Cardiology in the Young (2017), **27(Suppl. 6)**, S22–S30
doi:10.1017/S104795111700258X

Original Article

Management of undernutrition and failure to thrive in children with congenital heart disease in low- and middle-income countries

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Abstract Poor growth with underweight for age, decreased length/height for age, and underweight-for-height are all relatively common in children with CHD. The underlying causes of this failure to thrive may be multifactorial, including innate growth potential, severity of cardiac disease, increased energy requirements, decreased nutritional intake, malabsorption, and poor utilisation of absorbed nutrition. These factors are particularly common and severe in low- and middle-income countries.

Although nutrition should be carefully assessed in all patients, failure of growth is not a contraindication to surgical repair, and patients should receive surgical repair where indicated as soon as possible.

Close attention should be paid to nutritional support – primarily enteral feeding, with particular use of breast milk in infancy – in the perioperative period and in the paediatric ICU. This nutritional support requires specific attention and allocation of resources, including appropriately skilled personnel.

Thereafter, it is essential to monitor growth and development and to identify causes for failure to catch-up or grow appropriately.

Keywords: CHD; low- and middle-income countries; nutrition; cardiac surgery; paediatric intensive care

Received: 15 September 2017; Accepted: 15 September 2017

Many children with CHD are underweight for age[1–11] and/or stunted – even at an early age. Being significantly underweight for age and wasted has been associated with higher perioperative morbidity and mortality in children with CHD.[12] In addition, the perioperative period is frequently complicated by difficulties with enteral nutrition[10,13] and potentially with increased nutritional loss associated with problems such as chylothorax.

There is a significant burden of childhood undernutrition in low- and middle-income countries where some 90% of the children born with CHD across the world live.[14] The co-existence of CHD increases the likelihood and severity of undernutrition, and this adds to challenges for the management of CHD including resource constraints; late presentation and diagnosis; and perioperative infection.[15–18] The number of children, including infants and newborns being operated for CHD, has recently increased in these regions.[15]

This review seeks to summarise existing evidence on prevalence of undernutrition and CHD and its impact on surgical outcomes with a focus on implications for low- and middle-income countries. An effort has been made to identify specific gaps in knowledge as a basis for future multicentre studies.

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Definition of malnutrition in CHD

In the context of CHD, it is important to reach a clear consensus on what is meant by malnutrition. Simple

