UNIVERSITE DE NANTES

FACULTE DE MEDECINE

Année : 2019 N° 2019-213

T H E S E

pour le

DIPLOME D'ETAT DE DOCTEUR EN MEDECINE

DES de Pédiatrie

par

Sandie JORE

Née le 12 janvier 1992 à Angers (49)

Présentée et soutenue publiquement le 23 octobre 2019

« Réalimentation du nourrisson de moins de 1 an après chirurgie cardiaque sous circulation extracorporelle : étude rétrospective au CHU de Nantes »

Président du jury : Monsieur le Professeur Cyril FLAMANT

Directeur de thèse : Monsieur le Docteur Hugues PILOQUET

REMERCIEMENTS

A Monsieur le Pr Cyril Flamant, pour avoir accepté de présider mon jury de thèse et pour ton accompagnement bienveillant pendant mon internat ;

A Monsieur le Dr Hugues Piloquet, pour la direction de ce travail de thèse et votre enseignement de gastropédiatrie toujours dans la bonne humeur ;

A Monsieur le Pr Jean Christophe Rozé, pour votre enseignement en méthodologie de la recherche et statistiques et pour votre aide dans mes travaux universitaires ;

A Madame la Pr Elise Launay, pour ta participation à mon jury de thèse, pour ton enseignement de la pédiatrie, de l'infectiologie et ta bienveillance ;

A Madame la Dr Bénédicte Le Roux, pour ta participation à mon jury de thèse et pour ton aide précieuse dans ce travail ;

A Monsieur le Dr Alban Baruteau, pour ta disponibilité pour les relectures de mes travaux de recherche et ta participation à mon jury de thèse ;

A Madame la Dr Dominique Caldari, merci pour le partage de tes connaissances de la gastropédiatrie et le temps que tu prends pour répondre à toutes mes questions ;

A mes parents, pour votre soutien dans tous mes projets personnels, de sport et d'étude, pour vos encouragements sans lesquels je ne serais jamais devenue médecin et pour votre présence en toutes circonstances. Merci de m'avoir toujours poussée à donner le meilleur ;

A Jérémy et Laurine, mes frangin(e)s, merci d'avoir supporté mon stress pendant toutes ces années d'études ;

A mes amis, cette bande de fous, tous (aussi) à l'Ouest les uns que les autres, Lise, Claire, Joa, Clarisse, Céline, Sam, Romain, Carole, sans qui mes années médecine n'auraient pas été ce qu'elles furent, merci pour tous ces bons moments passés ensemble et pour tous ceux à venir, merci pour cette amitié inestimable ;

A mes co-internes, Alice, Sarah, Joss, Pauline et tous les autres, pour votre soutien, votre bonne humeur et ces nouvelles amitiés, à ces belles rencontres sans qui ces années d'internat n'auraient pas été aussi belles ;

A mes deux compères de DU, Lydie et Ophélia, pour nos sympathiques soirées dans ces semaines de parenthèse, nos choix de film (souvent) ratés et nos petits restos ;

A tous les médecins, internes, infirmier(ère)s et auxiliaires que j'ai pu rencontrer pendant toutes ces années ;

Et à toi, mon Adrien, pour ton soutien au quotidien, ton amour et ta réassurance à chacun de mes coups de stress, pour la force d'avancer que tu me donnes à chaque fois que je doute, pour le bonheur que tu m'apportes et pour tous nos projets à venir.

TABLE DES MATIERES

INTRODUCTION

Les malformations cardiaques sont les anomalies congénitales les plus fréquentes (environ 1% des naissances vivantes) (1). Depuis plusieurs années, l'amélioration de la prise en charge des cardiopathies congénitales, et notamment des techniques chirurgicales, a permis une amélioration de la survie de ces patients. Les enfants porteurs de cardiopathie congénitale sont ainsi de plus en plus nombreux et une proportion significative d'entre eux nécessite une prise en charge chirurgicale dans la première année de vie.

Ces enfants sont à risque de dénutrition protéino-énergétique en particulier les enfants symptomatiques (2–4), qui sont également les patients nécessitant une prise en charge chirurgicale. Il a été montré que cette dénutrition est plus fréquente chez les nourrissons que chez les enfants plus grands (3). L'insuffisance cardiaque déséquilibre la balance énergétique : d'une part, en augmentant la dépense énergétique par augmentation de la consommation en oxygène du myocarde hypertrophié, et par majoration du travail respiratoire (5) ; d'autre part, en diminuant les apports caloriques souvent rendus difficiles du fait de la dyspnée, d'une satiété plus précoce, d'une hépatomégalie pouvant majorer un reflux gastro-œsophagien ou diminuer le volume gastrique et d'un œdème et d'une hypoxie chronique intestinale pouvant entrainer une malabsorption (6,7). Dans certains cas, la cardiopathie s'associe à une anomalie génétique ou à un syndrome poly-malformatif qui peuvent également favoriser la dénutrition.

La dénutrition peut avoir de sérieuses conséquences. Elle peut être à l'origine d'un retard de croissance, d'un retard de développement psychomoteur (8), de complications post-opératoires plus fréquentes (9) et d'une durée prolongée d'hospitalisation.

La période post-opératoire est marquée par un catabolisme important dû à la chirurgie et à l'inflammation secondaire à la circulation extracorporelle. Après une chirurgie cardiaque, un apport calorique optimal est nécessaire pour favoriser la cicatrisation (10,11) et éviter une détérioration de la croissance et de l'état nutritionnel. En effet, la dénutrition est fréquente chez les enfants hospitalisés et notamment dans les unités de réanimations pédiatriques (12) : même chez des enfants sans dénutrition préalable, un tiers d'entre eux développent une dénutrition aigüe dans les 48 premières heures d'hospitalisation en réanimation (13,14). De plus, certains auteurs rapportent une association inverse entre des apports caloriques entéraux optimaux et d'une part la mortalité à 60 jours, et d'autre part la prévalence des infections nosocomiales chez des enfants graves (15).

L'autonomie alimentaire influence la durée d'hospitalisation. En effet, Nydegger et Bines ont montré que la durée de séjour en réanimation était corrélée au délai d'initiation de l'alimentation entérale, puis au délai d'obtention d'une alimentation entérale puis orale complète (16). Ainsi, une attention particulière à la prise en charge nutritionnelle après chirurgie cardiaque chez le nourrisson est nécessaire pour améliorer les soins post-opératoires et éviter une malnutrition aigüe ainsi que ses complications, qui accroissent la mortalité et la morbidité.

