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Author for correspondence:
R. Krishna Kumar, MD, DM, FAHA, Clinical Professor and Head, Pediatric Cardiology, Amrita Institute of Medical Sciences and Research Centre, Cochin 682041, Kerala, India. Tel: +91-4842853570; Fax: +91-484-2852020. E-mail: rkrishnakumar@aims.amrita.edu

Early weight trends after congenital heart surgery and their determinants

Nayan Banerji[1], Abish Sudhakar[1], Rakhi Balachandran[2], Gopalraj Sumangala Sunil[3], Brijesh P. Kotayil[3] and Raman Krishna Kumar[1]

[1]Department of Pediatric Cardiology, Amrita Institute of Medical Sciences and Research Center, Cochin, Kerala, India; [2]Department of Cardiac Anesthesiology, Amrita Institute of Medical Sciences and Research Center, Cochin, Kerala, India and [3]Department of Pediatric Cardiac Surgery, Amrita Institute of Medical Sciences and Research Center, Cochin, Kerala, India

Abstract

Background: Early weight trends after cardiac surgery in infants from low- and middle-income countries where the majority are undernourished have not been defined. We studied the early post-operative weight trends to identify specific factors associated with early weight loss and poor weight gain after discharge following congenital heart surgery in consecutive infants undergoing cardiac surgery at a referral hospital in Southern India. *Methods:* This was a prospective observational study. Weights of the babies were recorded at different time points during the hospital stay and at 1-month post-discharge. A comprehensive database of pre-operative, operative, and post-operative variables was created and entered into a multivariate logistic regression analysis model to identify factors associated with excessive early weight loss after cardiac surgery, and poor weight gain following hospital discharge. *Results:* The study enrolled 192 infants (mean age 110.7 ± 99.9 days; weight z scores -2.5 ± 1.5). There was a small but significant ($p < 0.001$) decline in weight in the hospital following surgery (1.6% decline (interquartile range −5.3 to +1.7)); however, there was substantial growth following discharge (26.7% increase (interquartile range 15.3–41.8)). The variables associated with post-operative weight loss were cumulative nil-per-oral duration and cardiopulmonary bypass time, while weight gain following discharge was only associated with age. *Conclusion:* Weight loss is almost universal early after congenital heart surgery and is associated with complex surgery and cumulative nil-per-oral duration. After discharge, weight gain is almost universal and not associated with any of the perioperative variables.

There is a significant burden of childhood malnutrition in low- and middle-income countries.[1] The co-existence of CHD increases the likelihood and severity of malnutrition, which in turn adds to the prevailing challenges for the management of CHD.[2–4] Studies from high-income countries have shown normalisation of somatic growth if corrective surgery for CHD is performed early in life.[5–10] However, in low- and middle-income countries, due to resource constraints, corrective interventions for CHD are mostly performed late, leading to a vicious cycle of malnutrition, congestive heart failure, and infections.[11]

The catabolic state after cardiac surgery is a significant deterrent in performing early corrective operations for CHD in the presence of undernutrition. This catabolic state is potentially worsened by common co-morbid conditions in low-resource environments that include respiratory infections and sepsis.[12]

While studies from high-income nations have previously shown that early weight loss after cardiac surgery is overcome soon after discharge,[5–10] there are no prospective studies from low and middle-income countries on the early weight gain trends after congenital heart surgery. Factors that determine early nutritional recovery have not been adequately studied in the context of cardiac surgery. Identification of correctable factors for delayed or suboptimal recovery will enable better nutritional recovery after congenital heart surgery.

We sought to prospectively study the early post-operative weight trends in consecutive infants undergoing cardiac surgery. We also sought to identify pre-operative, operative, and post-operative factors that were associated with increased weight loss after surgery and poor weight gain following discharge.

