



# ENTERAL FEEDING AND CALORIC INTAKE IN NEONATES AFTER CARDIAC SURGERY

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**Background** Adequate enteral nutrition may be difficult to achieve early in neonates after cardiac surgery, but it is essential for growth, wound healing, and immune function.

**Objective** To assess caloric intake in neonates receiving enteral nutrition after surgery.

**Methods** A retrospective chart review was conducted of daily enteral caloric intake in the cardiac intensive care unit of a tertiary children's hospital. Data on the institution of enteral feeding and the discontinuation of parenteral nutrition were assessed for full-term neonates who had undergone cardiac surgery.

**Results** Caloric intake was assessed in 100 patients, 52 with biventricular cardiac defects and 48 with a functional single ventricle. The median duration of stay in the cardiac intensive care unit was 13 days (range, 4-69), and patients received enteral feeding exclusively for a median of 5 days (range, 1-43). In total, 705 patient days were evaluated. The median caloric intake per day was 93 kcal/kg (range, 43-142). A goal of 100 kcal/kg was achieved for 48.4% of patient days and 120 kcal/kg for only 19.7% of patient days. Median weight change for the period of enteral feeding was -20 g (range, -775 to 1485 g).

**Conclusions** Enteral feeding alone is often suboptimal after neonatal cardiac surgery. New strategies to improve caloric intake may enhance postoperative recovery. (*American Journal of Critical Care*. 2008;18:52-57)

**G**rowth failure and malnutrition are common in neonates with congenital heart disease.<sup>1</sup> Adequate nutrition is essential for growth, wound healing, and immune function.<sup>2</sup> The etiology of growth failure in these patients is multifactorial and most likely includes a hypermetabolic state, inadequate caloric intake, malabsorption, genetic factors, or a consequence of fluid restriction as part of hemodynamic intervention. Inadequate caloric intake is probably a major contributor to growth failure in neonates who require cardiac surgery. Although standards exist for caloric intake in healthy neonates, such standards are lacking for neonates with congenital heart disease. Congenital heart disease causes an increase in cardiac and respiratory effort, particularly immediately after cardiac surgery. Strategies used to optimize nutrition include early use of perioperative parenteral nutrition, use of high-calorie enteral nutrition, and use of nasogastric/gastrostomy feedings.<sup>3</sup> The purpose of this study was to assess caloric intake in neonates shortly after cardiac surgery while they were receiving enteral nutrition exclusively.

At The Children's Hospital of Philadelphia, we have a multidisciplinary approach to the care of infants in the cardiac intensive care unit (CICU). A registered dietician dedicated to the CICU evaluates infants on a daily basis and makes recommendations to the CICU team about both parenteral and enteral nutrition. Infants with duct-dependent lesions who are being treated with prostaglandins and infants with umbilical arterial catheters are not fed; hence, most infants are not fed in the preoperative period. The usual feeding protocol involves starting total parenteral nutrition on the second postoperative day for most infants. Most neonates have umbilical arterial catheters, which are typically removed within 12 to 24 hours of extubation in patients with stable hemodynamic status. Enteral feeding is started after the umbilical arterial catheters

are removed. The usual practice in single-ventricle patients is to begin continuous nasogastric feeding with 20 kcal per ounce (30 mL) of formula (breast milk or other standard formula based on cow's milk). Because of the risk of necrotizing enterocolitis in patients with an aortopulmonary shunt, feedings are usually increased slowly during a 48- to 72-hour period to a volume of 100 to 120 mL/kg per day. The caloric density of the formula is increased once the target volume is reached. Bolus nasogastric feeding along with oral feeding is subsequently attempted. The target for these patients is a total volume of 120 to 150 mL/kg per day of formula that contains 24 or 27 kcal per 30 mL. The protocol is generally less rigid in the 2-ventricle patients, in whom early oral feeding is attempted with nasogastric supplementation as needed. In all these infants, parenteral nutrition is typically discontinued once a goal fluid volume of 100 mL/kg per day is achieved.

Caloric standards for neonates with congenital heart disease are lacking.