Plusieurs études ont démontré l'efficacité et la sécurité de protocole de réalimentation post-opératoires (17,18). Cependant, on note dans la littérature une grande variabilité des pratiques parmi les différents centres chirurgicaux et il n'existe pas de consensus concernant la prise en charge nutritionnelle optimale des enfants après chirurgie cardiaque (19). Une meilleure connaissance des facteurs influençant la reprise alimentaire pourrait permettre aux cliniciens d'ajuster à chaque situation la prescription d'alimentation entérale pour favoriser une reprise rapide de l'autonomie alimentaire tout en assurant des apports caloriques optimaux.

A ce jour, quelques études se sont intéressées à l'alimentation chez les enfants porteurs de cardiopathie congénitale opérés en période néonatale, mais les données concernant l'alimentation post-opératoire des nourrissons opérés en dehors de la période néonatale sont peu nombreuses. Or, ces enfants peuvent déjà présenter un retentissement préopératoire nutritionnel et alimentaire de leur cardiopathie, et représentent un nombre de patients non négligeable.

L'objectif de notre étude était d'évaluer les apports caloriques post-opératoires entéraux et oraux des nourrissons après chirurgie cardiaque sous circulation extracorporelle au centre hospitalier universitaire de Nantes, et de rechercher les facteurs pouvant influencer la vitesse de reprise d'une alimentation par voie orale.

Predictive factors of feeding difficulties after congenital heart surgery in infants

Authors: Sandie Jore[1], Dr Alban Baruteau[1], Dr Bénédicte Le Roux[2], Dr Dominique Caldari[1], Pr Jean-Christophe Rozé[3], Dr Hugues Piloquet[1]

[1]Service des maladies chroniques de l'enfant, CHU Nantes, Nantes, France

[2]Service de réanimation pédiatrique, CHU Nantes, Nantes, France

[3]Service de réanimation néonatale, CHU Nantes, Nantes, France

Abstract

Objectives: The aim of this study was to evaluate enteral and oral caloric intakes after surgery for congenital heart disease in infants, and to identify risk factors for oral feeding difficulties.

Method: We conducted a monocenter, retrospective study to examine the determinants of oral feeding difficulties 10 days after surgery for a congenital heart disease. We included all infants aged from 29 to 365 days undergoing cardiopulmonary bypass surgery between June 2018 and May 2019 at Nantes University Hospital. Preoperative, operative and postoperative data were reviewed to identify risk factors for feeding difficulties. Feeding difficulties were defined as (a) included infants with a nasogastric feeding tube at discharge or (b) infants that were part of the lowest tercile of oral caloric intake.

Results: 60 patients were included. At day 10, mean oral caloric intake was 62% (±34.7) of the estimated caloric needs. 13 (21.7%) patients were discharged from the hospital with a nasogastric feeding tube. Patients with feeding difficulties had longer CPB (146.3±73 vs 104.6±36 minutes, $p=0.004$), longer mechanical ventilation (3.0±3.4 vs 0.6±1.1 days, $p<0.001$), longer non-invasive ventilation (5.9±4.8 vs 2.7±2.4 days, $p=0.001$), and longer inotropic support (3.8±1.7 vs 2.6±1.4 days, $p=0.007$). They were more likely to have an associated extracardiac congenital abnormality ($p=0.049$) and preoperative enteral feeding on a nasogastric tube ($p<0.001$). There was no difference for gestational age, age at surgery and preoperative nutritional status.

Conclusion: Feeding difficulties were associated with CPB length, mechanical ventilation length and associated congenital abnormality.

Abbreviations

BMI: body mass index

CHD: congenital heart disease

CPB: cardiopulmonary bypass

LOS: length of stay

ICU: intensive care unit

Introduction

Congenital heart diseases (CHD) are the most common congenital abnormalities (about 1% of live births) (1). For several years, the improvement of CHD cares and particularly surgical techniques have led to an improved survival rate. Thus, children with CHD represent a growing population. A significant portion of infants with CHD requires surgery during the first year of life.

Infants with CHD are at risk of malnutrition, in particularly symptomatic infants (2–4) who represent the population requiring surgery. Malnutrition is mainly due to an energy imbalance. On the one hand, infants with CHD have an increased resting energy expenditure due to: increased oxygen consumption by hypertrophic myocardium, increased activity of sympathetic nervous system, increased respiratory work. On the other hand, these children have a decreased energy intake because of: feeding difficulties secondary to dyspnea, early satiety, hepatomegaly which may lead to a decreased gastric volume and an increased gastroesophageal reflux, malabsorption secondary to edema and chronic gut hypoxia (5,6). Chromosomal disorders may also participate in malnutrition development. Malnutrition has serious consequences such as growth failure, impaired psychomotor development (7), poor postoperative outcomes after surgery for CHD (8) and prolonged hospital length of stay (LOS).

The postoperative course is an important catabolic period because of surgery and inflammation secondary to cardiopulmonary bypass (CPB). Therefore, after cardiac surgery, optimal energy intakes are necessary to equilibrate the energy balance to help healing (9,10) and to avoid faltering growth or nutritional status deterioration. In fact, nutritional deterioration is frequent in pediatric intensive care unit (ICU) (11), and even in well-nourished children, a third of patients developing acute malnutrition in the first 48 hours of the hospitalization (12,13). Mehta et al. have also shown that adequate enteral energy intake was inversely associated with 60 days mortality and with the prevalence of acquired infections in critically ill children (14).

The feeding autonomy influences the hospital LOS. Nydegger and Bines have shown that ICU LOS was associated with the delay in initiating enteral feeding, to obtain full enteral then full oral feeding (15). So, the attention to nutritional practices after cardiac surgery in infants is really substantial to improve perioperative cares and to avoid acute malnutrition and its complications, which increase morbidity and mortality.

Optimizing perioperative nutrition may improve overall outcomes after cardiac surgery. Several studies have demonstrated the efficacy and safety of perioperative feeding protocols (16,17). However, literature shows an important variability in postoperative nutritional cares between surgical centers and there is no consensus regarding optimal feeding management in infants after cardiac surgery (18).

Besides, many studies were interested in nutrition after cardiac surgery in neonates but data concerning infants are limited while these patients may already have nutritional consequences of their CHD.

The aim of our study was to evaluate oral and enteral caloric intakes in infants after cardiac surgery with cardio-pulmonary bypass (CPB) and to assess the determinants of oral caloric intakes.

Method

Study design.

We conducted a retrospective, observational, monocenter cohort study at Nantes University Hospital, France. The records of infants under one year old undergoing surgery with CPB for CHD between June 2018 and May 2019 in our institution were reviewed.