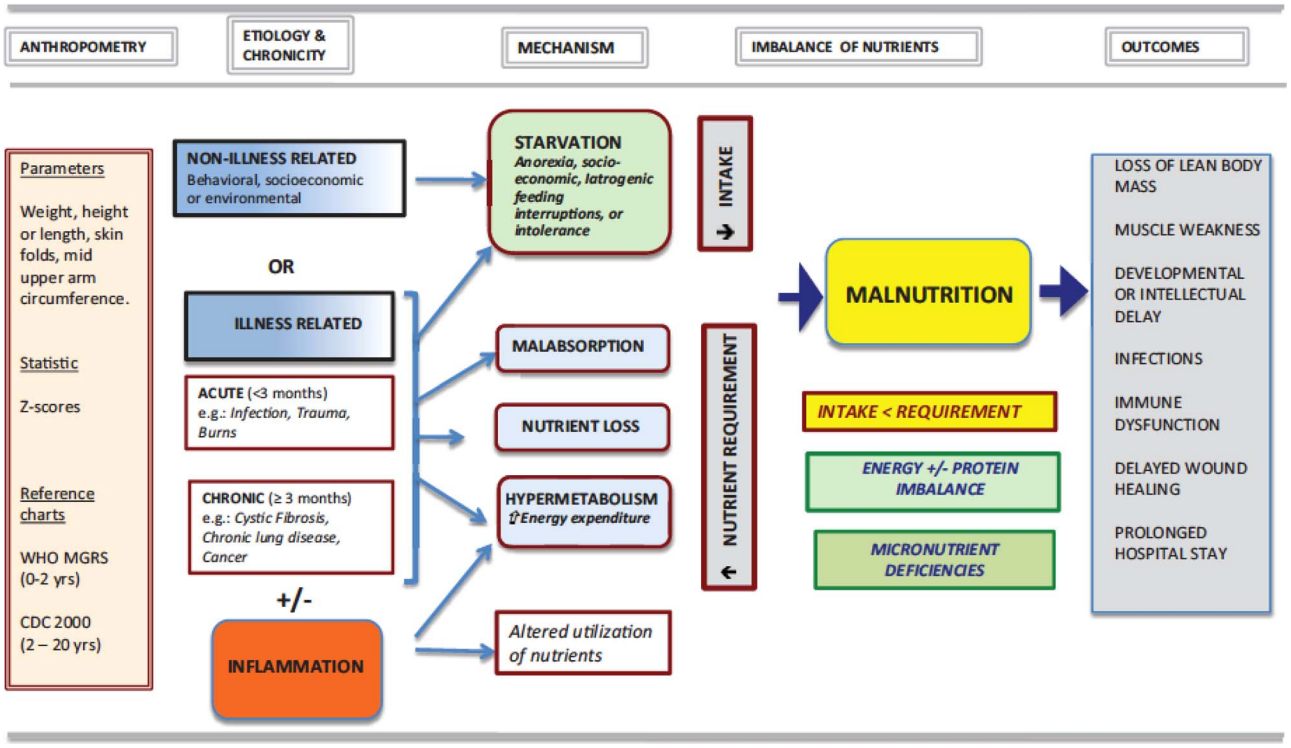

Figure 1.
An approach to nutrition in the child with failure to grow or to gain weight, from Mehta et al.[22]

measurements, such as height, weight, skinfold thickness, or mid-upper arm circumference, and their relationships, for example, weight-for-height, have been the basis of most definitions of nutritional status.[19] It is not possible to exclude malnutrition on the grounds of normal anthropometry alone, as there may be children with acute malnutrition who fall within the "normal" ranges for standard anthropometry.[20] Green Corkins has recently highlighted the importance of a full clinical evaluation – versus simply viewing anthropometry – in the assessment of nutrition status in children.[21]

Mehta et al defined malnutrition as "an imbalance between nutrient requirement and intake, resulting in cumulative deficits of energy, protein, or micronutrients that may negatively affect growth, development, and other relevant outcomes"[22] (see Fig 1). Ideally, any assessment of nutrition and investigations on the role of nutrition in patient management should include data regarding growth over a period of time: actual dietary intake available (and provided); evidence for malabsorption; evidence of inflammatory processes; and evidence of any underlying disease.[23]

Failure to thrive in children with CHD

The basis of growth failure or underweight in CHD appears to be multifactorial and may differ in aetiology from patient to patient. It includes the underlying cardiac anomaly,[24] haemodynamic factors, hypoxaemia, inadequate calorie, or macronutrient intake,[1,13,25–28] increased energy expenditure relative to intake,[29–31] increased inflammation,[32] or associated comorbidities that include gut dysfunction,[25], respiratory infections, associated genetic syndromes, and reduced growth potential.[7,33–37]

A study of anthropometric data in children with CHD in India showed that recorded dietary intake was not associated with the probability of being underweight.[6] Another study concluded that there was no reduction in intake in children with CHD relative to normal children, whereas "normal serum prealbumin and albumin in the infants with CHD ruled out protein–calorie malnutrition."[36] The plasma amino acid profile was normal preoperatively in a group of children with CHD, regardless of anthropometric values.[38] A study from Latin America of children with CHD showed that anthropometric measures of malnutrition were present in >80% of the children; albumin and prealbumin levels were lower than in normal controls, although transferrin levels were no different; and that failure to thrive was worse in children with pulmonary hypertension.[39]

