
Left to right shunt	49	45
Mixing lesion	12	11
Right heart obstructive lesion	18	16.5
Right to left shunt	1	0.9
Single ventricle	9	8.3
Cardiac disease classification		
Acyanotic	77	70.6
Cyanotic	32	29.4
Type of cardiac surgery		
Ventricular septal defect (VSD) repair	34	31.2
Tetralogy of Fallot (TOF) repair	14	12.8
Atrial septal defect (ASD) repair	19	17.4
Sub-aortic membrane (SAM) excision	9	8.3
Total anomalous venous connection (TAPVC) repair	3	2.8
Scimitar syndrome repair	2	1.8
Pulmonary valvotomy	5	4.6
Mitral valve repair (MVR) repair	4	3.7
Partial atrioventricular canal (AVC) repair	2	1.8
Double outlet right ventricle (DORV) repair	1	0.9
Complete atrioventricular canal (CAVC) repair	4	3.7
Arterial switch repair surgery	6	5.5
Aortic valvotomy	6	5.5
Aortic reconstruction surgery	1	0.9
Other surgery†	4	3.7
Aortic cross-clamp time ACCT (minutes), mean (SD)		49.69 (23.31)
Total cardiopulmonary bypass time CPBT (minutes), mean (SD)		85.42 (39.28)
Serum lactate after the surgery mmol/l, mean (SD)		1.53 (0.82)
Intensive care unit length of stay (days), mean (SD)		2.89 (2.44)
Requirement for haemo-filtration		
No	95	87.2
Yes	14	12.8

*Other types of congenital cardiac defects included: Hypoplastic left heart syndrome (HLHS), Truncus arteriosus (TA), Hypertrophic obstructive cardiomyopathy (HOCM) and interrupted aortic arch (IAA).

† Other surgery included: Norwood procedure, Rastelli procedure, Marrow procedure and aorto-pulmonary (AP) window repair

Table 3: Bivariate analysis of the cyanotic vs acyanotic congenital heart disease among cardiac surgical children.

Variables	Acyanotic (n=77)	Cyanotic(n=32)	Test-statistic	P value
Sex				
Female	37 (48.1)	13 (40.6)	Chi (1)=0.50	0.479
Male	40 (51.9)	19 (59.4)		
Age (years), mean (SD)	4.81 (4.9)	1.01 (1.10)	T (91.34)=6.42	<0.001
Age groups (Years)				
Infant (age<1)	20 (26)	19 (59.4)	Chi (4)=27.2	<0.001
Toddler 1-3	21 (27.3)	12 (37.5)		
Pre-schooler (age>3 to 6)	15 (19.5)	1 (3.1)		
School age 7-9	8 (10.4)	0		
Teenager ≥10	13 (16.9)	0		
Weight (kg), mean (SD)	18.40 (15.66)	6.76 (2.93)	T (87.87)=6.30	<0.001
Weight percentile, mean (SD)	25.21 (20.76)	4.92 (7.20)	T (104.8)=7.60	<0.001
Weight percentile categories				
5 th percentile	12 (15.6)	24 (75)	Chi (5)=42.7	<0.001
10 th percentile	12 (15.6)	1 (3.1)		
25 th percentile	20 (26)	6 (18.8)		
50 th percentile	23 (29.9)	1 (3.1)		
75 th percentile	8 (10.4)	0		
90 th percentile	2 (2.6)	0		
Weight for age (kg)				
Normal	64 (83.1)	9 (28.1)	Chi (2)=36.96	<0.001
Underweight	10 (13)	23 (71.9)		
At risk of overweight	3 (3.9)	0		
Height (Centimetres), mean (SD)	97.76 (33.27)	65.70 (14.60)	T (106.64)=7	<0.001
Height percentile, mean (SD)	23.63 (17.50)	7.65 (1.40)	T (106.67)=7.2	<0.001
Height percentile categories				
5 th percentile	7 (9.1)	21 (65.6)	Chi (5)=42.6	<0.001
10 th percentile	10 (13)	5 (15.6)		
25 th percentile	31 (40.3)	2 (6.2)		
50 th percentile	23 (29.9)	2 (6.2)		
75 th percentile	5 (6.5)	0		
>90 th percentile	1 (1.3)	0		
Height for age (cm)				
Normal	70 (90.9)	11 (34.4)	Chi (1)=37.9	<0.001
Short	7 (9.1)	21 (65.6)		
BMI (children aged >2 yrs), mean (SD)	16.45 (3.1)	15.31 (1.42)	T (55)=0.94	0.353
Failure to thrive				
No	72 (93.5)	15 (46.9)	Chi (1)=30.51	<0.001
Yes	5 (6.5)	17 (53.1)		
Malnutrition				
Normal	70 (90.9)	25 (78.1)	Chi (1)=2.26	0.133
Malnutrition	7 (9.1)	7 (21.9)		
Definitive indications/etiology for the cardiac surgery				
APVC	2 (2.6)	3 (9.4)	Chi (1)=1.1	0.299
Atrial septal defect (ASD)	19 (24.7)	1 (3.1)	Chi (1)=7.01	0.008
Aortic stenosis (AS)	15 (19.5)	0	Chi (1)=5.68	0.017
Mitral regurgitation (MR)	1 (1.3)	0	Chi (1)<0.001	1
Pulmonary stenosis (PS)	0	4 (12.5)	Chi (1)=6.77	0.009
Double chamber right ventricle (DCRV)	1 (1.3)	0	Chi (1)<0.001	1
Ventricular septal defect (VSD)	32 (41.6)	3 (9.4)	Chi (1)=10.74	0.001
Double outlet right ventricle (DORV)	0	2 (6.2)	Chi (1)=2.10	0.153
Atrio-ventricular canal (AVC)	6 (7.8)	0	Chi (1)=1.35	0.245
Transposition of great vessels (TGV)	0	6 (18.8)	Chi (1)=11.9	0.001
Tetralogy of Fallot (TOF)	0	14 (43.8)	Chi (1)=34.84	<0.001
Mitral stenosis (MS)	4 (5.2)	0	Chi (1)=0.60	0.451
Other cardiac disease*	2 (2.6)	2 (6.2)	Chi (1)=0.13	0.716

