Nutritional status of children with congenital heart disease

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Abstract

Objective—To assess the nutritional status of children with congenital heart disease.

Design—Six anthropometric, 24 biochemical, and five haematological markers of nutritional wellbeing were measured in children with congenital heart disease.

Setting—The west of Scotland.

Patients—48 children admitted consecutively for surgical correction of congenital heart disease.

Main outcome measures—Height, weight, and triceps and subscapular skin fold thicknesses were considered abnormal if they were below the third centile compared with standard reference data for age matched British children. Mid-arm circumference and arm muscle circumference were considered abnormal if they fell below the fifth centile compared with standard data. Biochemical and haematological data were compared with age matched and locally validated laboratory normals.

Results—A marked degree of undernutrition was evident in all children; 52% had weight less than the third centile, 37% were below the third centile for height, and 12.5% were below the third centile for triceps skin fold thickness and 18.8% for subscapular skin fold thickness. Mid-arm circumference and arm muscle circumference were below the fifth centile in 20.1% and 16.7% of children respectively. Five or more of the 29 biochemical and haematological measurements were abnormal in 83.3% of patients; 10 or more were abnormal in 12.5% of patients.

Conclusions—Children with congenital heart disease are frequently undernourished, irrespective of the nature of cardiac defect and the presence or absence of cyanosis.

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Keywords: nutritional status; congenital heart disease; paediatrics

Congenital heart disease accounts for more infant deaths than all other congenital defects put together^{1 2}; about half of those who survive require surgery within the first year of life, equivalent to an "infant surgery rate" of approximately 1400 per million live births.^{3 4} Despite this significant workload and recent

advances in medical and surgical management the pre-existing state of nutrition is one aspect of congenital heart disease that has received little attention.

It is a popular view that children with congenital heart disease are often small and undernourished. Several studies have examined height, weight, and protein status⁵⁻¹⁷ but there has been no detailed assessment of nutrition. As nutritional status is one of the major determinants of the magnitude of the metabolic response to surgery¹⁸⁻²⁰ and since it has become increasingly common to operate at an early age, poor body reserves in these children may be an even more significant factor in militating against a successful outcome.

Assessment of the state of nutrition is made difficult by the number of factors that contribute to nutritional wellbeing (protein stores, fat stores, trace elements, etc.). Clinical examination alone appears to be a poor indicator of nutritional status^{21 22} and most studies therefore depend on the measurement of specific markers. Weight is the traditional guide but in reality is a crude estimate which may be affected as much by the degree of oedema as by the true body mass. Similarly, protein status is a useful biochemical guide, but measurement of this variable alone gives no estimate of other body reserves. This argument is true of all measurements and there is clearly no single variable which, on its own, can accurately define the state of nutrition.^{23 24} The Seltzer index (relying on the albumin concentration and lymphocyte count),²⁵ and the nutritional assessment of Blackburn *et al*,²³ are more useful, yet there is no scoring system which can adequately combine multiple measurements into a more accurate "nutritional index" that can be calculated and compared with reference data. In the absence of such an index we have attempted to define the state of nutrition as accurately as possible by making multiple measurements of anthropometric, biochemical, and haematological factors in order to construct a nutritional profile.

The aim of this study was therefore to determine the nutritional status of a cohort of children with congenital heart disease about to undergo corrective open heart surgery and to define which groups of patients were most severely undernourished.

Patients and materials

PATIENTS

This study was approved by the local hospital

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ethics committee and informed consent was obtained from the parents of the children.

Forty eight unselected, consecutive admissions to the paediatric cardiac surgical unit were studied at the Royal Hospital for Sick Children, Glasgow. The study comprised 23 males and 25 females (mean (range) age 1.52 (2 days-4.77) years) with congenital heart disease who were about to undergo urgent or elective surgery involving cardiopulmonary bypass. Children who had had previous surgery (cardiac or otherwise), those with foci of active infection or inflammation, or with any other coexisting pathological condition or chromosomal abnormality, those of non-Caucasian ethnic origin and children who had recently lived abroad or who were taking any form of dietary supplement were excluded.

The cardiac defects in this group of children represented a typical distribution of congenital heart disease (table). Twelve patients had cyanosis.

NUTRITIONAL SURVEY

Thirty five variables were measured in each patient to determine the overall state of nutrition. These measurements were divided into three categories: anthropometric (six), biochemical (24) and haematological (five).

Anthropometry

Anthropometric measurements were performed on the day before operation, using the same equipment throughout the study, by one of us (IMM) to eliminate inter-observer error.^{26 27}

Height was measured in centimetres and nude weight in kilograms. Mid-arm circumference was measured at a point mid-way between the acromion process of the scapula and the olecranon process of the ulna in the dependent left arm, with the elbow flexed to 90°. This was recorded in centimetres, using a flexible, non-stretch tape.