In low- and middle-income countries with resource limitations, the prevalence of abnormal preoperative anthropometry is high owing to late presentation, delays in corrective intervention, and

frequent hospitalisations related to respiratory infections.[6,16] In a cohort of 100 consecutive infants undergoing ventricular septal defect closure, severe underweight (weight z-score <– 3) was observed in 46% of patients.[33] In a prospective study of 476 consecutive patients undergoing corrective intervention for CHD, Vaidyanathan et al reported z-scores <– 2 in 59% (weight), 26.3% (height), and 55.9% (weight/height), respectively; z-scores <– 3 were observed in 27.7% (weight), 10.1% (height), and 24.2% (weight/height).[6] Congestive heart failure, older age at correction, and limited growth potential as suggested by lower birth weight for gestation, lower parental anthropometry, and genetic syndromes were identified as predictors of "malnutrition". The International Quality Improvement Collaborative for Congenital Heart Surgery in low- and middle-income countries uses a registry to collect data from over 50 sites. An analysis of data from 15,049 patients with CHD revealed that >50% of children had weight z-scores of –3 or less and 12% had an emaciated appearance before their surgery.[16]

Although anthropometric measurements in children with CHD are frequently abnormal, classical features of malnutrition such as skin changes, presence of oedema, hair changes, and so on are relatively rare in children with CHD. In the setting of malnutrition in Africa, a discrepancy between clinical signs of acute malnutrition and anthropometry[20] may be an important issue to pursue.

Finally, there is evidence that micronutrient deficiencies may be relatively common in children with CHD.[40] This has never been explored in low- and middle-income countries where it is even more likely to be an issue.

Supplementary Table 1 summarises data from publications on nutritional status in CHD from low- and middle-income countries.

Impact of preoperative state on postoperative outcome

Because of their lower protein and energy reserves, infants and newborns may be particularly vulnerable to the hypercatabolic state that is expected following heart surgery,[41,42] although hypercatabolism may not follow all paediatric cardiac operations.[43] This situation is further worsened by comorbidities such as lack of protein:calorie provision or major infections (Fig 1). When the acute phase of metabolic stress resolves, the anabolic phase begins, resulting in somatic growth, with decreasing concentrations of acute-phase reactants, proteins, and total urinary nitrogen values, and with increasing concentrations of visceral proteins.[44] The timing of transition to the anabolic phase is influenced by the extent of "surgical stress", associated comorbidities, quality of nutritional support, and a number of other potential factors.

Within that framework, there has been concern that cardiac surgery in underweight children with CHD would be associated with worse outcomes. However, there is very little evidence to support the notion that lower weights are associated with poorer surgical outcomes. In a study published in 1992, Hardin et al[45] compared two groups of patients undergoing closure of ventricular septal defects (>4 kg and <4 kg) and found no significant difference in outcomes.

In a study from southern India on 100 consecutive infants undergoing surgical closure of ventricular septal defects, 46% had weight z-scores of –3 or lower, although this did not affect postoperative mortality or morbidity, duration of mechanical ventilation, or length-of-stay in the ICU or hospital.[16] A more recent prospective study of 1028 infants from the same centre studied the impact of preoperative factors on postoperative outcomes after congenital heart surgery.[17] Weight z-scores <– 3 and low birth weight (<2.5 kg) did not adversely affect mortality or morbidity. These results reinforce the strategy of early correction of CHDs irrespective of nutritional status. Preoperative optimisation of nutritional status through aggressive feeding is not necessary in most patients, although it may make sense to use this technique if there are ongoing delays in access to surgical repair.

Correction verses palliation

The question of correction versus palliation in a severely undernourished child with CHD is likely to be dictated by several factors that include the specific defect, the experience and expertise of the surgical and intensive care teams, and associated comorbidities. Relatively simple CHD that can be corrected through a single operation, such as a ventricular septal defect, should be closed surgically. A study in South Africa demonstrated that when the realities of a staged approach using pulmonary artery banding – including loss to follow-up, delays in definitive procedures, the challenges of two surgical procedures in a context with limited surgical time, and so on – were taken into account, mortality after a staged approach using pulmonary artery banding was higher than primary surgical closure of the ventricular septal defect.[46] Nonetheless, there are clearly situations where pulmonary artery banding may be a useful stage en route to full correction.

