Prevalence, profile and predictors of malnutrition in children with congenital heart defects: a case–control observational study

Christy A N Okoromah,[1] Ekanem N Ekure,[1] Foluso E A Lesi,[1] Wahab O Okunowo,[2] Bolande O Tijani,[3] Jonathan C Okeiyi[4]

[1]Department of Paediatrics, College of Medicine, University of Lagos, Idi-Araba, Lagos, Nigeria
[2]Department of Biochemistry, College of Medicine, University of Lagos, Idi-Araba, Lagos, Nigeria
[3]Nutrition Unit, Lagos University Teaching Hospital, Idi-Araba, Lagos, Nigeria
[4]Department of Laboratory Medicine, Lagos University Teaching Hospital, Idi-Araba, Lagos, Nigeria

Correspondence to
Christy A N Okoromah, Associate Professor and Consultant, Cardiology and Infectious Disease Unit, Department of Paediatrics, College of Medicine, University of Lagos, PMB 12003, Surulere, Idi-Araba, Lagos, Nigeria; faimer2004_christy@yahoo.com

ABSTRACT

Objective To investigate the prevalence, profile and predictors of severe malnutrition in children with congenital heart defects (CHDs).
Design Case–control, observational study.
Setting Tertiary teaching hospital in Lagos, Nigeria (March 2006 to March 2008).
Participants Children aged 3–192 months with uncorrected symptomatic CHD and healthy controls, frequency matched for age and sex.
Main outcome measures Prevalence of malnutrition based on WHO/National Center for Health Statistics/Centers for Disease Control and Prevention z score ≤ -2; weight for age, weight for height/length and height for age; proportions of underweight, wasting and stunting in cases and controls, and in acyanotic and cyanotic CHD; and predictors of malnutrition using multivariate logistic analysis.
Results 90.4% of cases and 21.1% of controls had malnutrition (p=0.0001), and 61.2% and 2.6%, respectively, had severe malnutrition (p=0.0001). Wasting, stunting and underweight were identified in 41.1%, 28.8% and 20.5%, and 2.6%, 3.9% and 14.5% of cases and controls, respectively. Wasting was significantly higher (58.3%) in acyanotic CHD (p=0.0001), and stunting (68.0%) in cyanotic CHD (p=0.0001). Age at weaning was significantly lower in cases than controls (3.24±0.88 and 7.04±3.04 months, respectively; p=0.0001) and in acyanotic than cyanotic CHD (2.14±0.33 and 5.33±1.22 months, respectively; p=0.004). Predictors of malnutrition in CHD were anaemia, moderate to severe congestive heart failure (CHF), poor dietary intake of fat and prolonged unoperated disease.
Conclusion Severe malnutrition in association with anaemia and moderate to severe CHF is highly prevalent in CHD preoperatively in these children. Early weaning may be a marker of feeding difficulties in heart failure.

INTRODUCTION

Malnutrition in children with congenital heart defects (CHDs) has been linked to increased morbidity and mortality as indicated by frequent hospitalisation, poor surgical outcomes, persistent impairment of somatic growth and increased death.[1 2] Children with growth retardation tend to have more episodes of severe diarrhoea and a heightened susceptibility to certain infectious diseases, for example, malaria, meningitis and pneumonia.[3] All types of malnutrition, and severe forms in particular, contribute to mortality in childhood.[4] There is strong evidence that poor growth is associated with delayed mental development, and that there is a relationship between impaired growth status and both poor school performance and reduced intellectual achievement.[5] Growth retardation in early childhood is also associated with significant functional impairment in adult life and reduced work capacity, thus affecting economic productivity.[4–6]

The mechanisms for growth deficiency in CHD are multifactorial[7–13] and include associated chromosomal anomalies/genetic syndromes, inadequate nutritional intake due to feeding difficulties, and poor absorption of nutrients from the digestive tract in chronic congestive heart failure (CHF). Also, increased calories are required to sustain the increased myocardial, respiratory and neuro-humoral functions in CHD-related heart failure. Chronic CHF and chronic hypoxaemia in CHD impair cellular metabolism and cell growth, while repeated chest infections are associated with increased metabolic demands. Other mechanisms of growth deficiency in CHD have been reported.[7–13]