Triceps skin fold thickness was measured with the arm by the patient's side, at the same midpoint and in a vertical line up from the olecranon. Subscapular skin fold thickness was measured just below the angle of the scapula also on the left side. The same pair of Harpenden skinfold calipers (British Indicators, St Albans) was used throughout and the measurement recorded on each occasion was the average of three attempts.²⁷

Distribution of congenital heart disease in 48 children from the west of Scotland

	No of patients
Atrial septal defect	11
Ventricular septal defect	9
Tetralogy of Fallot	7
Transposition of the great arteries	5
Atrial septal defect/pulmonary stenosis	4
Atrioventricular septal defect	3
Double outlet right ventricle	3
Aortic stenosis	2
Double outlet left ventricle	1
Partial anomalous pulmonary venous drainage	1
Total anomalous pulmonary venous drainage	1
Tricuspid valve membrane	1

The arm muscle circumference (AMC) was calculated from direct measurements of mid-arm circumference (MAC) and triceps skin fold thickness (TST) using the formula²⁸:

$$AMC = MAC - \pi(TST)$$

where AMC and MAC are in centimetres and TST is in millimetres.

Anthropometric measurements were assessed in terms of centile distribution, as this method of analysis allows easy recognition of abnormal groups within a normally distributed population.²⁹ Height, weight, triceps skin fold thickness, and subscapular skin fold thickness were compared with standard reference data for British children (Castlemead Publications, Welwyn Garden City) based on studies conducted by Tanner and Whitehouse.³⁰⁻³² Measurements were deemed abnormal if they were less than or equal to the third centile.

Mid-arm circumference and arm muscle circumference were compared with data reported by Jelliffe²⁸ and considered as abnormal if they fell below the fifth centile.³³

Validation of reference data The standard anthropometric tables quoted here are those currently in use in most nutrition clinics. These were constructed from data largely obtained in the 1960s based on observations made in the Midlands and the southeast of England. Clearly, growth patterns of children from the west of Scotland in the 1990s may differ, but construction of local reference tables would be a major undertaking and beyond the scope of this investigation. In an attempt to validate use of the published data, however, height, weight, triceps skin fold thickness, subscapular skin fold thickness, mid-arm circumference, and arm muscle circumference were measured in a cohort of 35 children of similar age attending the hospital day unit for minor surgery. These children were not by definition a random sample from the community but can be considered as typical. None had any illness or abnormality other than that for which they were attending; these included minor otolaryngological problems, requiring tonsillectomy, insertion of grommets, etc., ophthalmic problems (squints, etc.), and minor general surgical conditions (phimosis, hernia, etc.).

Biochemical measurements

Blood and urine samples for biochemical and haematological tests were obtained between the hours of 0800 and 1000 to eliminate the possibility of diurnal variation.

Sample analysis was performed at the department of biochemistry, Royal Hospital for Sick Children, Glasgow. The following variables were measured using standard laboratory techniques: sodium, potassium, chloride, bicarbonate, urea, creatinine, calcium, phosphate, alkaline phosphatase, aspartate transaminase, alanine transaminase, γ glutamyl transferase, bilirubin, total protein, albumin, glucose, cholesterol, triglyceride, magnesium, zinc, copper, transferrin, C reactive protein, and urine 3-methylhistidine.

The results were compared with normal age matched reference data from our laboratory.

Haematological measurements

Blood samples were obtained as described earlier and analysed to determine the haemoglobin concentration, white cell count, packed cell volume, and serum and red cell folate concentrations. Sample analysis was performed at the department of haematology, Royal Hospital for Sick Children, Glasgow and results compared with our own age related normal reference data.

DATA ANALYSIS

Data analysis was performed both for the whole group and for subgroups to determine the influence of cyanosis and different types of congenital heart disease on the state of nutrition.

Results

VALIDATION OF ANTHROPOMETRIC REFERENCE DATA

Anthropometric data from 35 children about to undergo minor surgery were compared

with standard reference charts (figs 1–3). Results, graded into centiles, conform to roughly normal distribution, and allowing for the small sample size, these findings support the use of the standard reference data in our community and circumstances.

NUTRITIONAL SURVEY OF CHILDREN WITH CONGENITAL HEART DISEASE

Results obtained from 48 patients about to undergo surgical correction of congenital heart disease were considered in relation to the whole group and to certain subgroups.

Whole Group analysis

Anthropometry Figures 4–6 demonstrate a marked shift towards smaller size in the six variables studied. For example, 52% of children with congenital heart disease had a weight less than the third centile, more than 37% were below the third centile for height, 12.5% were below the third centile for triceps skin fold thickness and 18.8% for subscapular skin fold thickness, and 20.1% were below the fifth centile for mid-arm circumference and 16.7% for arm muscle circumference.