Management of undernutrition

Cardiac teams in low- and middle-income countries are frequently faced with children with CHD who are

underweight, thin, and stunted. The first response should be to regard that as further evidence that the diagnosis of CHD is being delayed and to focus on interventions to improve early diagnosis and referral.

Preoperative assessment of nutritional status:

A full preoperative assessment should be obtained as it provides essential baseline information for further monitoring of progress following surgical correction. This would typically include accurate measurements of height, weight, and head circumference. The measurement of biceps or triceps skinfold thickness is a simple method for determining fat stores, which is not routinely performed during preoperative assessment,[19] but might provide useful data for follow-up, both for individual patients and for patient groups. Laboratory tests that include plasma levels of albumin, transferrin, prealbumin, and retinol-binding protein are seldom undertaken because they are thought to be of limited value.

Nutritional support

Significant caloric supplementation in children with CHD could lead to improved growth[47] and, in some, improved growth could be achieved using continuous enteral feeds.[48–50]

Enteral nutrition is the preferred mode of nutritional support in paediatric ICUs.[51] Enteral nutrition is physiological, has a favourable effect on the intestinal mucosa, and has fewer complications compared with parenteral nutrition.[52,53] It has the additional benefit that it is considerably cheaper than parenteral nutrition and more easily available in low- and middle-income countries. Intragastric feeding is the most common route, and there are insufficient data to recommend routine use of post-pyloric feeding, unless there are particular concerns such as poor tolerance of gastric feeding or evidence of gastro-oesophageal reflux with aspiration. In a single randomised controlled trial in 74 critically ill children, a higher number of patients with post-pyloric feeding reached caloric goals.[54]

There are particular challenges with feeding of neonates before surgery, although in most cases it is possible to start enteral feeding – even while on prostaglandins. Many of these infants may continue to require gavage feeding postoperatively.[55]

Postoperative nutrition

Postoperative enteral feeds should be initiated as soon as possible, and parenteral nutrition should only be used if absolutely essential. Recent data suggest that early parenteral nutrition, within 7 days of admission, in the paediatric ICU is associated with worse patient outcomes, at least in high-income countries.[56]

Initiation and advancement of feeds:

Guidelines for withholding feeds after paediatric cardiac surgery are not clearly defined, and there are extremely limited data available specific to low- and middle-income countries. The most common concern in early initiation of feeds is the potential for low cardiac output with gut hypoperfusion, especially in neonates with duct-dependent circulation, leading to necrotising enterocolitis.[57,58] With careful monitoring and slow advancement of feeds, early enteral nutrition is feasible in most neonates within the first 24 hours. In a retrospective review of 67 neonates, including 52 patients with duct-dependent circulation undergoing surgical repair, postoperative enteral feeds could be initiated within 3 days in 98.5% (n = 66); 64 patients could reach full feeds at a median duration of 7.5 days following surgical correction.[55]

In neonates and young infants, feeds are typically started – within 12–24 hours of surgery – at 1 ml/kg/hour and advanced at the same rate every 4–6 hours to reach the goal volume. Although continuous feeds have not been shown to minimise aspiration or feed intolerance, it is sometimes resorted to in infants with poor weight gain and feeding complications.[49] Feeds are withheld before extubation, around invasive procedures, in patients with haemodynamic instability, or with impending respiratory failure.

In the early postoperative phase, feed volume is dictated by the maintenance fluid rate. Fluid intake is usually restricted to 50–80% of maintenance rate in neonates and infants undergoing open-heart surgery.[59] On the basis of studies in patients with CHD, the resting energy expenditure is estimated to be 55–75 kcal/kg/day in the first 3–5 days.[60] This guides initial feeding, which can be escalated to 120–150 kcal/kg/day with transitioning to step down care to facilitate catch-up growth in infants.