Methods

This was a prospective observational study conducted in a tertiary referral hospital in Southern India. All children <1 year undergoing heart surgery for a period of 1 year from January 2018 to January 2019 were included in the study. The centre receives patients from a population of ~30 million in the state of Kerala and neighbouring regions. A detailed description of the study setting and the manner in which care is organised in the unit has been published previously.[4]

A pilot study was conducted on 18 babies and, based on the results of the mean and standard deviation of the change observed in pilot study, with 20% allowable error and 95% confidence, the sample size was estimated to be 140. The study was approved by the review board of the Institution as well as the Institutional Ethics Committee.

A comprehensive evaluation of determinants of malnutrition was performed at admission, which included demographic, birth-related, socio-economic factors, as well as feeding practices. Socio-economic status was classified using the modified Kuppuswamy scale.[13] All patients underwent an anthropometric evaluation at admission; z scores for weight and length were calculated using World Health Organization reference values. The weight and height of parents were recorded, and mid-parental height was estimated using standard formula.[14] Pre-operative variables included associated genetic abnormalities proven by karyotyping or fluorescence in situ hybridisation, co-morbidities, pre-operative bacterial or fungal sepsis, ventilation, ICU stay, use of prostaglandin infusion, nil-per-oral duration, type of surgery (palliative/corrective), and risk stratification based on pre-operative Risk Adjustment for Congenital Heart Surgery-1 Score.[15] Details of feeding in the post-operative period such as cumulative nil-per-oral duration, time of initiation of feeds, and time to achieve full feeds were recorded. Full feeds were defined as nasogastric feed (standard infant formula or expressed breast milk) as per their total fluid requirement appropriate for post-operative day. Other parameters such as cardiopulmonary bypass time, aortic cross clamp time, re-exploration, delayed sternal closure, duration of mechanical ventilation and continuous positive airway pressure (non-invasive ventilation) administration in the post-operative period, any major cardiac events, evidence of liver, kidney or brain injury, re-intubation or evidence of culture positive bacterial or fungal sepsis were noted.

Recording of weight of the babies was conducted at admission, in post-operative ICU after extubation, after transfer to ward from ICU, at discharge, and after 1 month of discharge (first follow-up) using standardised electronic weighing scales. Percentage change in weight of the babies was calculated between admission and discharge as well as between discharge and first follow-up, respectively. The babies were dichotomised into two groups: those having poor weight gain (percentage change in weight < mean – 1 SD) and those having adequate weight gain (percentage change in weight ≥ mean – 1 SD).

Number and percentages were calculated for categorical variables. Mean and standard deviation were calculated in normally distributed variables, and median with interquartile range was used for variables that were not normally distributed. Chi-square test was applied for comparison of categorical variables. Independent sample t-test or Mann–Whitney U-test was used to compare continuous variables between poor weight gain and adequate weight gain groups. Forward conditional multiple binary logistic regression analysis was used to estimate the odds ratio (95% confidence interval) and prediction model. Statistical analysis was conducted using SPSS Version 20.0 for Windows (IBM Corporation, Armonk, NY, United States of America).

Results

We had 194 infants that underwent cardiac surgery during the study period. Two babies died in hospital after surgery. Of the 192 babies enrolled in our study, eight were then lost to follow-up. Mean age of the babies was 110.7 ± 99.9 days. Mean weight of the babies at admission was 4.2 ± 1.5 kg (z score – 2.5 ± 1.5). Forty-two (22%) babies were low-birthweight infants, and this was not taken into account when calculating z scores. Of the 42 low-birthweight infants, 33 were preterm. Seventy-three (38%) belonged to lower middle socioeconomic class. There was a slight male preponderance (54%); 9.4% of babies had genetic abnormalities; 13% required prostaglandin infusion; 42.7% had a pre-operative ICU stay with 14.6% requiring mechanical ventilation. The majority of the babies were exclusively breast-fed (66.1%), and the incidence of pre-operative sepsis was 5.2%. Most of the surgeries belonged to Risk Adjusted Congenital Heart Surgery-1 category 2 (55.2%) followed by category 4 (21.9%) and category 3 (18.2%), respectively. Palliative surgeries constituted 13% of the total number of cases. Details of the case profile and nature of surgery are included in Table 1. Mean cardiopulmonary bypass time was 127.5 ± 73.8 minutes with aortic cross clamp time being 70.8 ± 44.2 minutes. Delayed sternal closure was required in 6.3% cases. The re-intubation rate was 14.1%, and the incidence of culture-positive sepsis in the post-operative period was 9.8%. The median cumulative nil-per-oral duration was 21 hours during the entire hospital stay (interquartile range 14–40 hours). The median duration of hospital stay was 11 days with an interquartile range of 8–17 days, and the median duration of post-operative ICU stay was 92 hours with an interquartile range of 72–160 hours.