In developed countries, advancements in paediatric cardiac care, early prenatal and postnatal diagnosis, and supportive and timely corrective interventions for cardiac lesions have almost eliminated the impact of CHD on nutritional status.[14–18] In contrast, in many developing

countries paediatric cardiac programmes are not fully established, and epidemiological data on CHD-related morbidity and mortality are lacking. Previous reports are generally from India and South East Asia.[19 20] In sub-Saharan Africa, although CHD has been studied and there have been recent reports,[21] previous studies on somatic growth in CHD are out-dated and were limited by methodology and case definitions.[22–24] The WHO recommends the WHO/National Center for Health Statistics (NCHS) growth standards for nutrition surveys.[25–31] The present study aimed to describe the prevalence, profile and predictors of malnutrition (undernutrition) using recommended case definitions. The findings of the present study could be applied to current and future paediatric cardiac care practice, and also used for policy decision-making and future research.

METHODS

This was a case–control observational study of 73 children with diverse, symptomatic CHD, recruited from the Paediatric Cardiology outpatient clinic at a referral tertiary teaching hospital in Lagos, Nigeria between March 2006 and March 2008. Seventy-six age- and sex-matched apparently healthy controls without CHD were enrolled from the Well Child Clinics of the same hospital, and from a neighbourhood primary school. Informed consent was obtained from parents and other caregivers before enrolment. CHD was diagnosed or excluded by clinical, echocardiographic and other routine tests. Based on the type of CHD, cases were assigned to either an acyanotic or a cyanotic group. In this case–control study, we hypothesised that malnutrition was common and severe in children with CHD (cases) compared with apparently healthy children (controls) with neither CHD or overt malnutrition. Cases and controls were frequency matched for age and sex, the two critical demographic variables that could influence the outcome of interest, that is, malnutrition. These patients were investigated retrospectively regarding risk factors, associations and determinants of malnutrition based on their nutrition/dietary history and obstetric history (birth weight). Other data such as anthropometric measurements and laboratory indices were collected prospectively in a cross-sectional design.

Exclusion criteria

The following were considered exclusion criteria: corrective interventions including catheter or surgically palliated or corrected CHD, additional morbidities such as genetic/chromosomal anomalies, dysmorphic features, obvious extracardiac malformations, HIV infection, tuberculosis, syndromic anomalies, chronic illnesses other than CHD associated with visible/demonstrable oedema, and any serious ongoing acute illness requiring hospitalisation.

Social classification

Study participants were grouped into upper, middle and lower socioeconomic classes based on the classification of Oyedeji.[32]

Participant handling protocol

A standard pretested questionnaire was used to obtain information on biodata and to evaluate determinants of malnutrition such as parental education, occupation and income, family size, birth order, birth weight and nutrition history (duration of breastfeeding, age at weaning, weaning diet, 24 h dietary recall). Social class was categorised based on a previous report.[32] Three independent investigators (one paediatrician, one biochemist and one nutritionist) carried out a detailed dietary analysis of each child based on a 24 h dietary recall preceding their physical examination. The relative proportions of protein, carbohydrate and fat consumed in 24 h were calculated based on local standard charts of the nutritive values of common dietary items. Physical signs of malnutrition such as symmetrical oedema, skin lesions and dry, thin, depigmented hair were assessed.

Anthropometry measurements

Anthropometry measurements were performed according to standard WHO procedures.[26] Weights were measured using a Tanita BF-350E body composition analyser (Tanita, Arlington Heights, Illinois, USA) and a Seca 336 electronic baby scale (Seca, Birmingham, UK) accurate to 0.5 kg. Heights or recumbent length (for children <2 years of age) were measured to within 0.25 cm using a portable Leicester Height Measure (Seca) and Seca 416 mechanical infantometer, respectively, and mid-upper arm and occipito-frontal circumferences were measured with a Seca 200 measuring tape using standard procedures.