Protein intake is crucial as protein catabolism could manifest as loss of respiratory muscle mass, failed weaning, poor weight gain, depressed immune function, and poor wound healing. In a small study from Brazil, patients became anabolic post-cardiac surgery with a calorie intake of 54 kcal/kg/day and a protein intake of 1.1 g/kg/day.[42] The decline in C-reactive protein levels to values <2 is considered an indirect marker of the onset of the anabolic phase in critically ill patients; however, its relevance in post-cardiac surgical patients has not been proven.[59]

For neonates and infants, particularly in low- and middle-income countries, human breast milk is the preferred form of enteral feeding, although the

practicalities of maintaining breast milk production in this context may be challenging.[61] Breast milk is cost-effective, has immunological benefits, promotes better absorption of trace elements, and may even lower the risk of developing necrotising enterocolitis when used exclusively.[62] In the setting where tight fluid restriction is required, it may be necessary to increase the energy density of feeds – both for formula and expressed breast milk. An energy density of ~1 kcal/ml is well tolerated. Further increases should be monitored carefully as high calorie density may precipitate osmotic diarrhoea. Cost-effective options to fortify formula feeds include additives such as coconut oil or medium-chain triglyceride oil.

A feeding gastrostomy or jejunostomy may be a reasonable option when long-term enteral nutrition is required in children.[63,64] It may also be considered in patients with gastro-oesophageal reflux, aspiration, or severe failure to thrive. In a retrospective cohort of 54 patients who required gastrostomy tube placement after surgery for single-ventricle palliation, patients who underwent earlier placement of a gastrostomy tube had shorter ICU and hospital stays.[64]

Monitoring enteral nutrition should include regular audits of weight, fluid and dietary intake, calories prescribed and calories achieved, gastrointestinal function, feeding tube integrity, and feeding complications. Undue attention to gastric residual volumes may be a deterrent to enteral feeding in critical care settings. Decisions to interrupt feeds should be considered with signs of feeding intolerance such as distention, vomiting, or diarrhoea, rather than relying on residual volumes alone.[65] The most important aspect of monitoring enteral nutrition may be to detect and minimise interruptions in feeding. In a recent prospective study in a paediatric ICU, implementation of a stepwise enteral nutrition algorithm led to a significant decrease in the number of avoidable episodes of feeding interruptions ($n = 3$ versus $n = 51$, $p = 0.0001$), shortened the time to reach energy goals from 4 days to 1 ($p < 0.0001$), and resulted in a higher proportion of patients reaching their energy goals (99 versus 61%, $p = 0.01$).[66]

Underfeeding is common in critically ill children even in most advanced units.[67–69] Algorithm-led nutritional therapy and attention to energy and protein goals by dedicated nutrition support teams has translated to better postoperative outcomes in high-income countries.[68,69] However, in emerging economies there is a perceived lack of dedicated nutrition support teams. A viable option is to use existing personnel in monitoring and supervising nutrition delivery. The initial phase should focus on education of in-house staff to bridge knowledge gaps in feeding practices.[70] As primary caregivers, intensive care nurses should be empowered to initiate, monitor, and maintain nutrition delivery in the postoperative phase. A nutrition algorithm can be formulated to serve as a clinical aid to guide the therapy (Fig 2). This can be successfully integrated into multidisciplinary ICU rounds as nurse-led nutrition rounds.[71]

There are very limited data on recommendations for feeding children who were previously underweight and failing to thrive. We recommend that such children be started on the nutritional programme as outlined above, together with close monitoring of progress and weight gain. Failure to gain weight should stimulate renewed focus on adequacy of the cardiac repair; the presence of complications such as chylothorax, with associated nutritional deficits; and the possibility of other underlying conditions that may cause malabsorption of enteral feeds. In addition, there needs to be focus on optimisation of the diet available to the child, and provision of supplements of essential macronutrients and micronutrients.

