Nutritional Problems and Management in Acyanotic Congenital Heart Disease

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Abstract

Background: Congenital heart disease (CHD) constitutes one third of all major congenital abnormalities and is often associated with malnutrition and failure to thrive in children. The nutritional status of CHD patients experienced a significant improvement after correction. Congenital heart disease is divided into two groups, namely cyanotic CHD and acyanotic CHD. Cyanotic CHD is a heart disease in children which is characterized by central cyanosis due to a shunt from right to left, whereas acyanotic CHD in children is not characterized by cyanosis and has a leak in the heart septum accompanied by a shunt or not. Malnutrition is a major challenge that is estimated to affect 50-90% of children with CHD in developing countries. Congenital Heart Disease can also cause moderate to severe malnutrition. Children with acyanotic CHD can experience complications in several organ systems and the respiratory system is the most important complication. Lower respiratory tract infections are the main reason for morbidity and mortality, prolonged hospital stay, respiratory failure, prolonged use of mechanical ventilation, and delayed definitive surgery.

Keywords: Nutritional Problem, Acyanotic, Congenital Heart Disease

Congenital heart disease (CHD) constitutes one third of all major congenital abnormalities and is often associated with malnutrition and failure to thrive in children. (1) Asia has the highest prevalence compared to other continents, 9.3 per 1,000 live births, while the lowest prevalence rate comes from the African continent with an incidence rate of 1.9 per 1,000 live births. (2) The incidence of CHD in Indonesia is quite high, with 45,000 Indonesian babies born with CHD every year. Of the 220,000,000 population of Indonesia, it is estimated that 6,600,000 babies were born and 48,800 of them were people with CHD. The nutritional status of CHD patients experienced a significant improvement after correction. (3)

Congenital heart disease is divided into two groups, namely cyanotic CHD and acyanotic CHD. Cyanotic CHD is a heart disease in children which is characterized by central cyanosis due to a shunt from right to left, whereas acyanotic CHD in children is not characterized by cyanosis and has a leak in the heart septum accompanied by a shunt or not. (4)

Atwa et al's research reported that the frequency of acyanotic CHD type Arterial Septal Defect (ASD) was 28.8% more than Ventricular Septal Defect (VSD) of 28.2%. Research by Alenezil (2015) also reported acyanotic CHD VSD as much as 39.5% of all diagnoses, followed by ASD 18.1% and pulmonary stenosis 12.4%. (5) In research in the pediatric health sciences section of RSUP Prof. Dr. R. D. Kandou Manado during 2009-2013 obtained from 53 children, with 34 children being male and 19 children being female, aged 1-6 years were the most sufferers, with the type of CHD most commonly suffered being ASD, namely 34, 0 %, followed by VSD 28.3 %. (6)

Malnutrition is a major challenge that is estimated to affect 50-90% of children with CHD in developing countries. (1) Congenital Heart Disease can also cause moderate to severe malnutrition. (7) Ratanachu-ek's research (2011) reported that 40% of congenital heart disease patients experienced malnutrition before surgery. Malnutrition that occurs includes underweight (28%), wasting (22%), and stunting (16%). (8) Research from Türkiye reports that the prevalence of malnutrition in CHD children is 27%. (9) Research in Nigeria also found a higher rate of malnutrition in children with uncorrected CHD of 90.4%. (10) Research conducted by Artiko (2015) on patients with acyanotic congenital heart disease patent ductus arteriosus (PDA) who could experience malnutrition and growth disorders before closure catheterization was carried out. (11)

Children with acyanotic CHD can experience complications in several organ systems and the respiratory system is the most important complication. Lower respiratory tract infections are the main reason for morbidity and mortality, prolonged hospital stay, respiratory failure, prolonged use of mechanical ventilation, and delayed definitive surgery. (12)

The purpose of writing this abstract is to explain nutritional problems in children with acyanotic congenital heart disease and their management.