Definition of normal nutrition and malnutrition (undernutrition)

The WHO recommends the use of standard definitions and classifications for malnutrition (undernutrition) based on calculated Z scores for anthropometric indices.[28 29] Z scores for weight for age (WAZ), weight for height (WHZ) and height for age (HAZ) are computed using the Epi-Nut component of the Epi Info 2002 software package (v 3.4.3) from the Centers for Disease Control and Prevention (Atlanta, Georgia, USA) 2000 anthropometry program reference value (based on NCHS reference median values).[25–31] The WHO global database on child growth and malnutrition (undernutrition) recommends a cut-off z score of ≤−2 to classify low WAZ (underweight), low HAZ (stunting) and low WHZ (wasting) as moderate malnutrition, and a z score of ≤−3 SD to define severe malnutrition. A z score of ≤−2 indicates that a child's WAZ, WHZ or HAZ is 2 SD below the age- and gender-specific median for the normal population, and 3 SD below the median cut-off if the z score is ≤−3. Normal nutrition is indicated by a WAZ z score of between >−2 and ≤2.

Modified Ross score for grading heart failure

The modified Ross score[33] was used to diagnose and grade heart failure severity in patients with CHD into three groups: no heart failure (score 0–2), mild heart failure (score 3–6) and moderate to severe heart failure (score 7–12).

Laboratory tests

Haemoglobin was measured using a HemoCue B-Hemoglobin Photometer (HemoCue, Ängelholm, Sweden). Anaemia was defined as a haemoglobin level ≤10 g/dl for all controls and for children with acyanotic CHD. For children with cyanotic CHD, a haemoglobin level ≤15 g/dl was considered to indicate anaemia based on a consensus of local experts. Polycythaemia was defined as a haemoglobin level ≥22 g/dl. Blood samples were collected and analysed for serum proteins using standard procedures. Arterial oxygen saturation was measured using a digital Nellcor pulse oximeter (Covidien-Nellcor,

Boulder, Colorado, USA). HIV screening was carried out using standard kits.

Ethics approval and informed consent
The study was approved by the local research ethics committee and informed consent was obtained from the parents/caregivers of participants.

Analysis
The data were entered, validated and analysed using SPSS v 11 and Epi Info v 6.04 to determine the prevalence of malnutrition in relation to other variables. Comparisons were made between the two main study groups (controls and cases) and the three subgroups (controls, acyanotic group and cyanotic group). Continuous variables were expressed as means and SDs if they were normally distributed and as median and range if skewed. Two sample (unpaired) Student t tests, two-way analysis of variance and multivariate logistic regression analysis were used to compare means and test the relationships between covariates. The χ^2, Mann–Whitney U and other appropriate non-parametric tests were used for categorical (discrete) variables. For variables that were highly skewed, such as duration of symptoms and age at diagnosis of CHD, a logarithmic transformation was carried out before analysis. Where numbers were small, Fisher's exact test was used. Pearson's and Spearman's r correlation coefficients were used for symmetric quantitative and ordered or asymmetric variables, respectively. Differences were considered significant at p<0.05. All risk variables significant at p<0.001 were included in a stepwise multivariate logistic regression analysis. ORs with 95% CIs were computed.

RESULTS
Baseline, sociodemographic and other characteristics of the study population
Table 1 gives the baseline, sociodemographic and other characteristics of the study population. The main study groups (cases and controls) were comparable regarding age, sex, birth weight, family size, birth order, mother's educational level and

socioeconomic class. Overall, 64.3% of children were aged 0–59 months 23.1% were aged 60–120 months and 12.6% were aged >120 months.

Distribution of CHD
Table 2 shows the distribution of cardiovascular malformations in cases. Ventricular septal defect (VSD) was the leading cardiac lesion among all cases of CHD (35.6%) and accounted for 54.2% of cases in the acyanotic group. Tetralogy of Fallot (TOF) was the most frequent cyanotic lesion among all cases of CHD (15.1%) and among the cyanotic group (44.0%).