Data were collected through the review of electronic medical records and nurses' daily flow sheets. The local institutional review board approved the study.

Population.

All infants aged from 29 days to one year of age at the time of cardiac surgery were included in the study. When patients underwent several surgeries during the study period, we only examined the hospitalization for the first surgery with CPB.

Infants were excluded from the analysis in case of an early postoperative death, if surgery was performed without CPB, or because of age (neonates < 28 days at time of surgery, and infants older than a year old). We also excluded infants who do not live in France and who came for cardiac surgery thanks to associations or sponsoring. In fact, most of these patients come from developing countries. We thought that they represent a different population because of potential more severe malnutrition prior to surgery and different social and cultural situations. For example, these infants are separated from their parents during postoperative care, which may influence feeding behavior.

Outcomes.

Parenteral, enteral and oral caloric intakes were evaluated from nurses' flow sheets on a daily basis until hospital discharge. These caloric intakes were compared to recommended caloric intakes based on French nutritional consensus guidelines, which represents 92 kcal/kg/day during the first year of life (19). When patients were discharged from the hospital before the 10^{th} postoperative day, the highest daily oral and enteral caloric intake known during hospitalization was used to estimate daily caloric intake until day 10 after surgery. For breastfed infants, we considered that they had a successful oral feeding when the nasogastric feeding tube stopped being used to complete oral intakes.

For the determinants of postoperative caloric intakes analysis, the following variables were obtained: diagnosis and characteristics of CHD (cyanosis, pulmonary hypertension), birth term, associated anatomic or chromosomal abnormalities, nutritional status (weight, size, BMI z-scores), age at the time of surgery, feeding behavior (use of a nasogastric feeding tube prior to surgery, breastfeeding or bottle-feeding). Then we recorded the following post-operative data: CPB duration, mechanical ventilation duration, non-invasive ventilation (high flow nasal cannula) duration, inotropic support duration, chest tube removal delay after surgery, complications (infection defined by the prescription of a curative antibiotic therapy, cardiac rhythm disorder, chylothorax, recurrent laryngeal nerve palsy, diaphragmatic palsy), duration of nasogastric feeding tube use, ICU and hospital LOS.

Statistical analysis.

First, we calculated oral and enteral caloric intakes each day after surgery. Then, to assess determinants of oral caloric intakes, we compared infants with successful oral feeding at day 10 and those with persistent oral feeding difficulties. We included in the persistent oral feeding difficulties group, patients who still had a nasogastric feeding tube at day 10 after surgery and patients of the tercile with the lowest oral caloric intakes at day 10. Inversely, the group with successful oral feeding included the two terciles with the highest oral caloric intakes at day 10 after surgery. For the analysis, we included breastfed infants in the group of successful oral feeding.

Data are expressed as mean (standard deviation) or number (percent). Means of continuous variables were analyzed with Anova. Proportions for qualitative variables were compared with the χ^2 test or the Fisher exact test. To assess determinants of oral feeding we performed a multivariate analysis with logistic regression. The statistical significance was determined prior with a p value lower than 0.05. Statistical analysis was performed with the SPSS (Statistical Package for the Social Sciences) software.

Results

Between May 2018 and June 2019, 116 infants aged less than one year old have been hospitalized at the university hospital of Nantes for a cardiac surgery. 56 infants were excluded from our analysis: 32 were neonates, 13 had surgery without CPB, 7 were non-France resident infants and 4 died during the first days after surgery, leaving 60 patients in the final analysis.

Preoperative characteristics.

Of the 60 included patients, 33 (55%) were boys. 5 (8.3%) infants were born preterm. 9 (15%) patients had chromosomal abnormalities or associated extracardiac congenital abnormality: 6 (10%) Down's syndrome, 2 (3.3%) 22q11 microdeletion, 1 (1.7%) 1p31 microdeletion, 3 (5%) heterotaxy and 1 (1.7%) VACTERL association.

The mean age at surgery was 132 ± 69 days. Diagnoses are summarized in table 1. 10 (16.7%) infants presented cyanosis before surgery and 23 (38.3%) had signs of pulmonary hypertension on cardiac ultrasound.

7 (11.7%) patients were totally or partially breastfed. 13 (21.7%) patients had enteral nutrition with a nasogastric feeding tube before surgery and 5 of them had associated anatomic or chromosomal abnormalities. Prior to surgery, 20 (33%) patients had a weight z-score lower than -2 and 19 (32%) had a body mass index z-score lower than -2. 9 (15%) and 18 (30%) patients had a weight/weight for length ratio lower than 80% and between 80 and 90%, respectively. No patient had a weight/weight for length ratio lower than 70%.

Caloric intakes after surgery.

Figure 1 shows the evolution of daily digestive (the amount of enteral and oral intakes) and oral caloric intakes with time after surgery. During hospitalization, mean maximal enteral caloric intake achieved was 90.2% (±27.76) of the estimated caloric needs, and mean maximal oral caloric intake achieved was 72.7% (±35.34) of the estimated caloric needs. At day 10, mean oral caloric intake was 62% (±34.7) of the estimated caloric needs.

7 (11.7%) infants were breastfed after surgery. Only one of them still had a nasogastric feeding tube used to complete oral intakes 10 days after surgery.

13 (21.7%) patients were discharged from the hospital or transferred to a local hospital center with a nasogastric feeding tube. 9 of them had an enteral nutrition prior to surgery.

Determinants of caloric intakes.

Figure 2 shows the oral caloric intakes of the 3 separate terciles of the population 10 days after surgery. There was a statistically significant difference between groups in associated congenital abnormality, preoperative enteral feeding on nasogastric feeding tube, CPB length, mechanical ventilation length, ventilation and inotropic supports length. ICU and hospital LOS were also statistically longer in the group of patients with feeding difficulties. Table 2 compared the oral feeding difficulties group to patients with successful oral feeding 10 days after surgery.

Figure 3 shows ROC curves of 2 predictive models of feeding difficulties 10 days after surgery.

Discussion

Despite the daily increase of caloric intakes, we observed an under delivery of calories compared to estimated needs during the postoperative period after heart surgery with CPB in infants. This result is concordant with other studies. Toole et al.(20) found in their cohort of infants under 2 years old that the mean caloric parenteral and enteral delivery by day 7 was less than 70% of calculated requirements. In our study, we did not take into account parenteral caloric intake, since only one patient received parenteral nutrition because of prolonged fast imposed by a chylothorax resistant to enteral nutrition with low long chain triglycerides formula. For all the other patients, only a 5% glucose solution was used, which represents a negligible quantity of calories.