Acyanotic congenital heart disease constitutes the largest proportion of all congenital heart diseases. As the name suggests, in patients with acyanotic congenital heart disease there are no symptoms or signs of cyanosis. In this group ventricular septal defects (VSD) is the most frequently found abnormality, and accounts for 30% of all congenital heart diseases. Atrial Septal Defect (ASD) is the second most frequently found disorder, followed by Patent Ductus Arteriousus (PDA) and pulmonary stenosis. Aortic stenosis and coarctation Aortic and other left heart lesions, which are reported to be found mostly in white people, are very rare in Indonesia. (4)

Symptoms and signs of acyanotic CHD that may be seen in babies and children include: rapid breathing, fatigue, poor blood circulation, and reduced appetite. Normal growth depends on the workload of the heart and the flow of oxygen-rich blood throughout the body. Babies with acyanotic CHD from birth will feel tired easily when feeding so that growth does not match what it should. (13)

Acyanotic CHD can be divided into: (13) Left to right shunt is Ventricular Septal Defects (VSD), Atrial Septal Defect (ASD), Atrioventricular Septal Defect (AVSD), Patent Ductus Arteriousus (PDA) and then with Obstructive such as Pulmonary stenosis, Aortic stenosis and Coarctation of the aorta.

Ventricular Septal Defect (VSD)

In VSD there is a shunt from left to right. The size of the shunt depends on the size, not the location of the defect and the degree of pulmonary vascular resistance. There is an excess volume load on the left ventricle, left atrium and right ventricle, due to shunt of blood flow from left to right. Initially the right ventricle will experience dilatation, followed by hypertrophy of the left ventricle and left atrium or vice versa. And this shunt from left to right over time will affect pulmonary resistance and pressure in the pulmonary arteries. If pulmonary hypertension is higher and this is an excessive pressure load on the right ventricle, the blood flow shunt will slowly change to bidirectional. Pulmonary resistance can exceed systemic resistance during activity, so that the shunt switches from right to left, while at rest there is still a small shunt from left to right. (14)

Ventricular Septal Defect (VSD) can be classified into: 1. Perimembranous VSD. In this type, most defects are in the membranous ventricular septum, but almost always include also the adjacent pars muscularis septum. Therefore, this VSD is more often referred to as a perimembranous or subaortic VSD. 2. VSD outlets. In this type of VSD, it is located in the outlet septum and its edges are formed by the aortic and pulmonary valve annulus. This type was previously also called supracristal, conal, subpulmonary or subarterial defect VSD or subarterial VSD or oriental type VSD. 3. VSD inlets. The VSD is located posterior and inferior to the membranous ventricular septum, below the leaflet of the tricuspid valve, pars septalis valve and inferior to the papillary muscle. 4. Muscular VSD. This type of VSD constitutes 5-20% of the VSD types. The most common defects are multiple. (14)

Based on its location, muscularis VSD is further divided into 4: Apical VSD is located at the apex of the heart. Midmuscular VSD is located posterior to the septomarginal trabecula. Anterior or Marginalis. The VSDs are usually multiple, small and tortuous, located along the septal junction of the right ventricle. Sweet Cheese. Multiple VSD, including all components of the ventricular septum. (14)

Atrial Septal Defect (ASD)

Atrial septal defect found during adolescence compared to babies and children, because it is asymptomatic so it is only discovered after the child is older or an adult. (15) Atrial septal defect is characterized by a defect in the intra-atrial septum that allows pulmonary venous return from the left atrium to the right atrium. (16) In classification is divided according to its location in the atrial septum, namely: a. Ostium primum, is the result of failure of fusion of the ostium primum with the endocardial cushion and leaves a defect at the base of the septum. b. Ostium secundum, this defect is found in the fossa ovalis area. This is the most common form of atrial septal defect and is associated with normal atrioventricular valves. These defects may be single or multiple. Women are at risk 3 times more than men. c. Sinus venosus, a defect located at the top of the atrial septum associated with the entry of the superior vena cava. Often, one or more pulmonary veins 4 (usually from the right lung) anomalously drains into the superior vena cava. d. Coronary sinus, this defect is located in the part of the atrial septum that includes the coronary sinus opening and is characterized by the absence of at least part of the wall that normally separates the coronary sinus from the left atrium. (16)

Atrioventricular Septal Defect (AVSD)

Atrioventricular septal defect is a congenital heart disease with Atrioventricular Septal Defect (AVSD), embryonic