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#### Materials and Methods

A retrospective review of 100 charts was conducted. All full-term neonates (gestational age  $\geq$  36 weeks) admitted to the CICU between November 2003 and August 2004 who required surgery with cardiopulmonary bypass were included in the study. Neonates who underwent surgery without cardiopulmonary bypass and those with less than 2 days of countable enteral feeding before discharge or transfer from the CICU were excluded. The study was approved by the institutional review board of the hospital. Documents reviewed included anesthesia records, birth records, daily CICU flow sheets, and intraoperative records. Each patient's daily CICU flow sheet was reviewed for total calories per day,

weight, presence or absence of feeding, method of feeding (oral vs nasogastric or gastrostomy tube feeding), duration of feeding, frequency of stools and emesis, and reasons for discontinuation of feedings.

For the purpose of this study, caloric intake was assessed after enteral feeding was started and parenteral nutrition was discontinued while patients were in the CICU. Therefore, data were not included in total caloric intake if a patient was also given parenteral nutrition. Similarly, for this study, data collection was stopped once patients were transferred from the CICU to the cardiac step-down unit.

Nonparametric measures of central tendency, variability, and association were computed for all relevant variables in the data set, with a particular emphasis on daily caloric intake (in kilocalories per kilogram) and proportion of children meeting or exceeding 100 kcal/kg and/or 120 kcal/kg while in the CICU. Although the study was primarily descriptive, inferential tests were conducted to compare the feeding-related characteristics of children who had single-ventricle reconstruction with children who had biventricular repair. Wilcoxon rank-sum tests were used for these comparisons because of the small and nonnormative distributions. Data were analyzed by using SPSS version 12 (SPSS Inc, Chicago, Illinois) and STATA version 9 statistical software (STATA Corp, College Station, Texas).

## Results

A consecutive sample of 100 neonates (58 boys and 42 girls) met eligibility criteria. Median age at the time of surgery was 4 days (range, 1-70). Table 1 provides a summary of diagnosis and surgical procedures.

Biventricular repair was performed in 52 patients (52%) and single-ventricle reconstruction in 48 (48%). Of the 48 single-ventricle patients, 31 (65%) had hypoplastic left heart syndrome or one of its variants. The median length of stay in the CICU was 13 days (range, 4-69). Enteral feeding was started on median postoperative day 3 (range, day 2 to day 30). During the CICU stay, enteral feeding alone was provided for a median of 5 days (range, 1-43). Across all patients, a total of 705 days of enteral feeding were assessed. Patients had oral feedings exclusively on 133 of the 705 days (18.9%), nasogastric feedings exclusively on 286 days (40.6%), and a combination of both oral and nasogastric feedings on 265 days (37.6%). During the 705-day study period, enteral feedings were provided via a gastrostomy tube on 21 days (3%). Median daily caloric intake in the CICU was 93 kcal/kg (range, 43-142). A caloric intake of 100 kcal/kg was achieved on 341 feeding days (48.4%), and 120 kcal/kg was achieved

**Table 1**  
Diagnosis and surgical procedures

Diagnosis	Operation	No. of patients
<b>Single-ventricle repairs</b>		
Hypoplastic left heart syndrome or variants	Norwood procedure	31
Other single-ventricle, arch hypoplasia	Norwood procedure	9
Pulmonary atresia with intact ventricular septum	Aortopulmonary shunt	2
Other single ventricle, pulmonary atresia	Aortopulmonary shunt	6
<b>Biventricular repairs</b>		
Transposition of great arteries	Arterial switch operation	14
Transposition of great arteries, ventricular septal defect	Arterial switch operation, closure of defect	6
Interrupted aortic arch, ventricular septal defect	Closure of defect, arch repair	6
Coarctation, ventricular septal defect	Closure of defect, arch repair	4
Tetralogy of Fallot	Complete repair	5
Total anomalous pulmonary venous return	Complete repair	4
Ventricular septal defect	Closure of defect	3
Atrioventricular canal defect	Closure of defect	1
Tetralogy of Fallot, atrioventricular canal defect	Complete repair	1
Aortopulmonary window	Complete repair	2
Others	Complete repair	6

in 139 feeding days (19.7%). The median weight change in the CICU was -20 g (range, -775 to 1485).