Table 2 shows the list of demographic, pre-operative, intra-operative, and post-operative variables of the infants who underwent cardiac surgery.

There was a slight decline in weight in the post-operative period; however, a significant improvement following discharge (Fig 1) was noted. Both the initial weight loss and the subsequent gain in weight were found to be statistically significant ($p < 0.001$). The median percentage decline in weight early after surgery was 1.6% (interquartile range −5.3 to +1.7), and the median percentage weight gain after surgery was 26.7% (interquartile range 15.3–41.8). A similar trend was apparent in all the surgical risk (Risk Adjusted Congenital Heart Surgery-1) categories (Fig 2).

Table 3 shows the list of factors that were found to be significant on univariable analysis. They included age of the baby, Risk Adjusted Congenital Heart Surgery-1 score, prostaglandin infusion, pre-operative ventilation, pre-operative ICU stay, cardiopulmonary bypass time, cross clamp time, cumulative nil-per-oral duration, time of initiation of feeds, post-operative ventilation duration, and post-operative sepsis; however, cumulative nil-per-oral duration and cardiopulmonary bypass time were found to be the two most important factors associated with post-operative weight loss on multivariate analysis. Age was the only variable associated with weight gain following discharge. The results of multivariate logistic regression analysis of predictors of weight loss in the early post-operative period and the subsequent gain in weight are summarised in Table 4.

Discussion

The incidence of childhood undernutrition is particularly high in the low- and middle-income countries, and the presence of CHD further exaggerates its likelihood and severity. We have previously reported a high prevalence of undernutrition among CHD patients as reflected by z score of weight for age in a large cohort of patients with various CHD undergoing corrective as well as palliative surgeries.[3,4,16]

Table 1. Profile of lesions and types of operations performed in the 192 infants included in the study

Category	Details	Total numbers
Break up of individual lesions		
RACHS I	Patent arterial duct: 2	4
	Coarctation repair > 30 days: 2	
RACHS II	Ventricular septal defect: 66	106
	Tetralogy of Fallot: 19	
	Total anomalous pulmonary venous return > 30 days: 11	
	Glenn (superior cavopulmonary) shunt: 7	
	Coarctation repair < 30 days: 3	
RACHS III	Transposition of great arteries with intact ventricular septum: 19	35
	Pulmonary artery band: 3	
	Pulmonary artery band with cor-triatriatum repair: 1	
	Blalock–Taussig shunt (midline): 2; Central shunt:1	
	Atrioventricular septal defect repair: 3	
	Anomalous origin of left coronary artery from pulmonary artery repair: 3	
	Ventricular septal defect closure with mitral valve repair: 1	
	Other biventricular repair (Rastelli): 2	
RACHS IV	Transposition of great arteries with ventricular septal defect: 16	42
	Total anomalous pulmonary venous return < 30 days: 12	
	Pulmonary artery band with atrial septectomy: 2	
	Glenn (superior cavopulmonary) shunt with atrial septectomy: 4	
	Pulmonary artery band with arch repair: 1	
	Arch repair:1	
	Ventricular septal defect closure with arch repair: 2	
	Repair of common arterial trunk: 2	
	Aortopulmonary window with arch repair: 1	
	Arterial switch operation with ventricular septal defect closure with arch repair: 1	
RACHS VI	Norwood procedure: 2	5
	Superior cavopulmonary (Glenn) shunt with Damus–Kaye–Stansel operation: 3	
Palliative versus corrective operations		
Palliative	Pulmonary artery band: 7	26
	Blalock–Taussig/central shunts: 3	
	Superior cavopulmonary (Glenn) shunt:11 norwood procedure: 2	
	Superior cavopulmonary (Glenn) shunt with Damus–Kaye–Stansel operation: 3	
Corrective	All remaining operations	166
Open versus closed heart operations		
Closed heart	Patent arterial duct: 3, coarctation repair: 5, pulmonary artery band: 3	11
Open heart	All remaining operations	181