Prevalence and profile of malnutrition (undernutrition)
The prevalence, distribution and types of malnutrition observed in the main study groups and subgroups are shown in tables 3–5. Sixty-six of 73 children with CHD were malnourished with a WAZ score of ≤−2, giving an overall prevalence of malnutrition of 90.4% in cases compared with 21.1% in

Table 1 Baseline and other characteristics of the study population

Variable	Controls (n=76)	Cases (n=73)	p Value
Age, months	41.90 (48.08)	40.00 (44.96)	0.09
Age range, months	3–192	3–192	
Sex: male/female ratio	1.4:1	1.2:1	
Social class	2.67 (0.80)	2.64 (0.84)	0.82
Social class			
Upper class (I and II), n (%)	23 (15.4%)	26 (17.4%)	
Middle class (III), n (%)	28 (18.8%)	27 (18.1%)	
Lower class (IV and V), n (%)	25 (16.8%)	20 (13.4%)	
Family size (including parents)	5 (1.60)	5 (1.47)	0.21
Birth order	3 (1.29)	3 (1.60)	0.53
Gestational age, months	39.4 (0.27)	38.5 (0.46)	0.66
Birth weight, kg	3.1 (0.73)	3.3 (0.65)	0.39
Duration of breastfeeding, months	12.81 (6.66)	12.58 (5.28)	0.87
Age at commencement of weaning, months	7.04 (3.04)	3.24 (0.88)	0.0001
		2.14 (0.33)*	0.004
		5.33 (1.22)†	

Values for continuous variables are means (SD).
*Acyanotic group; †cyanotic group.
The social class of patients was determined by allocating index scores based on the educational level of mothers and occupation of their fathers as described by Oyedeji[32].

Table 2 Distribution of cardiovascular malformations in affected children (n=73)

Type of cardiac defects	n (%)
Acyanotic group (n=48)	
Ventricular septal defect (VSD)	26 (35.6%)
Patent ductus arteriosus (PDA)	10 (13.7%)
Atrial septal defect (ASD)	6 (8.2%)
VSD+ASD	2 (2.7%)
VSD+PDA	1 (1.4%)
Mitral stenosis (MS)+ASD	1 (1.4%)
Partial anomalous pulmonary venous return (PAPVR)	1 (1.4%)
Pulmonary stenosis (PS) without VSD	1 (1.4%)
Cyanotic group (n=25)	
Tetralogy of Fallot (TOF)	11 (15.1%)
Transposition of the great arteries (TGA)+VSD without PS	3 (4.1%)
Transposition of the great arteries (TGA)+ASD+VSD+ PDA without PS	2 (2.7%)
Single atrium	2 (2.7%)
Single ventricle with PS	2 (2.7%)
Single ventricle without PS	2 (2.7%)
Tricuspid atresia+ASD	1 (1.4%)
Persistent truncus arteriosus+VSD	1 (1.4%)
Double outlet right ventricle+VSD	1 (1.4%)
Total	73 (100%)

Table 3 Pattern of malnutrition (undernutrition) in cases and controls

Type of malnutrition	Controls (n=76)	Cases (n=73)	p Value
Underweight (WAZ)	11 (14.5%)	15 (20.5%)	0.33
Wasting or acute malnutrition (WHZ)	2 (2.6%)	30 (41.1%)	0.0001
Stunting or chronic malnutrition (HAZ)	3 (3.9%)	21 (28.8%)	0.0001

p<0.05 is statistically significant.
HAZ, height for age; WAZ, weight for age; WHZ, weight for height.

Table 4 Pattern of malnutrition (undernutrition) among patients with congenital heart defects

Type of malnutrition	Acyanotic group (n=48)	Cyanotic group (n=25)	p Value
Underweight (WAZ)	12 (25.0%)	2 (8.0%)	0.06
Wasting or acute malnutrition (WHZ)	28 (58.3%)	2 (8.0%)	0.0001
Stunting or chronic malnutrition (HAZ)	5 (10.4%)	17 (68.0%)	0.0001

p<0.05 is statistically significant.
HAZ, height for age; WAZ, weight for age; WHZ, weight for height.