In our center, there is no dedicated, written guidelines for nutritional support after cardiac surgery in infants. The feeding prescriptions are left to the appreciation of the medical team. Usually, we first reinitiate feeding with continuous enteral nutrition on a nasogastric feeding tube 1 or 2 days after surgery according to the respiratory and hemodynamical status of the patient. Then, we try oral feeding and split the enteral nutrition to complete the oral intake. When oral intakes seem adequate, the nasogastric feeding tube is removed. Thus, digestive caloric intakes are controlled by medical prescriptions. However, it is well established that many reasons can lead to an interruption of the nutritional support in ICU such as digestive intolerance signs, or technical cares, which may need a fasting period (planned extubation, chest tube removal, sedation issues…)(21). Besides, fluid restriction is often necessary after congenital heart surgery and can potentially limit the prescription of caloric intakes. Hemodynamic instability can also limit the prescription of enteral or oral nutrition because of the fear of intestinal ischemia in these situations.

Besides, to adjust feeding prescriptions, it may be interesting to evaluate more precisely infants' caloric needs. In fact, overfeeding is probably as deleterious as caloric underdelivery in the early postoperative period. The Pediatric Cardiac Intensive Care Society suggests covering basal energy expenditure in the immediate postoperative period. For that purpose, they recommend determining energy requirements by using, at best, indirect calorimetry or standard resting energy expenditure equations (World Health Organization, Harris-Benedict, and Schofield equations)(22), but indirect calorimetry is not used in our center. Furthermore, a number of pediatric ICU clinical conditions prevent the use of indirect calorimetry (27% of patients), such as $FiO_2 > 60\%$, air leaks, extracorporeal circulation (23).

Concerning oral feeding, in our study oral caloric intakes at day 10 after surgery were associated with the length of CPB. Infants with more complicated surgery needing a prolonged CPB had a higher risk of presenting oral feeding difficulties at day 10 than infants with shorter CPB. We also observed that oral feeding difficulties were associated with mechanical ventilation length, non-invasive ventilation, inotropic support length and delayed thorax closure. It seems coherent that infants with longer CPB present a more important postoperative instability and inflammatory reaction, which may delay extubation and oral feeding initiation. This is concordant with results observed in cohorts of neonatal cardiac surgeries (24,25). The difference concerning infections between groups is probably due to mechanical ventilation since 4 of the 5 infections in the group with feeding difficulties were ventilator-associated pneumoniae.

However, CPB length does not seem to be a really good prognostic factor to predict the occurrence or not of oral feeding difficulties delaying food autonomy. In fact, the ROC curves analysis shows a limited prognostic performance of CPB length. For a prolonged CPB, the risk of feeding difficulties 10 days after surgery is important. Yet, for short CPB, we may also observe feeding difficulties at day 10 after surgery. When we adjust the predictive model with the occurrence of associated congenital abnormalities, we obtain slightly better prognostic performances. We supposed that feeding difficulties for infants with short CPB can be explained by the syndromic nature of the CHD.

In our cohort, gestational age was not statistically associated with oral feeding difficulties. This result is concordant with studies focused on feeding after neonatal cardiac surgery which did not show a link between gestational age and feeding difficulties (24). Yet, neonatal studies often exclude preterm infants of their cohort. In our study, we only have 5 infants born before 37 weeks of gestation: one born at 32 weeks of gestation, one born at 34 weeks of gestation et 3 born at 35 weeks of gestation. The absence of association may also be due to a lack of power of our study secondary to our small population and the limited variation in gestational age.

Preoperative nutritional status was neither statistically associated with early oral feeding autonomy difficulties as well as the age at surgery. This is opposite to results found in patients operated on in the neonatal period. For example, Einarson and Arthur (25) showed in their cohort of 100 neonates an association between low body weight and feeding difficulties with an odds ratio of 0.34. In our study, patients with oral feeding difficulties 10 days after surgery even tended to present a better preoperative nutritional status than infants without oral feeding difficulties regarding weight z-score (-0.82 ± 1.9 vs -1.34 ± 1.5), BMI z-score (-0.79 ± 1.3 vs -1.35 ±1.4) or weight/weight for length ratio (-0.78 ± 1.2 vs -0.98 ± 1.3) without statistically significant differences (p=0.14). So, it seems that infants with impaired growth arriving at surgery with compromised nutritional status do not have more oral feeding difficulties than patients whose CHD did not impact child growth. This result is encouraging to rapidly achieve the goal of optimal caloric intakes after surgery in malnourished patients for the purpose of not perpetuating and even correcting the malnutrition post-operatively.

Our study has some limitations. First, this is a relatively small patients population with only 60 patients and with a large variety of CHD which necessary limits the power of our study to identify the factors associated with oral feeding. Then, we have potential biases involved with retrospective analysis. In fact, our data concerning caloric intakes are necessary approximative. For example, nurses take note of enteral and oral intakes but during continuous enteral feeding, interruptions are not always reported. For breastfed infants, we could not calculate the caloric intakes so we considered that they had achieved oral feeding autonomy when the nasogastric feeding tube stopped to be used which is arbitrary. In our cohort, the hospital LOS extends from 5 to 32 days. So, to evaluate at day 10 we simulated caloric intakes based on the last data available before hospital discharge, which probably underestimated the real caloric intakes obtained by patients at home.

Finally, we only evaluated objective determinants of postoperative oral feeding. In fact, a lot of social factors may influence the oral intakes such as the presence of parents or the parents' anxiety regarding their infant oral feeding. Feeding difficulties represent a really stressful situation for parents. Besides, for a part of infants with CHD, feeding difficulties were one of the arguments to indicate surgery. So, when difficulties persist after surgery, parents may be really stressed.

Several issues remain unclear and would deserve further investigations. First, it could be interesting to evaluate several measures to improve postoperative nutritional management after congenital heart surgery such as regular nutritional assessment during hospitalization, strategies to avoid irrelevant interruption of nutrition, use of early physiotherapy to stimulate orality or discuss the use of a high-energy formula as suggested by Zhang et al (26). Then, further study would be necessary to evaluate whether the optimization of caloric intake early after congenital heart surgery leads to better outcomes, notably on infants' growth.

Conclusion

Feeding difficulties were associated with congenital abnormality associated to the CHD, preoperative enteral feeding on a nasogastric feeding tube, CPB, mechanical ventilation, non-invasive ventilation and inotropic support lengths. Particular attention should be payed to these patients with an increased risk of feeding difficulties so that they meet nutritional requirements following congenital heart surgery.