This disorder is often found in patients Down Syndrome. Clinical symptoms appear in the first week of life and heart failure can occur in the first month of life. Pulmonary hypertension accompanied by loud and single heart sounds often occurs. Chest x-ray is the same as a secundum defect, namely the presence of cardiomegaly with pulmonary plethora and interstitial edema. (17)

Patent Ductus Arteriousus (PDA)

This is an abnormality in which the vessels connecting the pulmonary artery and aorta in the fetal phase remain patent until birth. Functional closure of the ductus normally occurs after birth, but if the ductus remains open when pulmonary vascular resistance decreases, blood in the aorta is drained into the pulmonary artery. PDA is one of the most frequent congenital cardiovascular anomalies resulting from maternal rubella infection during early pregnancy. (20)

Pulmonary Stenosis

Pulmonary stenosis is a common congenital heart defect characterized by obstruction of flow from the right ventricle to the pulmonary artery. Pulmonary stenosis can occur alone or in combination with other types of congenital heart defects. Pulmonary stenosis is used to indicate the presence of an outflow tract of the right ventricle or pulmonary artery and its branches. Narrowing in pulmonary stenosis occurs, among other things, under the infundibulum valve (subvalvular or infundibular stenosis), at the valve (valvular), above the valve (supravalvular). Nutritional status Patients with pulmonary stenosis are generally well with satisfactory weight gain. Infants and children with mild pulmonary stenosis are generally asymptomatic and not cyanotic, whereas neonates with severe or critical pulmonary stenosis will appear tachypnoeic and cyanotic. (21)

Aortic Stenosis

The most common form is aortic valve stenosis, the valve thickens and the commissures fuse to varying degrees. Left ventricular systolic pressure increases due to outflow obstruction. The left ventricular wall hypertrophies, decreases compliance, increased end-diastolic pressure. Aortic stenosis can occur at the subvalvular, valvular, or supravalvular level. Aortic stenosis can be found along with other conditions such as coarctation of the aorta or persistent ductus arteriosus. This disorder may not be diagnosed in childhood because the valve can function normally, but systolic murmurs are found in the aorta and are only discovered in adulthood, making it difficult to differentiate between congenital or acquired heart disease. The incidence of aortic stenosis is greater in white people than in Asians. (22)

Mild or moderate aortic stenosis is generally symptomatic so it is often diagnosed by chance because during a routine examination a systolic ejection murmur is heard with or without ejection clicks in the aorta area: parasternal between the left 2nd ribs up to the apex and neck. In mild aortic stenosis with a systolic pressure gradient of less than 50 mmHg there is no need for intervention. Valvotomy or non-surgical surgical intervention Balloon Aortic Valvuloplasty should be performed immediately in neonates and infants with severe valvular aortic stenosis or a systolic pressure gradient of 90-100 mmHg. (23)

Coarctation of the Aorta

Coarctation of the aorta is a localized narrowing of the aorta which generally occurs in the ductus arteriosus area. Coarctation of the aorta can also occur preductal or post ductal. Symptoms can appear suddenly. The classic sign of coarctation of the aorta is a brachial pulse that feels normal and strong, while the femoral and dorsalis pedis pulses are not palpable or feel small. (24)

Malnutrition in children with Acyanotic CHD.

Malnutrition is an imbalance between the intake of energy, protein and other nutrients and the body's needs so that it can have a negative impact on growth and development. Especially in developing countries, the main problem of concern is nutritional deficiencies(undernutrition), so malnutrition here refers to nutritional deficiencies. (22) Children with acyanotic CHD have a high prevalence of eating difficulties and malnutrition. (23) Data from developing countries shows that the prevalence of malnutrition in patients with acyanotic CHD before surgery reaches 45%. A study conducted at Cipto Mangunkusumo Hospital, Jakarta, showed a prevalence of malnutrition of 51.1% and severe malnutrition of 22.3% in acyanotic CHD children, with the prevalence of failure to thrive higher than the problem of malnutrition. (25)

The incidence of malnutrition based on the type of acyanotic congenital heart defect

In general, the type of congenital heart defect can affect body weight and height. Types of acyanotic type of CHD such as patent ductus arteriosus, atrial septal defects and ventricular septal defects (PDA, ASD, VSD) with left to right shunts, affects body weight more than height in the early stages. (26)