Table 5 Distribution of normal nutrition and malnutrition (undernutrition) in cases and controls

Nutritional status	Controls (n=76)	Acyanotic CHD (n=48)	Cyanotic CHD (n=25)	p Value
Normal nutrition (WAZ score >−2 to ≤2)	60 (78.9%)	5 (10.4%)	2 (8.0%)	0.0001
Malnutrition (WAZ score ≤−2 to ≤−3)	16 (21.1%)	45 (93.8%)	21 (84.0%)	0.0001
Moderate malnutrition (WAZ score ≤−2)	13 (17.1%)	11 (22.9%)	10 (40.0%)	0.16
Severe malnutrition (WAZ score ≤−3)	3 (3.9%)	34 (70.8%)	11 (44.0%)	0.0001

p<0.05 is statistically significant.
CHD, congenital heart defect; WAZ, weight for age.

controls (p=0.0001). The relative proportion of children with severe malnutrition (WAZ score ≤−3) was significantly higher among children with CHD compared with controls (61.2% and 3.9%, respectively; p=0.0001). In children with moderate malnutrition (WAZ ≤−2) or severe malnutrition (WAZ ≤−3), both wasting (low WHZ) and stunting (low HAZ) were significantly higher in the CHD group compared with the control group. Wasting was proportionately higher (58.3%) in acyanotic CHD (p=0.0001), while stunting was predominant (68.0%) in cyanotic CHD (p=0.0001).

Predictors of malnutrition

As shown in table 6, malnutrition correlated significantly (p<0.001) with low haemoglobin (anaemia), age under 5 years, heart failure, low arterial oxygen saturation, poor dietary fat intake and duration of symptoms of CHD, but not with social class, birth weight, sex or age at weaning. Sixty (82.2%) cases of CHD had varying degrees of heart failure based on the modified Ross scoring system. Forty-four (73.3%) of the 60 cases with CHF had moderate to severe CHF (Ross score of 7–15). Heart failure was significantly predictive of severe malnutrition (p<0.001).

Dietary analysis, biochemical and other indices of the study population

As shown in table 1, the duration of breast feeding was similar among cases and controls (12.81±6.66 and 12.58±5.28 months, respectively; p=0.87), but weaning and complementary feeds were introduced earlier in children with CHD compared with controls (at 3.24±0.88 and 7.04±3.04 months, respectively; p=0.0001). Age at commencement of weaning was significantly lower in acyanotic CHD compared with cyanotic CHD (2.14±0.33 and 5.33±1.22 months, respectively; p=0.004).

Using a 24 h dietary recall, the mean frequency of feeds in the postweaning period for children with CHD aged under 5 years was significantly lower compared with controls (2.21±1.22 and 4.12±0.99 times per day, respectively; p<0.05). Dietary analysis of the CHD group in this age category showed a poor dietary history, inadequate food intake and consumption of low calorie, fat-deficient diets. An average main meal among the under 5 age group consisted of unfortified gruel (pap), beverages consumed as 'tea', unfortified bread and local non-infant cereal ('Golden Morn'). Dietary history in 66% of cases was rated as poor and fortification of diets with lipids was rarely practiced by caregivers.

As shown in table 7, serum proteins and albumin were similar in cases and controls, and in the acyanotic and cyanotic groups. Overall, 54.6% of the acyanotic group, 11.4% of the cyanotic group and 12.8% of controls had anaemia (p=0.0001). Hypochromic, microcytic red blood cells suggestive of iron deficiency anaemia were found in 66.0% of all subjects. HIV screening was negative in all cases who consented to testing.

Table 6 Multivariate logistic regression analysis of predictors of malnutrition in children with CHD

Variable	OR (95% CI)	p Value
Haemoglobin level ≤10.0 g/dl	6.51 (4.01 to 8.00)	<0.001
Congestive heart failure	4.20 (2.30 to 6.64)	<0.001
Modified Ross score ≥7	4.34 (2.00 to 4.64)	<0.001
Low arterial oxygen saturation	4.15 (2.14 to 8.16)	<0.001
Type of CHD	2.53 (1.50 to 10.20)	<0.001
Duration of symptoms of CHD	3.33 (2.30 to 4.56)	<0.001
Poor dietary fat intake	2.12 (4.12 to 5.98)	<0.001
Age less than 5 years	3.23 (1.30 to 8.56)	<0.001
Age at weaning	3.02 (1.30 to 8.56)	0.090
Sex	2.98 (2.30 to 4.56)	0.340
Birth weight	1.96 (2.30 to 10.56)	0.060
Birth order	1.34 (2.30 to 4.12)	0.340
Social class	3.98 (1.30 to 5.56)	0.450

p Value is statistically significant at <0.001.
CHD, congenital heart defect.