RACHS = Risk Adjustment for Congenital Heart Surgery (RACHS-I method)

The baseline demographic profile is fairly typical of what is seen in the low- and middle-income country environment and similar to what has been previously reported by us.[4] A significant proportion of babies needed pre-operative ICU care, mechanical ventilation, and significant prevalence of pre-operative sepsis highlighting the pre-operative burden of undernutrition, heart failure, and infections. Delay in presentation is another potential factor contributing to baseline undernutrition. However, in our group of patients, the delay may have been lesser than typical for most low-resource environments.

Initially, the babies had significant loss of weight in the early post-operative period. The initial weight loss reflects the catabolic

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Table 2. Demographic, pre-operative, intra-operative, and post-operative variables of 192 infants undergoing CHD operations

Variables	Number (%)
Age (days)	110.74 ± 99.87
Gender	Male 54%, Female 46%
Weight (kg)	4.231 ± 1.51 (z score = −2.54 ± 1.5)
Length (cm)	58.12 ± 7.52 (z score = −0.98 ± 1.45)
Birth weight	Normal 77%, LBW 22%, VLBW 1%
Gestational age	Term 83%, preterm 17%
Mid parental height (cm)	163.38 ± 8.641
Socio-economic class	Lower middle 38%, upper lower 26%, upper middle 24.5%, upper 11.5%
Type of feeding	Breast-fed 66.1%, formula 6.8%, mixed 14.6%, weaned 12.5%
Genetic abnormality	18 (9.4)
Associated co-morbidities	12 (6.3)
Pre-operative sepsis	10 (5.2)
Pre-operative ventilation	28 (14.6)
Pre-operative NPO duration (hours)	4 (4–7.75)
Pre-operative ICU stay	82 (42.7)
PGE1 infusion	25 (13)
Type of surgery	Palliative 13%, Corrective 87%
RACHS-1 score	1 = 2.1%, 2 = 55.2%, 3 = 18.2%, 4 = 21.9%, 6 = 2.6%
CPB time (minutes)	127.51 ± 73.76
Cross clamp time (minutes)	70.80 ± 44.19
Delayed sternal closure	12 (6.3)
Post-operative ventilation duration (hours)	26 (19.25–67.25)
Post-operative non-invasive ventilation duration (hours)	22 (21–52)
Post-operative sepsis	19 (9.8)
Reintubation	27 (14.1)
Cardio-pulmonary resuscitation	2 (1.0)
Liver/kidney/brain injury	3 (1.6)
Cumulative NPO duration (hours)	21 (14–40)
Time of initiation of feeds (hours)	9 (7–24.5)
Time to achieve full feeds (hours)	62 (37.5–95)

Mean ± SD is used for normally distributed variables, and median (interquartile range) is used for variables which are not normally distributed.
LBW = Low birth weight; NPO = nil per oral; PGE-1 = prostaglandin E1, RACHS = Risk Adjustment for Congenital Heart Surgery; VLBW = very low birth weight

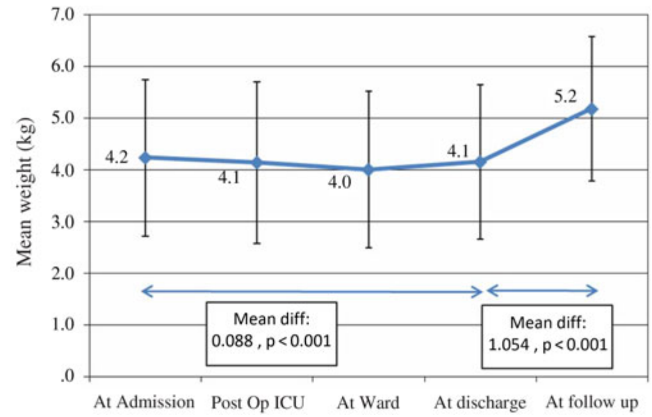

Figure 1. Weight trends recorded at different time points illustrating the average trends for the entire group with standard deviations shown as vertical bars on each of the time points.