Figure 1 Centile distribution of (A) height and (B) weight in 35 normal children.

Figure 2 Centile distribution of (A) triceps and (B) subscapular skin fold thicknesses in 35 normal children.

Figure 3 Centile distribution of (A) mid-arm and (B) arm muscle circumferences in 35 normal children.

Figure 4 Centile distribution of (A) height and (B) weight in 48 children with congenital heart disease.

Figure 5 Centile distribution of (A) triceps and (B) subscapular skin fold thicknesses in 48 children with congenital heart disease.

Figure 6 Centile distribution of (A) mid-arm and (B) arm muscle circumference in 48 children with congenital heart disease.

Biochemistry and haematology These results demonstrate that many biochemical and haematological variables are abnormal in children with congenital heart disease. The interpretation, however, is difficult, as it is impossible to ascertain the importance of individual variables to the overall wellbeing of each child. Albumin, transferrin, and serum zinc are nevertheless generally accepted to be useful indicators^{22 34-39} and in this series were abnormal in 64.6%, 29.2% and 16.7% respectively. In addition, urine 3-methylhistidine was abnormally high in 33.3%, suggesting a degree of active muscle wasting. C-reactive protein was minimally increased in three patients and substantially abnormal in one (32 mg/l).

Liver function tests were abnormal in only a few children: bilirubin and alanine transaminase were increased in 4.2% of patients, alkaline phosphatase in 8.3%, aspartate transaminase in 25%, and γ glutamyl transferase in 2.1%. Of the remaining tests, abnormal concentrations were determined for plasma sodium in 4.2% of patients, chloride in 75%, bicarbonate in 54.2%, urea in 18.8%, creatinine in 45.8%, calcium in 27.1%, phosphate in 2.1%, total protein in 45.8%, glucose

in 4.2%, cholesterol in 20.8%, triglyceride in 33.3%, magnesium in 8.3%, and copper in 14.6%, potassium concentrations were normal. Abnormal values were recorded for haemoglobin in 25% of patients (this was expected as 25% had cyanosis), white cell count in 4.2%, packed cell volume in 16.7%, serum folate in 41.2%, and red cell folate in 25%.

Although combining results and assuming each variable to be of equal importance may well be invalid, this technique has been used elsewhere⁴⁰ and it is interesting that five or more of the 29 measurements were abnormal in 83.3% of patients and 10 or more were abnormal in 12.5% of patients.

Subgroup analysis

Cyanosis Twelve of 48 patients had cyanosis before surgery. Examination of each variable (anthropometric, biochemical, and haematological) revealed no significant difference between those children with cyanosis and those without cyanosis ($P > 0.05$; χ^2 test).

Heart defect Children with atrial septal defects ($n = 15$) or tetralogy of Fallot ($n = 7$) were present in sufficient numbers to be studied as individual subgroups. There was no overall

statistical difference between these patients and the group as a whole with the exception of the plasma zinc concentration which was abnormally low more frequently in patients with atrial septal defects ($P < 0.05$; χ^2 test).

Discussion

The maintenance of nutritional homeostasis is fundamental to normal health. In children, not only do the added demands of growth make this goal more difficult to achieve, but in those who undergo surgery, it is not surprising that the pre-existing state of nutrition should have a profound effect on outcome. There is, for example, clear evidence of an association between malnutrition and poor wound healing,⁴¹⁻⁴³ impaired immunity,⁴⁴⁻⁴⁶ reduced muscle function,⁴⁷ and an increased risk of postoperative pneumonia.⁴⁸ In the long term malnutrition is an important cause of cardiac decompensation⁴⁹ and myocardial atrophy.^{50 51} Malnutrition may also affect the stress response to surgery, although postoperative nitrogen losses may be less in malnourished, than in well nourished patients, because of adaptation to cachexia and the development of nitrogen and protein sparing metabolic cycles.⁵² It has been suggested that patients undergoing cardiac surgical procedures associated with hypothermia, narcotic analgesia, and neuromuscular blockade may have an attenuated catabolic response and lose less nitrogen than other equivalent surgical patients.⁵³ Against this suggestion, however, is the lack of evidence correlating the degree of hypothermia with the degree of postoperative muscle protein breakdown.⁵⁴

Adults undergoing cardiac surgery, with the exception of those patients with end stage valvular heart disease,⁵⁵⁻⁵⁷ show little evidence of malnutrition,^{54 58} many patients are even obese. It is unlikely that postoperative complications leading to a relatively prolonged period of starvation would have much impact on the overall prognosis in patients with plentiful "reserves". Some patients, however, do develop cardiac cachexia and surgery in this group is undoubtedly associated with a higher mortality and morbidity.^{55 56 59}

In contrast to the adult population undergoing cardiac surgery, children with congenital heart disease often appear small and undernourished, but there are few studies that formally document this,⁵⁻¹⁴ and only three in the modern era of cardiac surgery.¹⁵⁻¹⁷ The complex nature of the operative and perfusion techniques currently available, combined with prolonged recovery times and the possibility of delay in starting an adequate feeding regimen in the early postoperative period suggest that pre-existing malnutrition might be associated with a relatively poor prognosis, particularly in view of the trend towards early surgery.