Table 7 Biochemical, haematological and other indices in the study population (n=149)

Blood test	Controls (n=76)	Cases (n=73)	p Value
Total serum protein, g/dl	7.4 (0.71)	7.3 (0.75)	0.34
Serum albumin, g/dl	4.0 (0.52)	3.8 (0.53)	0.81
Haemoglobin, g/l	12.1 (1.49)	10.1 (1.26)*	0.0001
		17.9 (4.71)†	
Packed cell volume, %	36.4 (4.64)	30.3 (4.07)	0.0001
Anaemia, %	12.8	54.6*	0.0001
		11.4†	0.0001
Microcytic, hypochromic red blood cells, %	6.2	34.8*	0.0001
		25.0†	0.026
Arterial oxygen saturation, %	96.5 (3.14)	94.4 (4.16)*	0.0001
		80.1 (3.90)†	

p<0.05 is statistically significant. Values for continuous variables are means (SD).
*Acyanotic group;†cyanotic group.

DISCUSSION

Growth is considered to be the best global indicator of children's well-being, and growth impairment has both short- and long-term consequences.[26–39] Progressive decline in nutritional status is linked with active and poorly controlled disease, and deteriorating cardiac function, morbidity and mortality.[4–6]

The present study reports a very high prevalence of malnutrition, in particular, severe forms of wasting and stunting, which were well above the WHO national estimates for growth deficiency in sub-Saharan Africa.[28] Overall, the prevalence of CHD-related malnutrition was 90.4%, with 61.2% of cases having severe malnutrition. Among cases, the relative proportions of wasting, stunting and underweight were 41.1%, 28.8% and 20.5%, respectively. Contrary to the usual distribution of growth deficiency in the general

paediatric population according to WHO reports, wasting was the most prevalent type of malnutrition in our study, rather than underweight and stunting.[28] [29] In the present study, the prevalence of wasting in children with CHD is five times higher than the WHO national estimate for wasting in Nigeria.

Wasting was associated with acyanotic CHD, while stunting was linked to cyanotic CHD.

As in the present study, previous reports showed that CHD-related malnutrition is especially common in developing countries, but prevalence varies widely from 27% up to 90.4% in the present study.[19] [20] [22–24] Mehrizi and Drash[23] reported a lower overall malnutrition prevalence of 27% among Turkish children based on percentiles. In South India, Vaidyanathan and colleagues reported a higher prevalence of underweight (59.0%) and wasting (55.9%) in children with CHD compared with the present findings, with wasting being more prevalent than stunting in children with CHD, as also in our study.[19] [20]

Plausible explanations for the magnitude, severity and distribution of CHD-related malnutrition in the present study include the study setting, the distribution of cardiac lesions in the study cohort, the presence of severe complications of CHD such as CHF, and poor standard of care. This study was conducted in a tertiary teaching hospital to which cases with severe disease and CHD complications are likely to be referred for evaluation. Also, left to right shunt lesions in association with predominantly moderate to severe CHF were the most common cardiac lesions in the present study. Wasting, also called acute malnutrition, is attributable to acute events, while stunting (chronic malnutrition) is usually associated with prolonged suboptimal dietary intake. The present study did not investigate the role of acute infections, such as recurrent chest infections, diarrhoeal disease and other acute childhood illnesses, that may have contributed to the high prevalence of wasting. The prolonged duration of unoperated CHD suggested by the broad age range of the children in our study, in association with chronic hypoxaemia and/or chronic heart failure, and protracted suboptimal dietary intake, predispose to stunting in these patients.