Continued.

Variables	Acyanotic (n=77)	Cyanotic (n=32)	Test-statistic	P value
Diagnostic physiologic classification				
Left heart obstructive lesion	20 (26)	0	Chi (5)=109.7	<0.001
Left to right shunt	49 (63.6)	0		
Mixing lesion	2 (2.6)	10 (31.2)		
Right heart obstructive lesion	0	18 (56.2)		
Right to left shunt	0	1 (3.1)		
Single ventricle	6 (7.8)	3 (9.4)		
Aortic cross-clamp time ACCT (minutes), mean (SD)	42.32 (18.79)	67.41 (23.83)	T (47.8)=5.31	<0.001
Total cardiopulmonary bypass time CPBT (Minutes), mean (SD)	71.88 (27.30)	118.00 (44.74)	T (40.9)=5.42	<0.001
Serum lactate after the surgery units/DL, mean (SD)	1.49 (0.78)	1.62 (0.92)	T (107)=0.80	0.445
Length of ICU stay days, mean (SD)	1.73 (1)	5.69 (2.61)	T (34)=8.34	<0.001
Requirement for haemo-filtration				
No	70 (90.9)	25 (78.1)	Chi (1)=2.26	0.133
Yes	7 (9.1)	7 (21.9)		

Table 4: Multivariate binary logistic regression analysis of cardiac patients with cyanotic congenital heart disease, (n=109).

Variables	Multivariate adjusted odds ratio	95% C.I. for OR		P value
		Lower	Upper	
Sex-male	1.860	0.296	11.689	0.508
Age (years)	0.804	0.398	1.624	0.544
Weight percentile score	0.957	0.865	1.058	0.392
Height percentile score	0.942	0.841	1.055	0.302
Positive history of failure to thrive	6.254	0.428	91.424	0.180
ICU length of stay days	3.027	1.515	6.049	0.002
Aortic cross-clamp time (minutes)	0.929	0.846	1.021	0.128
Total CPBT time (minutes)	1.058	0.993	1.127	0.082
Serum lactate level (intraoperative)	0.209	0.062	0.704	0.012
Constant	0.086			0.191
Dependent variable=Cyanotic congenital heart disease (No/Yes)				