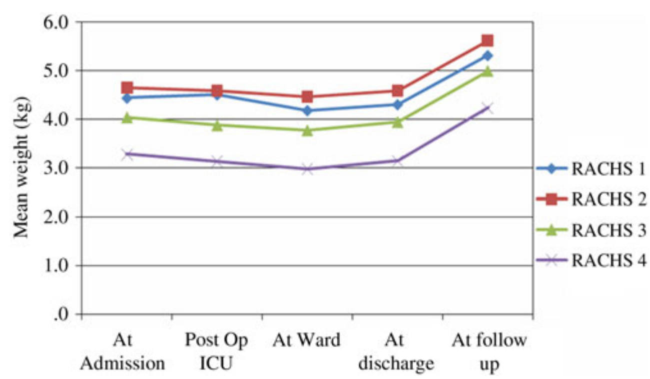

Figure 2. Weight trends recorded at different time points illustrating the average trend for the individual RACHS-1 categories with standard deviations shown as vertical bars on each of the time points. RACHS = Risk Adjustment for Congenital Heart Surgery.

state after surgery as has been reported previously.[17] This catabolic state can potentially lead to muscle wasting, impaired immune function, and wound healing[17] and may be particularly detrimental in the undernourished infant.[12] The use of diuretics in babies with heart failure or fluid resuscitation in cyanotic infants could also have potential impact on the early weight trends.

The weight loss is largely universal and essentially similar across all Risk Adjusted Congenital Heart Surgery-1 categories (Fig 2). It was only associated with nil-per-oral duration in the post-operative period and cardiopulmonary bypass time duration that may reflect the overall complexity of the underlying CHD.

In spite of significant baseline malnutrition and a relatively high prevalence of co-morbid conditions, almost all patients showed weight gain following discharge (Fig 1). While univariable analysis showed several associations, on multivariable analysis, post-operative weight gain was not associated with any variable other than age (Tables 3 and 4). As expected, younger infants will experience greater growth. However, none of the other variables seem to matter once the child leaves the hospital.

We have previously reported that early corrective intervention results in significant improvement in nutritional status on short-term follow-up.[16] We have also previously shown that poor nutritional status, pre-operative pneumonia, and age do not increase mortality rates after ventricular septal defect repair.[3]

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Table 3. Results of univariable analysis on weight trends

Variables	Admission to discharge OR (95%CI), p value	Discharge to first follow-up OR (95%CI), p value	Admission to first follow-up OR (95%CI), p value
Age	0.2 (0.1–0.5), p < 0.001	0.1 (0.03–0.2), p < 0.001	1.6 (0.6–4.1), p = 0.374
NPO duration	11.4 (2.6–50.4), p < 0.001	4.0 (1.6–9.9), p = 0.001	1.0 (0.4–2.3), p = 0.958
Time to initiation of full feeds	6.7 (1.9–23.6), p = 0.001	5.0 (2.0–12.9), p < 0.001	1.4 (0.6–3.4), p = 0.418
RACHS-1 score	4.2 (1.6–11.3), p = 0.002	5.4 (2.3–12.9), p < 0.001	1.1 (0.5–2.5), p = 0.861
Pre-operative ICU stay	3.3 (1.3–8.5), p = 0.010	10.1 (3.7–27.7), p < 0.001	0.6 (0.2–1.4), p = 0.213
PGE 1 infusion	3.9 (1.4–10.9), p = 0.005	4.5 (1.8–11.3), p = 0.001	0.9 (0.2–3.3), p = 1.000
Pre-operative ventilation	3.3 (1.2–9.1), p = 0.015	4.5 (1.8–10.9), p = 0.001	0.8 (0.2–2.8), p = 1.000
CPB time	19.0 (2.5–146.5), p < 0.001	2.3 (1.0–5.2), p = 0.048	2.4 (0.9–6.1), p = 0.072
Cross clamp time	5.3 (1.5–19.2), p = 0.009	3.0 (1.2–7.1), p = 0.013	2.6 (1.0–7.2), p = 0.051
Post-operative ventilation duration	5.4 (1.8–16.7), p = 0.001	2.6 (1.1–5.8), p = 0.020	1.1 (0.5–2.6), p = 0.830
Post-operative sepsis	3.3 (1.1–10.2), p = 0.049	1.3 (0.4–4.2), p = 0.748	3.5 (1.2–10.4), p = 0.016

