Somatic growth following congenital heart surgery in economically underprivileged children

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Accepted 12 October 2011

ABSTRACT

Objectives To assess the impact of congenital heart surgery on anthropometric scores of growth in economically disadvantaged children.

Methods A cohort of 100 economically disadvantaged children was followed up after cardiac surgery for their nutritional recovery. Weight, height and body mass index for age were measured just before surgery and at a median period of 48.1 months (range 9—59.9 months) after surgery. Z scores of the age-adjusted variables were computed and McNemar OR was calculated for odds of improvement.

Results The mean weight for age of the cohort increased from 14.74±5.76 to 23.83±7.83 kg. In malnourished children (weight for age Z score ≤−2) the mean weight changed from −3.01 to −1.6 ($p<0.05$), the median improvement being 0.85. The paired OR for improvement was highest for weight (14.5; 95% CI 5 to 27), modest for BMI (1.57; 95% CI 0.56 to 6.34) and least for height (0.25; 95% CI 0.04 to 0.87). The proportion of malnourished children decreased from 61% to 27% after surgery. Subgroup analysis of the children with initial malnutrition showed significant improvement in weight for age Z scores ($p=0.002$) compared with non-malnourished children (paired OR 17.54; 95% CI 6.13 to 32.26), those with worse malnutrition faring better. Children with residual malnutrition tended to have extreme economic backwardness, surgery for cyanotic congenital heart disease or associated syndromes.

Conclusion Congenital heart surgery resulted in a salutary improvement in the growth of children from economically underprivileged backgrounds. Residual malnutrition was likely to be associated with extreme economic backwardness, surgery for cyanotic congenital heart disease or coincidental syndromes.

INTRODUCTION

There has been remarkable development in the fields of paediatric cardiology and paediatric cardiac surgery in the last few decades. Today, a child born with congenital heart disease (CHD) in the USA has an 85% chance of surviving into adulthood after receiving surgical correction or palliation.[1] Selected centres in the developing world have interventional and surgical skills matching the best in the developed world. In India, with a population of over 1 billion, the number of centres offering major paediatric cardiac services is less than 14.[2] In such a scenario, access to healthcare is simply non-existent for the underprivileged.

Malnutrition and consequent poor somatic growth are rampant in economically underprivileged children. Children with CHD from underprivileged families have the double burden of poverty and heart disease. Very little is known about the impact of CHD surgery on their subsequent growth. The present study evaluated the anthropometric scores of growth in a cohort of economically underprivileged children (with annual family incomes way below the millennium development goal[3]) selected using an outreach programme outlined in the online supplementary appendix I, and attempted to identify predictors of residual malnutrition.

METHODS

Study design: interventional 'before and after' case series design

One hundred underprivileged children below the age of 12 years (annual family income <20 000 Indian rupees, equivalent to US$425) who underwent surgery for CHD during the period October 2004—October 2008 formed the study population. This cohort was an unselected consecutive series of cases. The institutional ethics committee approved the study protocol. The height and weight of the children were measured 1 day prior to surgery and subsequently during follow-up, at a median interval of 48.1 months (range 9—59.9 months). These values were normalised for age using Z scores provided by CDC 2000 reference values, as recommended by WHO.[4] Malnutrition was deemed to be present when Z scores were ≤−2 for weight for age (low weight for age); Z score of ≤−3 was classified as severe malnutrition.[5]

Statistical analysis

Distributions of age-adjusted Z scores of weight, height and body mass index (BMI) before and after surgery were compared; the change in Z score was analysed using appropriate statistical tests. The mean Z scores before and after surgery for each of the variables were computed and the mean change with 95% CI was calculated. The proportion of subjects who had Z scores below zero before and after surgery for each variable was compared and McNemar paired OR was calculated with 95% CIs. Subgroup analysis was done by comparing appropriate variables in subgroups before and after surgery. Statistical analysis was done using the 'R' software.[6]