In the present study, children with acyanotic CHD were more likely to be wasted, while those with cyanotic CHD were more likely to be stunted. Previous reports on the patterns of malnutrition in acyanotic and cyanotic CHD vary widely.[24] [30] [34] Linde and colleagues[34] reported that both wasting and stunting were more common in cyanotic CHD than in acyanotic CHD. Varan and colleagues[24] noted that most infants (88%) with cyanotic CHD without pulmonary hypertension had mild malnutrition and that stunting was more common than wasting in these patients. This finding is somewhat similar to that of the present study even though we did not investigate the role of pulmonary hypertension. According to Varan and colleagues, cyanosis and pulmonary hypertension were important predictors of nutrition and growth in cyanotic CHD. Salzer and coworkers[30] observed a preponderance of wasting in acyanotic CHD in association with left to right shunts and heart failure, compared with cyanotic CHD, which is similar to our findings. Notwithstanding the wide variation in the patterns and distribution of malnutrition in CHD, overall our findings are consistent with some previous reports, while some differences have been observed and highlighted.[24] [30] [34]

The heterogeneous nature of study methodologies across previous reports on somatic growth in CHD limits comparison

of their findings. Studies differed in their design, eligibility criteria, study settings and sample size, as well as in the clinical characteristics of their study populations (symptomatic and asymptomatic), classification of malnutrition and reference growth standards used for interpretation of anthropometric indicators. Also, regional variations in the prevalence and distribution of undernutrition may also contribute to differences.[28]

The predictors of malnutrition in the present study included CHF, type of CHD, duration of symptoms, age under 5 years and poor dietary fat intake. These predictors are similar to those in previous reports and are generally modifiable by early corrective interventions, growth monitoring and nutrition supplementation. Previous studies that compared growth impairment in CHD before and after corrective interventions including surgery have demonstrated satisfactory recovery in somatic growth, although most such studies focused on infants.[15–18] However, Vaidyanathan and colleagues[20] in South India recently reported that severe malnutrition is not always reversed by corrective intervention. They found that persistent malnutrition after corrective intervention is predicted by nutritional status at presentation, birth weight and parental anthropometry. Prolonged unoperated symptomatic CHD suggested by the wide age range of children in the present study leads to long-term severe growth impairment. The high proportion (64.3%) of young children aged 0–59 months in this study and its predictive effect of CHD on severe malnutrition may be related to the natural history of CHD in addition to the role of inadequate and poor breastfeeding, weaning, and complementary and supplementary feeds in this age group. Under fives are the most vulnerable age group affected by malnutrition (undernutrition) in the general population.[28] [29]

The predictive effect of pulmonary hypertension, birth weight, parental anthropometry, recent hospitalisation and recurrent respiratory infections on malnutrition in CHD, which have been previously reported,[19] [20] were not investigated in the present study.

It is noteworthy that notwithstanding the lower cut-off used (ie, a smaller p value to determine predictors of malnutrition in multiple regression analysis), a number of plausible predictors of malnutrition, some possibly related to one another (eg, low haemoglobin and low arterial oxygen saturation), were still highly and independently linked to the outcome. We postulate that this finding could reflect the strength of the impact of these factors on the development of malnutrition in this cohort of children. However, because our study had some limitations, especially possible selection bias due to the tertiary healthcare setting and aspects of our eligibility criteria, we cannot make any definite conclusions. Our study setting may have led to over-representation of children with severe and protracted disease, thereby increasing the number of factors significantly predicting malnutrition in these children. On the other hand, our eligibility criteria may have excluded some children with milder forms of malnutrition. Therefore, our finding cannot be extrapolated to the general population of children with CHD but will no doubt benefit from further investigations by other researchers in a more representative and heterogeneous population of children with symptomatic CHD.