Ventricular septal defect (VSD) is a type of congenital heart disease (CHD) which is characterized by a defect in the ventricular septum. This causes some of the oxygen-rich blood to return to the lungs. The incidence of VSD is quite high, around 20% of all CHD. Anatomically, VSD can be classified according to the location of the defect. (27)

In another study, it was found that 83% of VSD cases were accompanied by malnutrition, compared to previous research showing only 46% of CHD acyanotics include VSDs that are malnourished. One of the complications of VSD is pulmonary hypertension, present in 68.5% of cases with OR 9.678 (2.426– 38.605) and p=0.001. These findings support previous research which stated that pulmonary hypertension is a factor causing malnutrition in cyanotic and acyanotic CHD.28Research conducted by Leite et al stated that the pulmonary hypertension factor in acyanotic CHD is associated with a high incidence of malnutrition (p=0.0140). (29) Research in Iran found that 40% of the research subjects were below the 3rd percentile and there was a relationship between body weight, head circumference and VSD size ($p<0.05$). (30)

Patent ductus arteriosus (PDA) is a type of acyanotic CHD caused by failure of physiological closure of the ductus arteriosus after birth. PDA can affect children's growth and cause malnutrition. Malnutrition is a risk factor for child mortality and morbidity. Gunawan et al (2010) reported that the incidence of PDA in premature babies at the Department of Pediatrics in Cipto Mangunkusumo Hospital was 14%. (31)

Heart failure in acyanotic congenital heart disease

Acyanotic CHD disease will result in excessive volume load which causes heart failure.20Congestive heart failure is characterized by water and sodium retention accompanied by signs of pulmonary congestion (dyspnea, orthopnea, paroxysmal nocturnal dyspnea) and systemic venous congestion (edema, ascites, and hepatomegaly). Elevated left ventricular filling pressures in the absence of clinical symptoms constitute hemodynamic congestion that predicts uncompensated heart failure. Chronic and increased ventricular filling pressure plays a role in cardiac remodeling caused by neurohormonal activation, increased myocardial wall stress, increased myocardial oxygen demand due to ischemia and increased mitral regurgitation. From this event, a cycle of decline can be describedcardiac output with progressive water and salt retention. (32)

Metabolic changes in acyanotic CHD with heart failure

Metabolism that occurs in the myocardium is an important factor in the pathogenesis and progression of cardiac dysfunction. In heart failure there is a decrease in activity creatine kinase (CK) and decline flux from phosphocreatine 8 (PCr). The occurrence of hyper phosphorization of the sarcoplasmic reticulum will cause depression of the sodium pump and a decrease in contractility which is exacerbated by a lack of energy supply. (33)

Decreased energy production in heart failure is also caused by damage to the mitochondrial membrane. The integrity of the mitochondrial membrane causes its failure coupling protons in the respiratory chain process so that ATP is not formed. Several studies prove its high protein uncoupling (UCP) which indicates a lot of mitochondrial damage. This is due to one of the reasons reactive oxygen species (ROS). (34)

Several metabolic changes occur during cardiac contraction dysfunction and activation of the cardiac nervous system. The main ATP-producing substrate contribution is glucose. The dominant glucose metabolism in a hypertrophied heart is an increase in the glycolysis process. Several previous studies have shown an increase in the activity of lactate dehydrogenase, an enzyme that plays a role in converting pyruvate into lactate. This condition is accompanied by an increase efflux lactate from the myocardium. (35)

Overall fatty acid oxidation decreased. Fatty acids, which are the largest source of energy, normally require greater oxygen consumption. This causes metabolic changes in heart failure, namely increasing the glycolysis process originating from glucose and decreasing the fatty acid oxidation process. (36)

Respiratory tract infections in acyanotic congenital heart disease

Acyanotic type congenital heart disease aggravates acute lower respiratory tract infections. The most common acute lower respiratory tract infection is pneumonia. Based on Sodeh and Osarogiagbon's research in Nigeria, there were

(11.57%) had the most frequent CHD, namely ventricular septal defects (VSD) in about 50% of 14 children, which causes shunting left to right blood and increases blood flow in the lungs. (37)