RESULTS

A total of 100 underprivileged children (M:F 44:56; mean age 63.1±29.8 and 66.2±31.7 months for males and females, respectively) underwent cardiac surgery between October 2004 and October 2008. The diagnostic categories are shown in figure 1. The distribution of preoperative variables like height and weight in males and females was not statistically significant (mean weight 14.2±4.4 kg in males

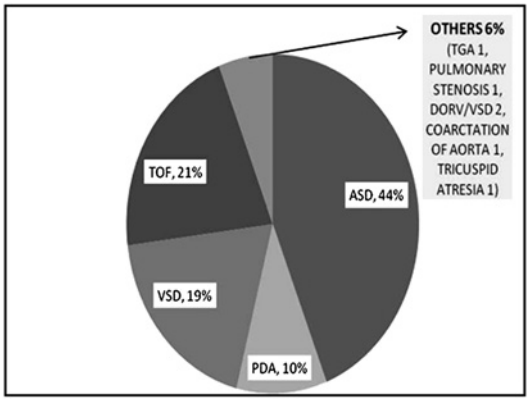

Figure 1 Preoperative diagnosis (n=100). ASD, Atrial Septal Defect; DORV, Double Outlet Right Ventricle; PDA, Patent Ductus Arteriosus; TGA, Transposition of great arteries; TOF, Tetralogy of Fallot; VSD, Ventricular Septal Defect.

and 15.2±6.7 kg in females; mean height 105±27 cm in males and 106±23.1 cm in females). There was no in-hospital mortality. The patients were followed up for a period ranging from 9 to 59.9 months (median 48.1 months).

The preoperative and postoperative anthropometric data are shown in table 1. The absolute number of children with age-adjusted Z score ≤−2 decreased from 61 to 27 for weight, from 40 to 23 for height and from 47 to 20 for BMI. The proportion of children with indicators of malnutrition before and after surgery is shown in figure 2.

Before surgery, only 8% of the subjects had weight for age Z score values of zero or above; following surgery, 35% had weight for age Z score zero or above ($p<0.05$). These figures were 23% (before surgery) and 13% (after surgery) for height for age Z score and 11% (before surgery) and 15% (after surgery) for BMI Z score. Table 2 shows the behaviour of the measured anthropometric variables with surgery and the paired OR for improvement.

Performance of malnourished children

The growth parameters of malnourished children, defined as having a weight for age Z score ≤2 (n=61), were separately analysed to assess the impact of the degree of malnutrition on anthropometric scores after surgery. The mean weight for age Z score of this group improved from −3.01±0.77 to −1.6±1.19 as against −0.8±1.01 to −0.32±0.831 for non-malnourished children (p=0.002). The median change was 0.85. The McNemar paired OR for improvement in weight was 17.54 (95% CI 6.13 to 32.26). Figure 3 is a bar chart showing the change in weight for age Z scores in these two groups with surgery. When a similar cut-off of ≤−2 was applied for age-adjusted height and BMI Z scores, these also showed some improvement (table 3).

Performance of severely malnourished children (weight for age Z score ≤−3)

Twenty-one children had weight for age Z score ≤−3 at initial presentation. The mean Z score of this group changed from

Table 1 Anthropometric data

Variable	Before surgery	After surgery	Mean increment*
Mean weight (±SD) kg	14.74±5.76	23.83±7.83	9.08 (8.2, 9.9)
Mean height (±SD) cm	104.31±21.33	125.87±13.84	21.57 (18.7, 24.4)
Mean BMI	13.35±2.57	14.63±2.09	1.28 (0.75, 1.82)

*Figures in parenthesis denote 95% CIs.
BMI, body mass index.