Further studies should be designed to address whether the optimization of caloric intake early after congenital heart surgery leads to better outcomes, notably on infants' growth.

References

1. Khoshnood B, Lelong N, Houyel L, Thieulin A-C, Jouannic J-M, Magnier S, et al. Prevalence, timing of diagnosis and mortality of newborns with congenital heart defects: a population-based study. Heart Br Card Soc. nov 2012;98(22):1667-73.

2. Venugopalan P, Akinbami FO, Al-Hinai KM, Agarwal AK. Malnutrition in children with congenital heart defects. Saudi Med J. nov 2001;22(11):964-7.

3. Cameron JW, Rosenthal A, Olson AD. Malnutrition in hospitalized children with congenital heart disease. Arch Pediatr Adolesc Med. oct 1995;149(10):1098-102.

4. Varan B, Tokel K, Yilmaz G. Malnutrition and growth failure in cyanotic and acyanotic congenital heart disease with and without pulmonary hypertension. Arch Dis Child. juill 1999;81(1):49-52.

5. Hansen SR, Dörup I. Energy and nutrient intakes in congenital heart disease. Acta Paediatr. févr 1993;82(2):166-72.

6. Colomb V, Lambe C. Cardiopathies et troubles nutritionnels chez l'enfant. Arch Pédiatrie. mai 2013;20(5):H72-3.

7. Emond AM, Blair PS, Emmett PM, Drewett RF. Weight faltering in infancy and IQ levels at 8 years in the Avon Longitudinal Study of Parents and Children. Pediatrics. oct 2007;120(4):e1051-1058.

8. Radman M, Mack R, Barnoya J, Castañeda A, Rosales M, Azakie A, et al. The effect of preoperative nutritional status on postoperative outcomes in children undergoing surgery for congenital heart defects in San Francisco (UCSF) and Guatemala City (UNICAR). J Thorac Cardiovasc Surg. janv 2014;147(1):442-50.

9. Coss-Bu JA, Klish WJ, Walding D, Stein F, Smith EO, Jefferson LS. Energy metabolism, nitrogen balance, and substrate utilization in critically ill children. Am J Clin Nutr. 1 nov 2001;74(5):664-9.

10. Floh AA, Nakada M, La Rotta G, Mah K, Herridge JE, Van Arsdell G, et al. Systemic inflammation increases energy expenditure following pediatric cardiopulmonary bypass. Pediatr Crit Care Med J Soc Crit Care Med World Fed Pediatr Intensive Crit Care Soc. mai 2015;16(4):343-51.

11. Valla FV, Baudin F, Gaillard Le Roux B, Ford-Chessel C, Gervet E, Giraud C, et al. Nutritional Status Deterioration Occurs Frequently During Children's ICU Stay. Pediatr Crit Care Med J Soc Crit Care Med World Fed Pediatr Intensive Crit Care Soc. août 2019;20(8):714-21.

12. Pollack MM, Wiley JS, Holbrook PR. Early nutritional depletion in critically ill children. Crit Care Med. août 1981;9(8):580-3.

13. Pollack MM, Ruttimann UE, Wiley JS. Nutritional depletions in critically ill children: associations with physiologic instability and increased quantity of care. JPEN J Parenter Enteral Nutr. juin 1985;9(3):309-13.

14. Mehta NM, Bechard LJ, Cahill N, Wang M, Day A, Duggan CP, et al. Nutritional practices and their relationship to clinical outcomes in critically ill children—An international multicenter cohort study. Crit Care Med. juill 2012;40(7):2204-11.

15. Wheeler DS, Dent CL, Manning PB, Nelson DP. Factors Prolonging Length of Stay in the Cardiac Intensive Care Unit Following the Arterial Switch Operation. Cardiol Young. févr 2008;18(1):41-50.

16. Yoshimura S, Miyazu M, Yoshizawa S, So M, Kusama N, Hirate H, et al. Efficacy of an enteral feeding protocol for providing nutritional support after paediatric cardiac surgery. Anaesth Intensive Care. sept 2015;43(5):587-93.

17. Braudis NJ, Curley MAQ, Beaupre K, Thomas KC, Hardiman G, Laussen P, et al. Enteral feeding algorithm for infants with hypoplastic left heart syndrome poststage I palliation. Pediatr Crit Care Med J Soc Crit Care Med World Fed Pediatr Intensive Crit Care Soc. juill 2009;10(4):460-6.

18. Tume LN, Balmaks R, da Cruz E, Latten L, Verbruggen S, Valla FV, et al. Enteral Feeding Practices in Infants With Congenital Heart Disease Across European PICUs: A European Society of Pediatric and Neonatal Intensive Care Survey. Pediatr Crit Care Med J Soc Crit Care Med World Fed Pediatr Intensive Crit Care Soc. 2018;19(2):137-44.

19. Martin A, Azaïs-Braesco V, Bresson J-L, Couet C. Apports nutritionnels conseillés pour la population française. 3ème édition. Paris, Londres, New York: Tec & Doc; 2002. 605 p.

20. Toole BJ, Toole LE, Kyle UG, Cabrera AG, Orellana RA, Coss-Bu JA. Perioperative nutritional support and malnutrition in infants and children with congenital heart disease. Congenit Heart Dis. févr 2014;9(1):15-25.

21. Keehn A, O'Brien C, Mazurak V, Brunet-Wood K, Joffe A, de Caen A, et al. Epidemiology of interruptions to nutrition support in critically ill children in the pediatric intensive care unit. JPEN J Parenter Enteral Nutr. févr 2015;39(2):211-7.

22. Justice L, Buckley JR, Floh A, Horsley M, Alten J, Anand V, et al. Nutrition Considerations in the Pediatric Cardiac Intensive Care Unit Patient. World J Pediatr Congenit Heart Surg. 2018;9(3):333-43.

23. Beggs MR, Garcia Guerra G, Larsen BMK. Do PICU patients meet technical criteria for performing indirect calorimetry? Clin Nutr ESPEN. oct 2016;15:80-4.

24. Kogon BE, Ramaswamy V, Todd K, Plattner C, Kirshbom PM, Kanter KR, et al. Feeding difficulty in newborns following congenital heart surgery. Congenit Heart Dis. oct 2007;2(5):332-7.