Parenteral nutrition

The overall use of parenteral nutrition in critical care settings in low- and middle-income countries is reported to be very low,[72] primarily owing to prohibitive costs and lack of dedicated personnel to ensure safe prescription and delivery. In addition, there are the biological complications related to parenteral nutrition including infection, venous thrombosis, electrolyte imbalances, and parenteral nutrition-induced cholestasis.[73] Notwithstanding these concerns, the use of parenteral nutrition may be warranted in critically ill patients after congenital heart surgery in situations in which enteral feeding is contraindicated or is insufficient to promote adequate growth. Guidelines are available for prescription of parenteral nutrition in children.[74] Prescription of parenteral nutrition is a complex process with potential for errors, requiring appropriate precautions and systems when used.[75]

Parenteral nutrition in the low-resource environment:

In paediatric ICUs of low- and middle-income countries, parenteral nutrition should be prescribed only if absolutely indicated. The paediatric intensivist in conjunction with the nurse leader and the hospital clinical pharmacist should be in charge of prescribing and ensuring its safe administration. The feasibility of re-introducing enteral nutrition should be constantly explored. Trophic feeds should be encouraged wherever feasible to prevent intestinal mucosal atrophy.[73]

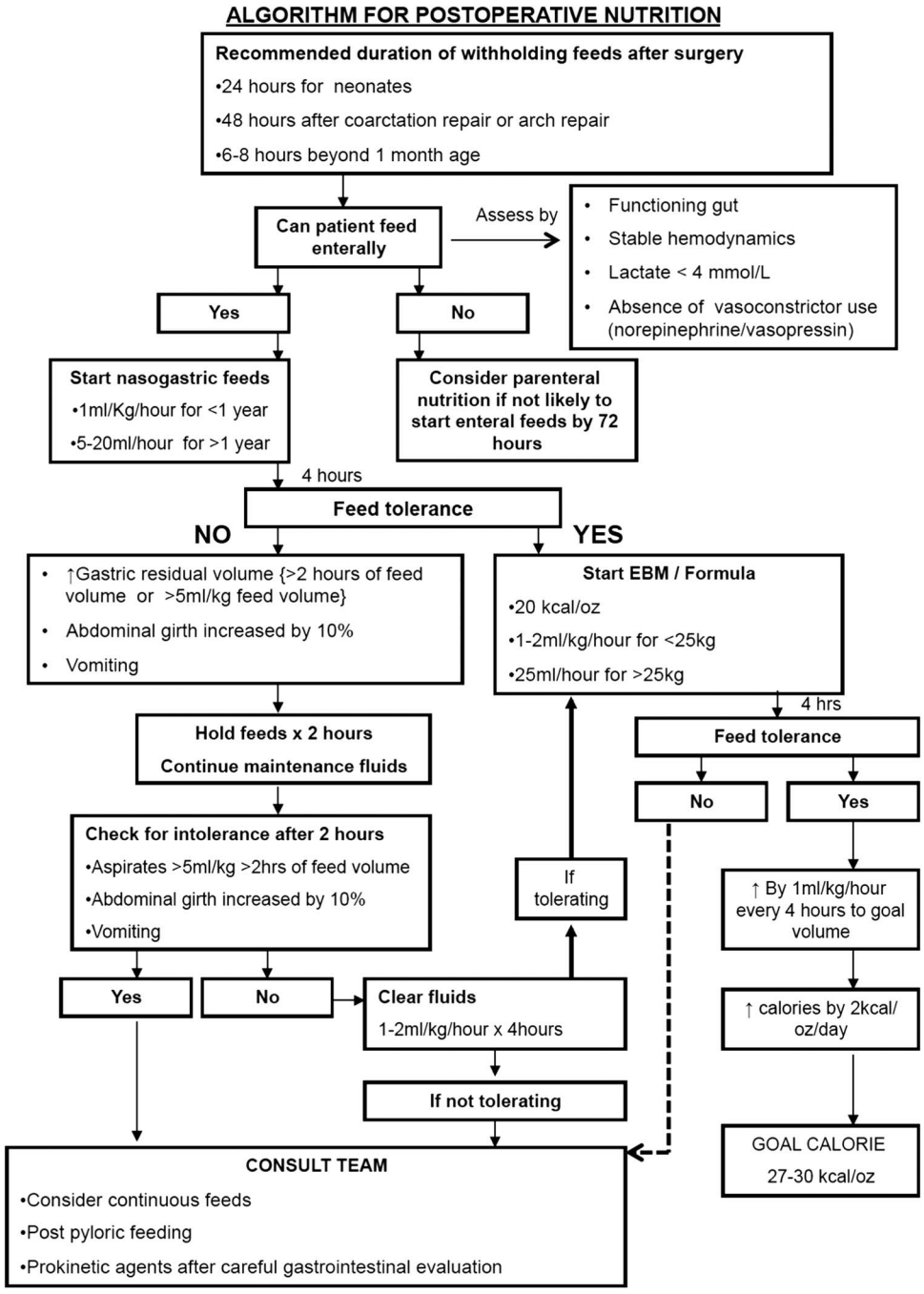

Figure 2.
Nutritional management in the early postoperative period: suggested algorithm for low-resource environments. EBM = expressed breast milk.

Nutritional recovery after corrective surgery

Studies from advanced nations have previously reported normalisation of somatic growth typically 6–12 months after corrective congenital heart surgery.[34,76] Weintraub et al[34] reported that after surgical closure of ventricular septal defects in infancy, growth parameters were almost comparable to the reference population by 5.7 years; however, in a study from southern India, the nutritional recovery on follow-up after ventricular septal defect closure in infancy was sub-optimal, with weight and height z-scores <– 2 in 42 and 27% of patients, respectively.[77] In a larger study including all forms of CHD, the same authors reported significant catch-up growth after correction, typically within 3–12 months postoperatively, followed by plateauing of growth curves after 1 year.[78] This reflects an