The increased prevalence of anaemia as a complicating problem in children with symptomatic CHD is a new finding in our study. Also, the additive and predictive effect of anaemia and moderate to severe CHF in CHD-related growth

deficiency is unique to the present study and deserves special comment. Anaemia with features suggestive of iron deficiency was highly prevalent in cases with CHD. Up to 66% of children with symptomatic CHD had anaemia, defined in this study as haemoglobin levels of ≤10.0 and ≤15 g/dl in acyanotic and cyanotic CHD, respectively. Anaemia was more common in acyanotic CHD (54.6%) than in cyanotic CHD (11.4%), and was associated with microcytic and hypochromic red blood cells in over half of the cases, suggesting that it may be caused by iron deficiency. Iron deficiency anaemia is linked with linear growth retardation in young children.[40] However, we are not completely sure that iron deficiency anaemia was present as we did not estimate serum levels of iron and other indicators of iron deficiency. Based on multivariate logistic analysis, children with CHD who had low haemoglobin levels were six times more likely to be malnourished, and so the high prevalence of anaemia may be a consequence of the moderate to severe malnutrition. However, in children with cyanotic CHD, the anaemia may have been relative rather than absolute due to their higher haemoglobin levels and, in some cases, polycythaemia. Future studies may explore in greater detail the incidence, distribution and determinants of anaemia in CHD.

Notwithstanding the limitations regarding the definition of anaemia in CHD in our study, a high prevalence of anaemia in CHD can exacerbate the symptoms and complications of CHD, such as exercise intolerance and heart failure, as well as contribute to growth deficiency.[40]

The present study investigated the relationship between CHD-related malnutrition and categories of heart failure severity based on a validated scoring system.[33] Although the predictive effect and mechanisms of heart failure in CHD-related malnutrition are widely reported,[7–20] previous studies on malnutrition in CHD did not relate their findings to the severity of heart failure. In the present study, moderate to severe heart failure (Ross score of 7–15) was highly prevalent and predictive of malnutrition, which was predominantly moderate to severe. Children with CHD complicated by heart failure were four times more likely to be malnourished. We recommend future research explores further the association between heart failure and malnutrition in CHD, and a possible reciprocal relationship.

The strengths of the present study include its case–control design that allows temporal relationships and associations between CHD and malnutrition to be examined. Also, anthropometric measurements and categorisation of malnutrition are based on standard reference growth standards and the study population is well characterised. Furthermore, the broad age range of these children with unoperated CHD allows long-term growth impairment (wasting and stunting) to be evaluated.

Limitations
There are few limitations to the present study, which include exclusion of children with palliated or corrected CHD, those with confirmed or suspected genetic syndromes, hospitalised children with CHD, and children with asymptomatic CHD. Our exclusion criteria may have caused selection bias, leading to underestimation of the true prevalence of malnutrition as some excluded cases may have had more severe malnutrition. The tertiary hospital setting may have led to over-representation of more severely affected children with CHD and, therefore, severe malnutrition. Also, our definition of anaemia

in cyanotic CHD may have overestimated the proportion of anaemia in this subgroup of patients.

Conclusions
The present study describes growth abnormalities in children with CHD in a situation where their course is much closer to the natural history of these cardiac anomalies than in developed countries where early intervention is the rule. Among children with CHD in a developing country in sub-Saharan Africa, severe malnutrition in association with anaemia and moderate to severe heart failure, is highly prevalent preoperatively. The predictors and risk factors of severe malnutrition are modifiable through growth monitoring, nutrition counselling, nutrition supplementation, adequate control of CHD symptoms, use of booster blood transfusions and early corrective interventions. Although the effects of severe and chronic malnutrition on surgical morbidity and mortality are not explored in the present study, they are likely to be significant.[19 20] Our study suggests that early weaning in acyanotic CHD may be a marker of fatigability associated with heart failure, which could help early recognition of CHD.

Findings in the present study could have significant implications for future research and for physicians caring for children with CHD as well as for policymakers in Nigeria and other developing countries. We recommend aggressive nutritional supplementation for the study population, while efforts at early definitive corrective interventions including surgery should be intensified.

Future research should explore the areas mentioned above as well as the short- and long-term impacts of nutrition supplementation on morbidity and mortality before and after corrective interventions for CHD. Also, micronutrient deficiencies in CHD should be examined so that this population of children can be given comprehensive nutrition supplementation.

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