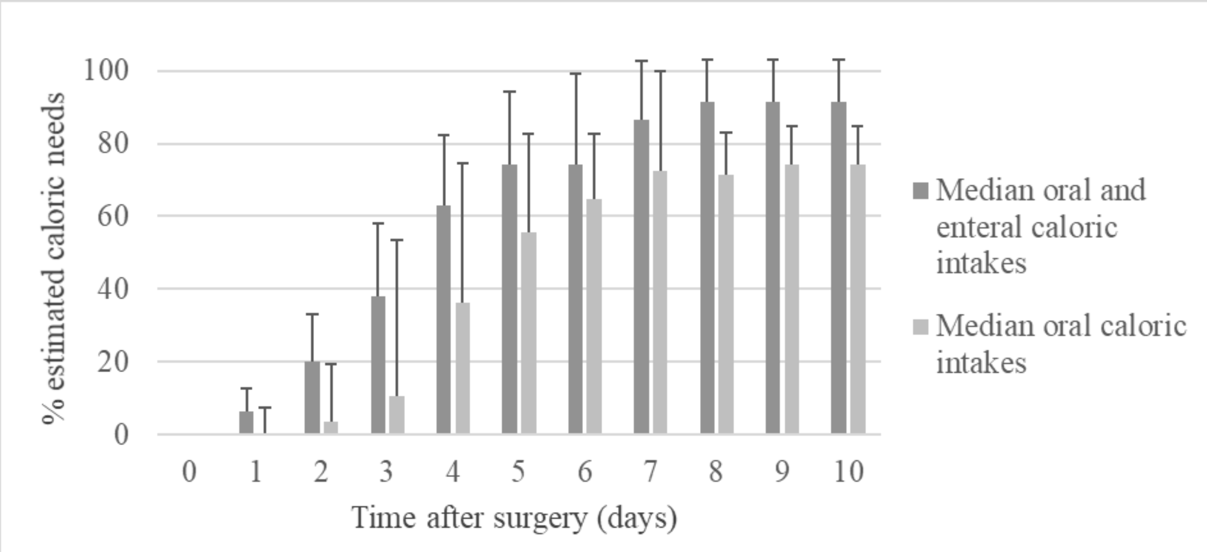
25. Einarson KD, Arthur HM. Predictors of oral feeding difficulty in cardiac surgical infants. Pediatr Nurs. août 2003;29(4):315-9.

26. Scheeffer VA, Ricachinevsky CP, Freitas AT, Salamon F, Rodrigues FFN, Brondani TG, et al. Tolerability and Effects of the Use of Energy-Enriched Infant Formula After Congenital Heart Surgery: A Randomized Controlled Trial. JPEN J Parenter Enteral Nutr. 22 mars 2019;

Tables and Figures

<u>Figure 1:</u> Oral and total digestive caloric intakes after cardiac surgery in infants

The figure shows the median percentage and the third quartile of oral and total digestive (enteral and oral) caloric intakes during the first 10 days after surgery. Top: caloric intakes in percentage of estimated needs. Bottom: caloric intakes in kcal/kg/day.



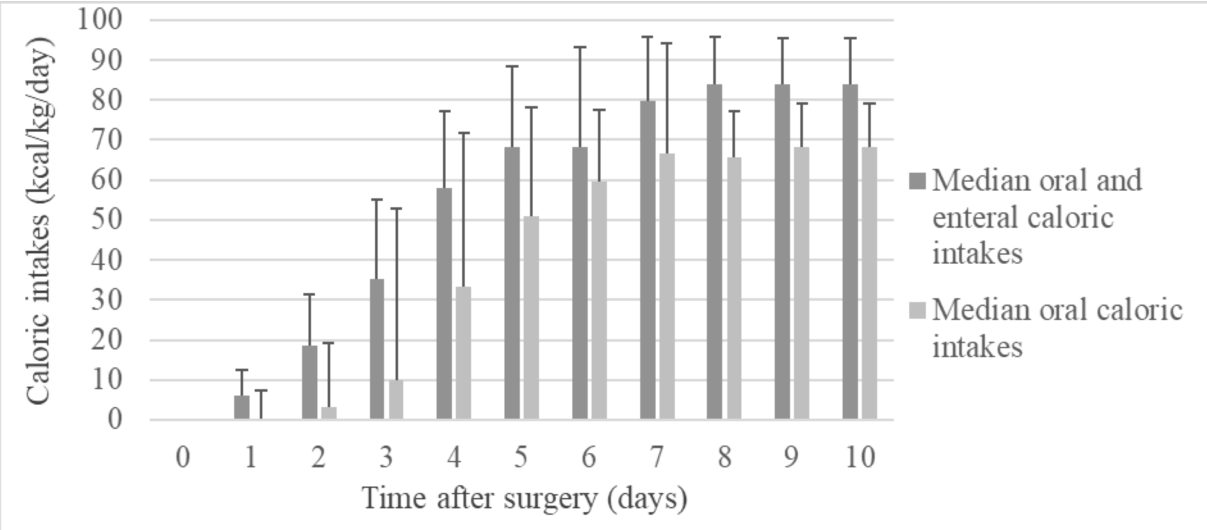


Figure 2: Oral caloric intakes 10 days after surgery.

Figure 2 shows the percentage of estimated caloric needs of the population's three terciles.