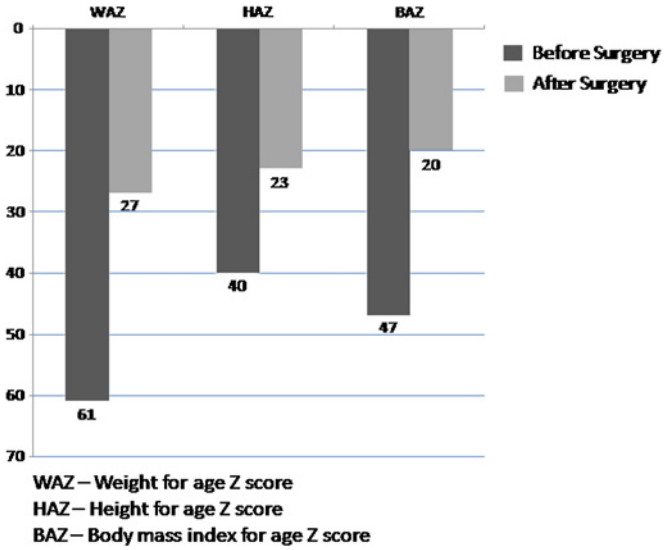

Figure 2 Proportion of malnourished children before and after surgery.

−3.85±0.69 preoperatively to −1.69±1.50 postoperatively ($p<0.001$). The McNemar paired OR for odds for improvement was 5.32 (95% CI 1.87 to 32.26). When a similar cut-off of ≤−3 was applied to age-adjusted height and BMI Z scores, these also showed some improvement (table 4).

Analysis of malnourished children (weight for age Z score ≤−2) who did not improve after surgery

Of the 61 children with initial malnutrition, 27 (44.2%) continued to have weight for age Z score less than -2 at the last follow-up. The clinical and socioeconomic profile of these children is shown in table 5.

This group had a higher incidence of extreme economic deprivation (annual income of <50% of the selection criterion, belonging to exceptionally vulnerable social groups like aborigines living in forests) and surgery for cyanotic CHD, and 11.1% had associated syndromes affecting growth. The number was too small for statistical analysis.

DISCUSSION

Poverty is global challenge. According to World Bank estimates, 1345 million people in the world subsisted on a daily income of US$1.25/day in 2008, which is inadequate to sustain adequate caloric intake;[7] 854 million people in the world suffer from chronic malnutrition of which 146 million are children.[8] This represents more than a quarter of children in the developing world.[8] The number of persons below the arbitrary poverty line (unable to purchase a basket of food providing 2400 kcal in rural and 2100 kcal in urban area) in India were 260 million (26%) in 2006.[9] Poverty and economic backwardness are closely linked to child malnutrition so much so that economists have argued

Table 2 Growth trends following surgery

Parameter	Before surgery <0	Before surgery ≥0	After surgery <0	After surgery ≥0	Odds for improvement*
WAZ	92	8	63	35	14.5 (5.0–27.0)
HAZ	77	23	87	13	0.25 (0.04–0.87)
BMIZ	89	11	85	15	1.57 (0.56–6.34)

*Figures in brackets denote 95% CIs.
BMIZ, body mass index for age Z score; HAZ, height for age Z score; WAZ, weight for age Z score.

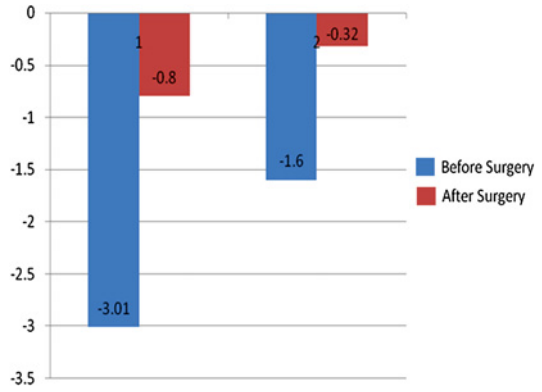

Figure 3 Malnourished group; 2—Non-malnourished group. Values denote mean weight for age Z scores of the group.

that the level of child malnutrition in a society can be an effective yard stick for measuring poverty.[10] The relation between poverty, malnutrition and childhood diseases is well established.[11]

CHD is a major contributor for poor growth in children. Possible mechanisms include inadequate caloric intake, malabsorption and increased energy requirement caused by increased metabolism. Congestive heart failure, hypoxia and cyanosis may all contribute[12–19] to poor growth in such children. Non-availability of food in the economically underprivileged results in deprivation of both energy and proteins critically needed for growth. Undernutrition during pregnancy and the first year of life has structural, metabolic and anthropometric effects on the child that persists throughout life.[8] This is a major consideration in the developing world where 35% of children have malnutrition measured by stunting.[20] Indeed, 70% of malnourished children live in Asia.[20] The fate of these children when they have the additional burden of CHD has not been discussed in literature.