immediate catch-up growth in the short term owing to correction of the haemodynamic derangement. Other determinants of growth such as dietary and constitutional factors play a more important long-term role. Sub-optimal nutritional recovery with persistent weight, z-score <– 2 was observed in 27% of patients and this was predicted by lower weight z-score at surgery, lower birth weight, and lower parental anthropometry.[78] It is important to identify patients at risk of sub-optimal recovery – those with lower growth potential – before intervention so that targeted nutritional rehabilitation may be provided on follow-up.

Review post-surgery and surgical recovery

Following paediatric ICU discharge, close attention to nutrition is required, particularly in some subsets of patients[79] such as those with Fontan circulations following complex CHD.[80] However, this may pose challenges in resource-limited settings.

Future directions

Ideally, nutritional support for children with CHD should be based on data that are appropriate to specific environments. Although there is a reasonable body of published evidence on the existence of failure of growth and weight gain in children with CHD in low- and middle-income countries (see Supplementary Table 1), there are very limited data available on the optimum way to address these deficits.

Much of the current data on children with CHD are limited to a relatively small spectrum of cardiac anomalies. As increasingly complex CHD is addressed in low- and middle-income countries, the issues related to nutrition may well change and require different approaches. The maintenance of regional databases of information and outcomes would provide an ideal basis for future research in this area.

Much work needs to be done in the areas of quality control and research implementation in order to carry through what is already known into clinical practice. There may need to be increased focus on supporting teams and structures that are implemented for clinicians who work with patients with CHD in low- and middle-income countries.

Conclusions

The overall management of children with CHD may be complex, and attention to nutrition is a critical element of that care. In general, nutritional support is relatively inexpensive. However, it relies on the existence of a structured system within the cardiac care environment to ensure appropriate recognition of the particular role of nutrition in a specific child. Repeated and accurate measurement of growth parameters together with detailed attention to nutritional intake and tolerance are crucial. It makes little sense to invest in the expense of cardiac surgery while ignoring the associated nutritional challenges.

Acknowledgement

None.

Financial Support

This research received no specific grant from any funding agency, commercial, or not-for-profit sectors.

Conflicts of Interest

None.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1047951117000258X

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