CI = confidence intervals; CPB = Cardiopulmonary bypass; ICU = Intensive care unit, NPO = Nil per oral; OR = Odds ratio; PGE-1 = Prostaglandin E1; RACHS = Risk Adjustment for Congenital Heart Surgery

Table 4. Results of multivariate analysis of factors associated with weight trends

Risk factors	Odds ratio (95% CI)	p value
Regression result of weight loss (admission to discharge)		
NPO duration > 21 hours	10.2 (1.3–81.4)	0.029
CPB time > 113 minutes	9.3 (1.2–75.1)	0.036
Regression result of weight gain (discharge to follow up)		
Age < 1 month	16.5 (5.8–47.2)	<0.001

CI = confidence interval; CPB = cardiopulmonary bypass; NPO = nil per oral

Additionally, we have also reported that pre-operative blood stream infection, pre-operative intensive care, and mechanical ventilation were strongly associated with adverse outcomes after infant cardiac surgery. However, failure to thrive and low birth weight were not found to adversely affect surgical outcomes.[4]

Cumulative nil-per-oral duration resulting from feeding interruptions in the early post-operative period was the only apparently correctable factor associated with early weight loss after surgery. Interruption of feeds in the post-operative period is fairly common, which is due to multiple factors including haemodynamic instability, poorly planned and failed extubation, non-invasive ventilation, and feed intolerance. The need to minimise feed interruptions in the post-operative period has been emphasised recently.[12] However, it is possible that the reasons that contribute to nil-per-oral duration may be related to other factors that indicate the overall sickness of the child. Our study is not designed to identify these factors.

Limitations

The following limitations in the study methodology must be acknowledged:

- There is variation introduced by the fact that the admission and discharge times are not fixed relative to surgical intervention. While this could influence the interpretation of in hospital weight trends, it is unlikely to influence post-discharge weight trends.
- One of the outcome measures "sepsis" has been defined somewhat narrowly as positive bacterial or fungal culture. We acknowledge that there are potentially other infections that may have occurred in this group which would not have been reported if we had used other markers of probable sepsis.
- About 30% of the operated patients were newborns who could have had weight changes due to being in the newborn period and not related to undernutrition.
- This is a single-centre study. The conclusions will be strengthened if the results are replicated in a multi-centre study in low- and middle-income country settings.
- The follow-up period is short. This was deliberate because we were seeking to understand early weight trends that had not been previously studied. We have previously examined the long-term recovery and identified variables to assess somatic growth after ventricular septal defect repair in severely malnourished infants and found that recovery of somatic growth is suboptimal in infants with severe pre-operative malnutrition.[18]

Conclusions

Weight loss is inevitable early after congenital heart surgery and is associated with complex surgery (cardiopulmonary bypass time duration) and cumulative nil-per-oral duration. After discharge, weight gain is almost universal and not associated with any of the perioperative variables, suggesting thereby that correction of the underlying cardiac defect leads to significant early catch-up growth.

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Financial Support. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national guidelines on human experimentation (Indian Council of Medical Research) and with the Helsinki Declaration of 1975, as revised in 2008, and has been approved by the institutional ethics committee of the Amrita Institute of Medical Sciences and Research Centre.

Conflicts of Interest. None.

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