It has been shown that the nutritional status of children with CHD significantly improves following correction of CHD. Vaidyanathan *et al*[21] reported a significant improvement in nutritional status at 3 months follow-up after cardiac surgery. The same group reported that 73% of children undergoing CHD repair below the age of 5 years had normalisation of growth at 2 years follow-up.[22] Earlier studies have reported that the catch up growth after CHD surgery is most rapid within 6–12 months.[23] Given the implications of poverty and malnutrition for long-term well-being, it is not clear whether CHD surgery will yield similar results in the economically underprivileged with a very high prevalence of malnutrition. The present study attempted to answer this question by following the anthropometric parameters of growth in a selected population of economically disadvantaged children.

The World Bank uses an income of US$1.25/day as the minimum amount required to sustain an individual's caloric requirement.[7] In Southeast Asia, 40.4% of population belong to the US$1.25/day poverty group.[7] In the Indian context with a single wage earner and family size of four, this amount would be US$5/day for the family (Rs 84 600, equivalent to US$1800 per annum for family). The present study was conducted in a group of children selected from families having an annual income of Rs 20 000 or less (US$425 per annum). One would expect that their income level would be grossly inadequate to sustain the caloric requirements. Thus, the children were selected from an extremely disadvantaged background. It must be mentioned that they still belong to the state with the highest human development index in India, having 100% literacy and the lowest figures for infant mortality rate.[24] This unique combination made access to these children possible and their follow-up thorough.

One need to choose simple and reliable means of monitoring growth in such a cohort. Weight and height are always measured prior to surgery and can be checked periodically by a healthcare worker. Both these values can be related to the age of the child. Weight for height has readily available Z score reference values (WHO) only below the age of 5 years; hence this parameter was not used in this study in which 60% of the population was above this age limit. BMI charts were used instead for uniformity in analysis. For comparison of growth parameters, CDC 2000 standards were used as these have been previously validated for use in Indian children.[22 25] The Z score is widely recognised as the best system for analysis and presentation of anthropometric data in surveys.

In the present study, 92% of the population had weight for age Z score below zero with 61% having weight for age Z score ≤−2. The absence of more severe forms of malnutrition in a still larger number could be explained by the unique status of population (high human development index and literacy rate, hence focus of care on the affected child) and the higher prevalence of simpler cardiac lesions (figure 1). Also, there was wide dispersion of human development within this group with some families showing extreme deprivation as in aborigines living in forests.

The present study showed that there was significant nutritional improvement following cardiac surgery in the cohort as a whole with the mean weight for age improving from 14.74±5.75 to 23.83±7.83 kg ($p<0.05$). The percentage of

Table 3 Impact of cardiac surgery on growth of malnourished children

Parameters	Before surgery		After surgery		OR
	Z score ≤−2	Z score >−2	Z score ≤−2	Z score >−2	
WFA	61	39	27	73	17.54 (6.13, 32.26)
HFA	40	60	23	77	3.42 (1.57, 14.93)
BMIFA	47	53	20	80	5.42 (2.57, 34.48)

BMIFA, body mass index for age; HFA, height for age; OR, McNemar paired OR; WFA, weight for age.

Table 4 Impact of cardiac surgery on growth of severely malnourished children

Parameters	Before surgery		After surgery		OR
	Z score ≤−3	Z score >−3	Z score ≤−3	Z score >−3	
WFA	21	79	8	92	5.32 (1.87, 32.26)
HFA	23	77	5	95	10.0 (3.23, 20.41)
BMIFA	47	53	20	80	5.42 (2.57, 34.48)

BMIFA, body mass index for age; HFA, height for age; OR, McNemar paired OR; WFA, weight for age.