In 705 feeding days, enteral feedings were temporarily discontinued on 149 days (21.1%). Feedings were most often discontinued (45 of the 149 days, 30.2%) in preparation for cardiac or noncardiac procedures such as cardiac catheterization, magnetic resonance imaging of the head, and placement of a gastrostomy tube. Other reasons for interrupting feedings included deterioration in the clinical status of the patient (33 days); planned extubation (11 days); placement of chest tubes or central venous catheters (18 days); various gastrointestinal issues such as emesis, abdominal distention, or presence of grossly bloody stools or stools positive for occult blood (11 days); or other factors such as arrhythmias, barium study, sedated echocardiogram, irritability, and unknown causes

**Feedings were discontinued in preparation for cardiac or noncardiac procedures.**

**Table 2**  
Comparison of patients with single-ventricle and biventricular repairs

Variable	Single-ventricle repairs		Biventricular repairs		P
	Median	Range (IQR)	Median	Range (IQR)	
Weight on day of surgery, kg	3.2	1.7-4.5 (0.7)	3.2	2.0-4.3 (0.8)	.60
Weight on day of discharge, kg	3.2	1.8-4.2 (0.6)	3.2	2.0-4.8 (0.7)	.78
Enteral caloric intake, kcal/kg	95.4	63.8-142.5 (21.8)	92.4	43.0-125.8 (28.4)	.23
Weight change, g	-20.0	-490.0 to 630.0 (363.0)	-25.0	-775.0 to 1485.0 (405.8)	.82
Length of stay in cardiac intensive care unit, d	14.5	7.0-69.0 (19.0)	10.5	4.0-60.0 (10.0)	.006
No. of days from surgery to first enteral feeding day	4.0	1.0-30.0 (4.0)	3.0	1.0-17.0 (4.0)	.05
No. of days of enteral feeding during stay in unit	6.5	1.0-43.0 (9.0)	3.5	1.0-38.0 (4.0)	<.001
Percentage of days >100 kcal/kg	47	0-100 (55)	41	0-100 (65)	.14
Percentage of days >120 kcal/kg	14	0-100 (28)	0	0-75 (16)	.007

Abbreviation: IQR, interquartile range.

Single-ventricle reconstruction patients had more enteral feeding days than did biventricular repair patients.

(31 days). Patients with a single-ventricle abnormality and patients with biventricular defects did not differ significantly with respect to the number of days feedings were off ( $P = .22$ ).

Neither caloric intake nor weight differed significantly between patients with single-ventricle defects and patients with biventricular defects. The length of stay was longer for patients with single-ventricle repairs than it was for patients with biventricular repairs ( $P = .006$ ; Table 2). Similarly, patients with single-ventricle repairs had a greater number of enteral feeding days than did patients with biventricular repairs ( $P < .001$ ). Percentage of feeding days was also evaluated because of the correlated nature of length of stay and number of feeding days. The percentage of days that patients received more than 100 kcal/kg per day did not differ

significantly between patients with single-ventricle repairs and patients with biventricular repairs ( $P = .14$ ). However, patients with single-ventricle repairs received more than 120 kcal/kg per day more often than did patients with biventricular repairs ( $P = .007$ ).

## Discussion

Malnutrition and failure to thrive have long been recognized as common systemic consequences of congenital heart disease. Infants with cyanotic congenital heart defects and complex single-ventricle lesions are particularly susceptible to acute and chronic malnutrition.<sup>4,6</sup> The recommended daily allowance for infants with complex cardiac defects requiring neonatal surgery is not well defined. However, children with less complex heart defects such as a ventricular septal defect may need as much as

50% more calories than healthy children in order to achieve normal growth.<sup>1</sup> Strategies to optimize caloric intake and promote weight gain include use of total parenteral nutrition in the early postoperative period, institution of nasogastric feeding, and use of high-calorie enteral feeding. Few investigators have evaluated caloric intake in neonates after cardiac surgery for complex congenital heart defects. We analyzed 705 days of enteral feeding in 100 neonates undergoing cardiac surgery with cardiopulmonary bypass. The median daily caloric intake was 93 kcal/kg (range, 43-142), and the median weight change was -20 g (range, -770 to 1485).