The origin of growth failure in children with congenital heart disease may be unrelated to the cardiac pathology, but perhaps is the result of genetic or hereditary factors. Alternatively, it has been suggested that

growth retardation may be indirectly related and due to chronic tissue hypoxia or an increased incidence of respiratory disease, both the result of pulmonary congestion and a left to right shunt.⁶ This view has been disputed,^{12 15} however, and genuine growth failure has been recorded in various congenital defects, being particularly severe in those associated with congestive heart failure¹³ and cyanosis.^{5 10 12} Furthermore, the severity of the growth failure has been linked to the severity of the cardiac defect,¹³ the worst affected being double outlet right ventricle, tetralogy of Fallot with pulmonary atresia, and transposition of the great vessels.¹⁰ Whether the surgically corrected child shows a period of accelerated growth ("catch-up") is disputed,¹⁴ but may in part relate to the age at which surgery was performed; the earlier surgery is carried out the more likely that catch-up will occur.^{13 14 60}

Most previous studies of nutrition and congenital heart disease have largely depended on measurements of height and weight. This study has sought to investigate the state of nutrition in greater depth, measuring 35 different parameters of wellbeing. While we have demonstrated profound undernutrition in general, we have not shown any relation between the severity of undernutrition and the type of cardiac defect nor have we demonstrated a link with cyanosis. Interestingly, Salzer *et al*¹⁷ also cast doubt on an association between cyanosis and the severity of growth failure, their observations being based not just on height and weight measurements, but also on subscapular and triceps skin fold thicknesses and serum albumin and prealbumin concentrations.

As some of the children with less severe malformations such as secundum atrial septal defects were younger than those in some other series, it could be argued that these children were operated on early *because* of failure to thrive and therefore comprise a subgroup not representative of the usual surgical population. There is, however, no difference in the degree of undernutrition between the younger and the older children in this series and it seems justified to conclude that although children with congenital heart disease may superficially appear well nourished, careful examination will frequently reveal that they are not.

Long-term diuretic treatment depletes zinc stores⁶¹; whether the biochemical changes were the result of drug treatment is uncertain, but this possibility seems unlikely as medication was minimal. Several children, however, might have been expected to have abnormal liver function as a result of right heart failure, yet this condition was present only in a few and it is also unlikely that this would be directly responsible for any significant undernutrition.

A genuine failure to thrive therefore seems to be a common feature of children with congenital heart disease. There are three possible explanations for this finding:

(1) Inadequacy of the food supply. It is

unlikely that this would contribute to growth failure in a modern society with the provision of social services. Most parents aware of their child's poor development are particularly well motivated to help.¹⁶

(2) Malabsorption⁶²⁻⁶⁴ or feeding difficulties, arising from fatigue⁶⁵ and breathlessness,⁹ for example, may restrict intake. Evidence to support this hypothesis derives from the observation that oxygen consumption relative to lean body mass or surface area is similar in normal children and those with congenital heart disease,¹⁵ plus the finding that force-feeding results in an improved weight gain.⁶³ Two recent studies, however, refute this explanation.^{16 17}

(3) Hypermetabolism. Despite the possibility of tissue hypoxia children with congenital heart disease may have relative hypermetabolism⁶⁶ and exhibit growth failure if the nutritional intake is not increased in line with increased requirements. Hypermetabolism is a feature of congestive heart failure in adults and although the exact cause is uncertain, it probably depends on increased catecholamine production and the abnormal demands of various organs, in particular the muscles of respiration, the myocardium, and the haematopoietic system. Excessive thyroxine does not seem to contribute.⁶²

Eighteen (age range 4–33 months) of the 48 children studied here participated in a further study which used the doubly labelled water method to determine energy expenditure in the week before surgery.⁶⁷ This group comprised six children with a secundum atrial septal defect, five with tetralogy of Fallot, three with ventricular septal defects, and one each with a coarctation, a double outlet left ventricle, a univentricular heart, and a primum atrial septal defect. Energy expenditure (measured in kcal/kg fat free mass) was compared with results from age matched normal children. There was clear evidence of hypermetabolism in five children with congenital heart disease (metabolic rate increased > 20%); this was not the case in the remainder nor did the findings correlate with the type of cardiac defect or the presence or absence of cyanosis. The cause of the observed failure to thrive in children with congenital heart disease therefore remains uncertain; although hypermetabolism is responsible in some patients, clearly other factors are also important.

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