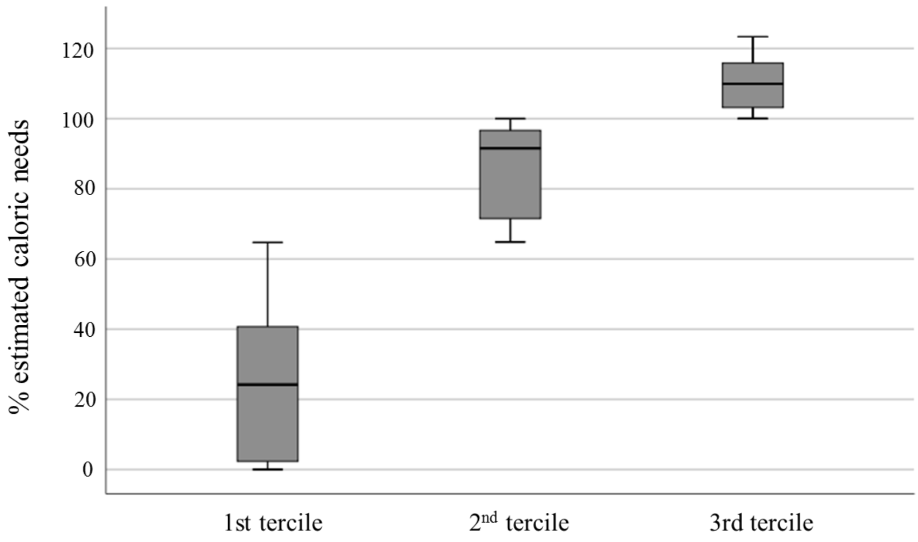
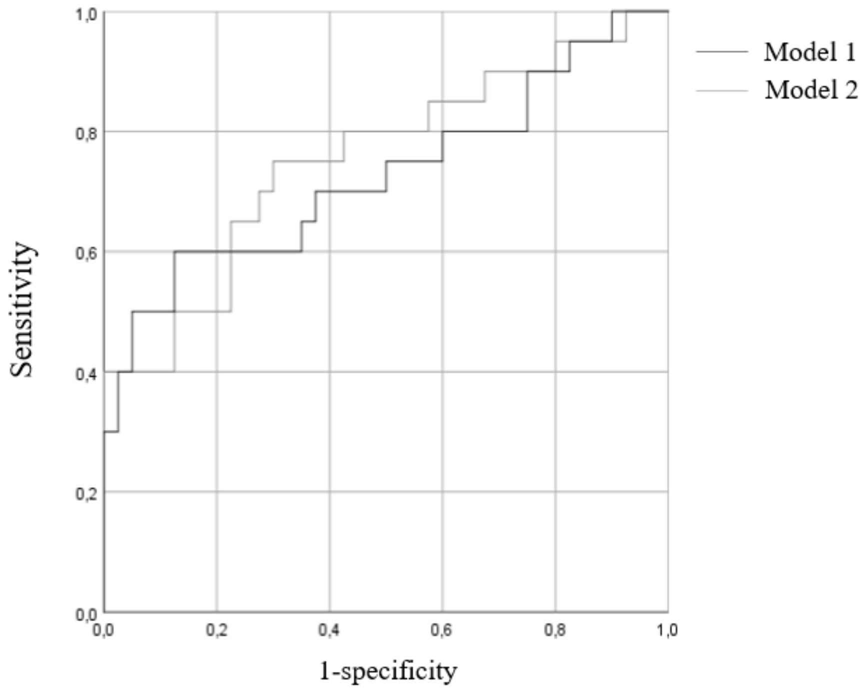


Figure 3: ROC curves for prediction of oral feeding difficulties 10 days after surgery.

Model 1 includes cardiopulmonary bypass length adjusted to gestational age and preoperative weight z-score. Model 2 includes cardiopulmonary bypass length adjusted to gestational age, preoperative weight z-score and associated congenital abnormalities.



Diagnosis	n (%)
Ventricular septal defect	17 (28)
Tetralogy of Fallot	13 (22)
Ventricular and atrial septal defect	8 (13)
Atrioventricular septal defect	5 (8.3)
Double outlet right ventricle	4 (6.7)
Pulmonary valve stenosis	3 (5)
Bicuspid aortic valve	3 (5)
Single ventricle	2 (3.3)
Coronary stenosis after arterial switch	1 (1.7)
Pulmonary atresia with ventricular septum defect	1 (1.7)
Pulmonary atresia with intact ventricular septum	1 (1.7)
Atrial septal defect	1 (1.7)
Patent ductus arteriosus	1 (1.7)

Table 1: Diagnosis of congenital heart disease

	Success of oral feeding at day 10 (n=40)	**Difficult oral feeding at day 10 (n=20)**	**p**
Age at surgery, days	136.2 (65.4)	125.0 (77.4)	0.558
Gestational age, weeks	38,9 (1,7)	38.2 (2.2)	0.128
Genetic abnormality, n	6 (15)	3 (15)	1.0
Associated congenital abnormality, n	3 (7.5)	6 (30)	0.049
Weight z-score before surgery	-1.3 (1.5)	- 0.8 (1.9)	0.252
BMI z-score before surgery	-1.4 (1.4)	-0.8 (1.3)	0.14
Weight/length z-score before surgery	-1.0 (1.3)	-0.8 (1.2)	0.585
Preoperative enteral feeding, n	3 (7.5)	10 (50)	<0.001
Cardiopulmonary bypass time, min	104.6 (36)	146.3 (73)	0.004
Mechanical ventilation duration, days	0.6 (1.1)	3.0 (3.4)	<0.001
Non-invasive ventilation duration, days	2.7 (2.4)	5.9 (4.8)	0.001
Chest tube removal delay, days	2.6 (1.0)	3.6 (3.4)	0.103
Inotropic support duration, days	2.6 (1.4)	3.8 (1.7)	0.007
Differed thorax closure, n	1 (2.5)	4 (20)	0.038
Postoperative infection*, n	2 (5)	5 (25)	0.035
Chylothorax, n	2 (5)	2 (10)	0.595
Cardiac rhythm disorder, n	6 (15)	6 (7.5)	0.307
Vocal cords palsy, n	1 (2.5)	2 (10)	0.255
Intensive care unit length of stay, days	4.0 (1.6)	7.7 (3.7)	<0.001
Hospital length of stay, days	7.2 (1.9)	12.0 (6.5)	0.005

Table 2: Comparison of infants with early oral feeding success and infants with oral feeding difficulties 10 days after surgery. *Data are expressed as mean (standard deviation) or number (percent). *Infection was defined by the prescription of a curative antibiotic therapy.*

CONCLUSION

Nos résultats montrent que malgré une augmentation des apports caloriques chaque jour post-opératoire, ceux-ci restent inférieurs aux apports nutritionnels conseillés. En effet, à 10 jours de la chirurgie les apports caloriques oraux médians observés dans notre population étaient de 74% [39-85] (soit 68,1 [35,9-78,2] kcal/kg/jour) des apports nutritionnels conseillés. La médiane des apports digestifs totaux (somme des apports oraux et entéraux) observée était de 91% [72-103] (soit 83,7 [66,2-94,8] kcal/kg/jour) des apports nutritionnels conseillés.