Our findings of inadequate nutrition are similar to those reported by Kelleher et al<sup>7</sup> from the Boston Children's Hospital. In 50 infants with hypoplastic left heart syndrome who underwent Norwood stage I reconstruction, median weight at discharge was unchanged from admission weight. Children with longer hospital stays, longer stays in the intensive care unit, shorter duration of parenteral nutrition, and higher diuretic dosage at discharge had a lower weight-for-age Z score at discharge. Cameron et al<sup>4</sup> reported a high incidence of malnutrition and growth failure in children with cardiac defects that were less complex than the defects in our study population. In their study,<sup>4</sup> the nutritional status of 160 patients admitted to the pediatric cardiology and thoracic surgery services at C. S. Mott Children's Hospital in Ann Arbor, Michigan, was evaluated. Acute malnutrition was determined by calculating a ratio of the patient's weight to the mean weight for the patient's height. Acute malnutrition was found in 11% of patients with left-sided obstructive lesions. The prevalence of acute malnutrition was highest in infants: 79% of infants (30/38) vs 30% of older children (34/112).

The etiology of malnutrition and growth failure in patients with congenital heart disease is multifactorial but basically is related to an imbalance between supply (caloric intake) and demand (energy expenditure). Energy expenditure may be increased in these patients because of tachypnea and tachycardia associated with congestive heart failure.

This increase in energy expenditure may be exaggerated in neonates and infants with single-ventricle physiology. Patients with an aortopulmonary shunt either alone or as part of the Norwood operation have an inherently inefficient circulation. These infants have a volume-loaded single ventricle that supplies both systemic and pulmonary blood flow. In addition, the inflammatory cascade activated by cardiopulmonary bypass may further increase energy expenditure in the immediate postoperative period. In critically ill children, energy requirements can increase by approximately 30% for mild to moderate stress, 50% in severe stress, and 100% in major burns.<sup>2</sup> Neonates undergoing cardiac surgery with cardiopulmonary bypass are at least moderately if not severely stressed. When metabolic demands are increased, these infants often have decreased caloric intake. Feeding difficulty in such infants may be due to congestive heart failure, vocal cord paresis, uncoordinated sucking and swallowing, or feeding aversion. In addition, digestion and absorption in the gastrointestinal tract can be impaired by gut edema. Patients with single-ventricle repairs and an aortopulmonary shunt may have relative splanchnic ischemia due to diastolic runoff from the shunt and are at increased risk for necrotizing colitis.<sup>8,9</sup> It is therefore not surprising that our cohort of infants with complex defects requiring neonatal surgery had difficulty gaining weight in the immediate postoperative period.

Because of the higher risk of infection with central catheters and parenteral nutrition, we usually discontinue total parenteral nutrition as soon as a volume of 100 mL/kg of enteral feeding is achieved. However, for all the reasons described in the "Results" section, feedings are often temporarily discontinued or reduced in these fragile patients, especially when enteral feeding is first started. Perhaps use of intravenous intralipids in addition to enteral feedings should be continued until patients are consistently receiving at least 100 kcal/kg per day. Intravenous intralipids can be safely administered in the absence of central intravenous access.

Another strategy to optimize caloric intake may be early placement of gastrostomy feeding tubes, especially in infants who are more or less exclusively fed via a nasogastric tube. Many of these infants have

feeding difficulties and potentially use a high number of calories in attempting to feed; this problem can be overcome by administering feedings via a nasogastric or gastrostomy tube.

Our study had all the limitations of a retrospective chart review. Neonates with suspected or known genetic disorders were not excluded; these infants are known to have a higher incidence of feeding intolerance and growth failure. We limited our data collection to the CICU. In general, most patients with single-ventricle repair are discharged from the CICU; however, our patients with biventricular repairs are more likely to be transferred to the step-down unit. So our data on the patients with biventricular repairs may not be truly representative of these patients. Another limitation is the use of weight to assess nutrition; although body weight is an easily measurable marker of nutritional status, weight change may reflect a change in fluid status, especially in the immediate postoperative period.

Many of these infants use significant calories attempting to feed.

## Conclusion

In this study of 100 neonates with complex heart defects, the median caloric intake with the exclusive use of enteral nutrition was 93 kcal/kg (range, 43-142). The results indicated that enteral feeding can be challenging and is often suboptimal immediately after cardiac surgery for complex congenital heart disease. Further studies are needed to better understand feeding difficulties in neonates with congenital heart disease. In an ongoing study at The Children's Hospital of Philadelphia, researchers are evaluating feeding behavior, caloric intake, and measures rather than estimates of energy expenditure in infants after cardiac surgery. We anticipate that this study may result in a better understanding of the caloric needs of neonates after cardiac surgery.

Enteral feeding is challenging and suboptimal in the immediate postoperative period.

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## FINANCIAL DISCLOSURES

None reported.

## eLetters

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