DISCUSSION

Malnutrition, stunted growth and FTT are common causes of morbidity and mortality in children with CHD.¹⁶ It is observed by clinicians and authors that paediatric cardiac surgical patients with CHD are often underweight at time of presentation for surgery.¹⁷ Different types of CHD can affect nutritional status of patients differently and different types of cardiac malformation can affect nutrition and growth to varying degrees. The severity of malnutrition can range from mild under-nutrition to FTT.¹⁸

Children with CHD are at an increased risk for wasting, underweight and stunting.¹⁹ The prevalence of malnutrition among these children increases their risk of postoperative complications and prolonged ICU stay.²⁰ Prevalence of malnutrition among paediatric CHD patients varied significantly in literature between 28 and 94%.²¹⁻²³ Heart failure, cyanosis, low haemoglobin, delay in surgical correction, pulmonary hypertension, recurrent hospital admissions are all triggering risk factors for malnutrition, growth stunting, underweight and FTT in patients with CHD.²⁴

Our study included paediatric patients with different types of CHD. The overall prevalence of malnutrition and FTT was 33.03% and 20.2% respectively. FTT is a multifactorial disorder resulting from malnutrition in infants and children. The international classification of diseases (ICD-10) defines FTT as the lack of expected normal physiological development and defines malnutrition as “The degree of malnutrition is usually measured in terms of weight, expressed in standard deviations from the mean of the relevant reference population.”²⁵ Our study showed that 75% of children with cyanotic CHD had a weight below 5th percentile while acyanotic CHD patients who had a weight below 5th percentile resembled 15.6%. Likewise, height below 5th percentile was much more common in cyanotic CHD in comparison with acyanotic CHD (65.6% vs 9.1%). Similar findings were reported by Tabib et al and Ulfa et al.^{26,27} Other growth parameters analysed in our study such as weight for age and height for age measured also significantly lower in cyanotic groups of CHD. Noticeably, results of our analysis showed that cyanotic CHD group had significantly longer cardiopulmonary bypass (CPB) time, aortic cross-clamp (ACC) time and

longer intensive care unit length of stay. Body mass index (BMI)-for age growth chart are used to assess growth for CHD patients who are above two years of age, as the centers for disease control and prevention (CDC) do not recommend its use for children below two years of age. BMI was slightly lower in the cyanotic CHD group of patients in comparison with the acyanotic group; however, the difference in BMI was not significant. This can be explained with fact that most of the cyanotic CHD patients were infants (59.4%) (Below 1 year of age) ($p=0.001$).

To study the impact of malnutrition and FTT on the postoperative course of patients with CHD we analysed and compared the duration of ICU stay of patients with normal nutritional status and patients with malnutrition (and FTT). In general, patients diagnosed with malnutrition spent more than double the time in ICU on average. Similar association between malnutrition in CHD and prolonged postoperative ICU stay was found by Silva et al and Ross et al.^{28,29}

Continuous assessment of nutritional status for patients with CHD, proper counselling from early stages of life and implementation of treatment strategies that aim to facilitate "catch-up" can improve operative and postoperative outcomes.³⁰⁻³²

Limitations

Our study has few drawbacks. Although our center is the largest tertiary cardiac center in the country; the study is still a single center study with limited number of patients. More anthropometric measurements could add more to this study. We did not include head circumference and arm circumference. We hope to extend our work in the future to a larger study population and to include more anthropometric and biochemical variables.

CONCLUSION

Prevalence of malnutrition and FTT in paediatric patients with CHD at time of surgery is high. Less than half of CHD patients had a normal nutritional status. Higher incidence of malnutrition and FTT was associated with the cyanotic type of CHD and infant age. Cyanotic CHD had significantly lower weight for age and shorter length for age in comparison with acyanotic children. Malnutrition was associated with longer intraoperative cardiopulmonary bypass and aortic clamp times and longer intensive care unit length of stay (ICULOS).

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Khasawneh MA, Mohammad AF, Al-Fawares SG, Almomani O, Al-Husban F. Implications of congenital heart disease on growth and development of paediatric cardiac surgical patients. *Int J Adv Med* 2021;8:1011-9.