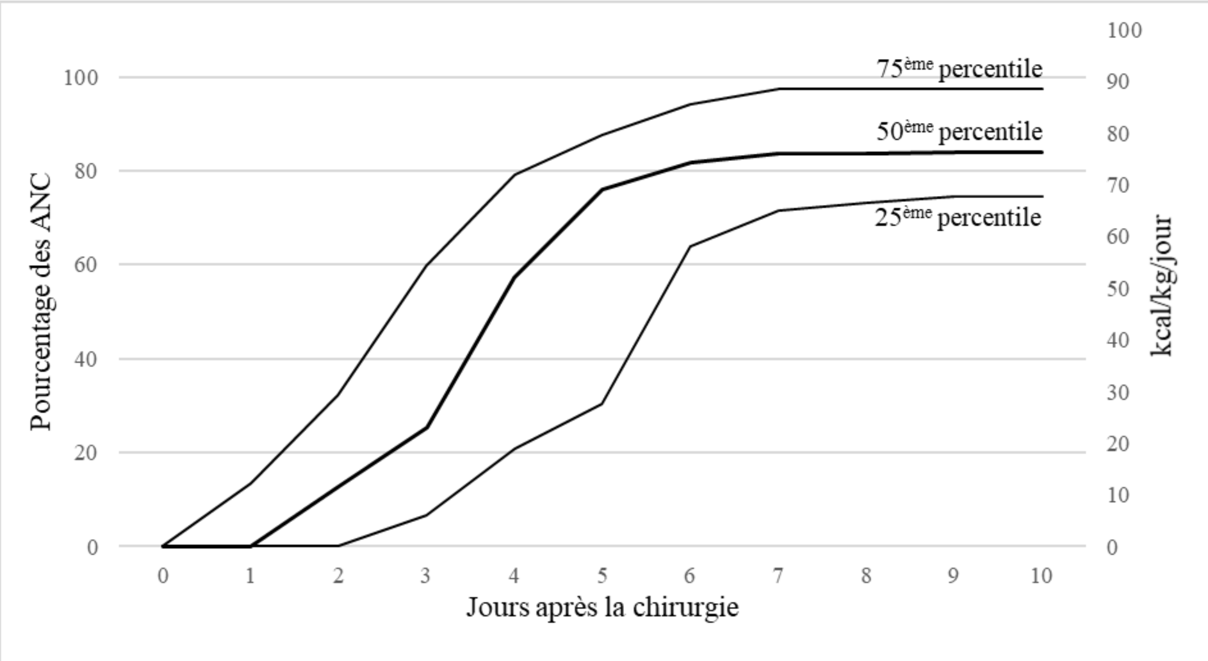
A 10 jours de la chirurgie, les difficultés alimentaires étaient statistiquement associées à la présence d'une malformation extracardiaque associée à la cardiopathie congénitale, à l'utilisation d'un support nutritionnel préopératoire par sonde nasogastrique, et des durées de circulation extracorporelle, de ventilation invasive, de ventilation non-invasive et de support inotrope plus longues. Ces patients avec difficultés alimentaires présentaient également des durées de séjours en réanimation et d'hospitalisation plus longues. Une attention particulière devrait donc être portée à ces patients présentant des difficultés d'alimentation orale afin d'assurer des apports caloriques optimaux au cours de la période post-opératoire.

Il persiste plusieurs zones d'ombres dans la gestion optimale de la prise en charge nutritionnelle post-opératoire et de nouvelles études seront nécessaires afin d'améliorer nos pratiques. En effet, il serait intéressant d'évaluer l'impact sur l'amélioration des apports caloriques post-opératoires de différentes mesures telles qu'une évaluation nutritionnelle régulière du patient, des stratégies pour limiter les interruptions non-justifiées de l'alimentation, une stimulation précoce de l'oralité par exemple à l'aide d'une kinésithérapie ou encore l'utilisation de formules infantiles enrichies comme ont pu le proposer Zhang et al. (26). Enfin, il sera important d'évaluer l'impact d'une optimisation de l'apport calorique sur l'évolution post-opératoire (cicatrisation, infection, durée d'hospitalisation…) et sur la croissance à moyen et long terme des enfants.

Cette étude nous a permis de faire un état des lieux des apports caloriques observés dans notre centre. En excluant les enfants présentant des difficultés alimentaires, nous avons pu modéliser les apports caloriques oraux observés après chirurgie cardiaque sous-circulation extracorporelle chez le nourrisson. Ce modèle présenté en annexes, pourra servir de repère pour les équipes médicales du service afin d'évaluer l'oralité et la reprise alimentaire des enfants au cours de l'hospitalisation.

ANNEXES

Modèle de reprise standard de l'alimentation orale après chirurgie cardiaque chez le nourrisson



La courbe représente la médiane, le premier et le troisième quartile des apports caloriques oraux observés après chirurgie cardiaque sous circulation extracorporelle (CEC) chez des nourrissons sans difficultés particulières d'alimentation orale. Les apports sont représentés en kcal/kg/jour et en pourcentage des apports nutritionnels conseillés pour la population française (soit 92 kcal/kg/jour avant 1 an).

Les patients avec des apports caloriques inférieurs présentent probablement des difficultés d'alimentation orale pouvant s'expliquer notamment par une durée de CEC plus longue suivie d'une période de soins de réanimation plus intenses ou par des malformations associées à la cardiopathie.

Vu, le Président du Jury,

(tampon et signature)

Professeur Cyril FLAMANT

Vu, le Directeur de Thèse,

(tampon et signature)

Docteur Hugues PILOQUET

Vu, le Doyen de la Faculté,

Professeur Pascale JOLLIET

NOM : JORE PRENOM : Sandie

Titre de Thèse : Réalimentation du nourrisson de moins de 1 an après chirurgie cardiaque sous circulation extracorporelle : étude rétrospective au CHU de Nantes

---

RESUME

Objectif : L'objectif de l'étude était d'évaluer les apports caloriques des nourrissons après chirurgie cardiaque et d'identifier les facteurs de risque de difficultés alimentaires.

Méthode : Notre étude rétrospective incluait les nourrissons âgés de 28 à 365 jours, opérés d'une cardiopathie congénitale sous circulation extracorporelle (CEC) au CHU de Nantes de juin 2018 à mai 2019. Les difficultés alimentaires étaient définies par le besoin d'une alimentation entérale à la sortie d'hospitalisation ou des apports caloriques oraux du tercile le plus bas de la population.

Résultats : Chez les 60 patients inclus, l'apport calorique oral moyen à 10 jours de la chirurgie était de 62% (±34,7) des apports conseillés. Les difficultés alimentaires étaient statistiquement associées à des durées plus longues de CEC (p=0,004), de ventilation mécanique (p<0,001), de support inotrope (p=0,007) et d'hospitalisation (p=0,005) ; aux malformations associées (p=0,049) et à une alimentation entérale préopératoire (p<0,001).

Conclusion : Les difficultés alimentaires étaient associées à la durée de CEC, à l'importance des soins de réanimation, aux malformations associées et à une durée d'hospitalisation prolongée.

MOTS-CLES

Cardiopathie congénitale ; Chirurgie cardiaque ; Nourrissons ; Dénutrition ; Alimentation orale