Table 5 Profile of children with residual malnutrition (n=27)

Variable	Children with residual malnutrition (n=27)	Children without residual malnutrition (n=34)
Extreme economic backwardness	15	7
Aborigines	5	0
Cyanotic congenital heart disease	14	6
Syndromes	3	4
Congestive heart failure	1	8

subjects whose anthropometric parameters were at or above the predicted level can be presumed to be a reflection of the effect of surgery on subsequent growth. Before surgery, only 8% of the subjects had weight for age Z score above zero; following surgery, 35% of the subjects crossed this level. The percentage of malnourished children also significantly decreased after cardiac surgery. While the decline in malnutrition in the operated children was gratifying, there still remained a proportion of children who were malnourished postoperatively. In the present study, the group with residual malnutrition showed higher prevalence of cyanotic CHD and extreme economic deprivation. A small number also had syndromes affecting growth. Suboptimal recovery of somatic growth after CHD surgery in severely malnourished infants has been reported earlier.[26 27] Uncorrected poverty has been a major contributor to malnutrition in the present series. The incidence of low birth weight in such a group would be significantly high and this would impact their recovery after surgery. However, the information on birth weight was not available in the majority of the patients in this study.

Interestingly, the odds for improvement were least impressive for height for age and BMI for age Z scores. Height is influenced by a number of factors that are not correctable by surgery, for example, mid-parental height. Also, catch up growth may not be possible after some age.

That the improvement in weight was not simply related to growth is established by the improvement in weight for age Z score. The median improvement in Z score was 0.85. Thus, 50% of the children improved their Z score by at least 0.85. This is also reflected by the decrease in the number of malnourished children from 61% to 27% after surgery. Recently, Vaidyanathan *et al*[22] reported that severe malnutrition at presentation was a predictor of poor postoperative weight gain. In the present series, however, those with worst malnutrition exhibited the best improvement. Mean weight for age Z score of malnourished children improved from −3.01 to −1.6 ($p<0.005$) with surgery; the change in the group without initial malnutrition was not statistically significant. When the severely malnourished children (weight for age Z score <-3) were analysed separately their Z scores for weight and BMI also improved significantly with surgery.

Vaidyanathan *et al*[22] observed residual malnutrition (weight for age Z score ≤-2) in 27.3% of children following cardiac surgery in an economically unselected series. The present study showed that 44.2% of the malnourished population still remained at weight for age Z score ≤-2, showing the impact of poverty. Residual malnutrition subjects in the present study tended to have extreme economic deprivation, cyanotic CHD and coexisting syndromes. Incidence of congestive heart failure at presentation in the series was too low to be a potential contributor.

CONCLUSION

In summary, the present study has shown that CHD was a major contributor to growth impairment in economically disadvantaged children. Correction of CHD had a salutary effect on the growth of these children. Given access to appropriate care, more than half of these children would catch up in growth just as their economically better off peers. Cardiac surgery in underprivileged children can occur in the developing world only by governmental intervention or by philanthropic funding. It would appear that such programmes have a larger impact on the target community by favourably influencing the growth of children.

What is already known on this subject

Somatic growth is frequently impaired in children with congenital heart disease (CHD). Growth has been shown to improve in such children once CHD is corrected.

What this study adds

When children bear the dual burden of CHD and poverty, correcting CHD without specific nutritional intervention has a satisfactory effect on the anthropometric indices of growth in a significant proportion of patients.

Limitations

This was not a randomised control study. In this study, patients were all from the southern Indian state of Kerala which has the best human development index in the country. Hence, the study may be biased towards the better off among the underprivileged children. Other contributors to the nutritional status like dietary intake and the effect of pubertal growth spurt have not been assessed separately.

Competing interests None.

Ethics approval Institutional Ethics Committee.

Contributors PAK has written the manuscript. RNSK and VRK have conceptualised the paper and reviewed the manuscript. VRK has performed the statistical analysis for the study.

Provenance and peer review Not commissioned; internally peer reviewed.

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