Ventricular septal defect which is not closed and patent ductus arteriosus (Large PDA) is known to have symptoms that appear earlier and has a greater tendency to suffer from pneumonia in children. Pneumonia patients with acyanotic CHD tend to experience heart failure and spend longer in hospital compared to children without acyanotic CHD. Acyanotic CHD patients with a significant increase in blood flow to the lungs makes it easier for pneumonia and congestive heart failure to occur. (37)

Age at Operation

The age at which surgery is carried out greatly influences the recovery period for children with congenital heart disease to keep up with their growth and development, both in height and weight. Without adequate nutrition, surgery at an earlier age will not be possible. Children weighing less than 4.5 kg have a high risk of death during surgery. Children who survive after surgery need a recovery time for weight gain of several months, while catch-up growth for head circumference and height takes more than a year. (13) Various medical and non-medical variables also influence the age at which a child undergoes surgery, including the type of health insurance and ease of access to health facilities. In the case of PDA, a significant acceleration of weight gain of 28% and height of 20% was obtained after surgery. Children born with normal birth weight with large VSD and congestive heart failure showed that 53 children experienced significant increases in weight, height and head circumference after surgery at an early age (less than 7 months), this improvement was achieved within 6 to 12 months after surgery. (13)

Inadequate calorie intake

In children with acyanotic congenital heart disease energy expenditure is increased and often occurs concurrently with inadequate caloric intake. Inadequate calorie intake occurs when children with acyanotic CHD begin to lose their appetite or as a result of the body's inability to use nutrients for the growth of the baby/child due to anorexia, acidosis, malabsorption and increased nutritional requirements. Enlargement of the liver due to congestive heart failure causes a reduction in gastric volume and potentially causes gastroesophageal refluxas well as aspirations. Congestive heart failure also causes gastrointestinal edema and hypoxia. (13)

Inefficient absorption

Intestinal dysfunction caused by decreased blood flow to and from the circulationsplanchnicoften found in acyanotic CHD patients and causes malabsorption. This is why acyanotic CHD patients cannot achieve normal weight even though they have received sufficient calorie intake. There is still much controversy regarding the role of malabsorption in growth disorders, therefore this mechanism still needs to be considered until further research is available. Most patients with congenital heart disease experience malnutrition by 82%. One fifth of patients experienced severe malnutrition and occurred in both types of congenital heart disease with malnutrition (47%) and marasmus (33%). (38)

Increased energy use

Research by Da Silva published in 2007 reported that babies experienced malnutrition and growth disorders in VSD because there was an increase of 40% of total energy expenditure (TEE). Meanwhile on resting energy expenditure (REE) is also found in children with VSD. The difference between REE and TEE was 2.5 times higher in children with VSD and this indicates that energy during activity was higher. The body composition of acyanotic CHD children has a thinner body mass. This is due to low calorie intake and greater energy expenditure, so as a consequence there is little energy available to store fat. The presentation of less body mass tends to increase basal metabolic rate, and if not managed well it will worsen health status. (39)

Management of acyanotic CHD in general

Medical therapy

Medical therapy for babies and children with malnutrition and failure to thrive in relation to acyanotic CHD is generally aimed at reducing symptoms due to heart failure. The use of digitalis will improve heart contractility, diuretics will reduce preload and vasodilators will reduce afterload so that hemodynamics improves. Better hemodynamics will improve the growth of CHD children. Although there are side effects from using heart failure

Interventional therapy for acyanotic CHD

Duct closure is indicated in symptomatic PDA with significant left-to-right shunt. In asymptomatic PDA with a significant left-to-right shunt causing cardiac enlargement, closure is aimed at minimizing the risk of complications. The transcatheter method has become the main choice in the management of PDA, its advantages are a high success rate, reduced length of stay, and low morbidity rates compared to surgery. (41)

Venticular septal defect (VSD) can be corrected by catheterization heart surgery with a success rate that can be said to be the same as heart surgery, but with much lighter risks. Closure using this method is ideally carried out at the age of 1-2 years or the child's weight is at least 8 kg. The advantages of this procedure compared to surgery include a relatively short length of stay, the patient avoids having to use a heart lung machine, avoids complications from thoracotomy, and cosmetically it is better without any scar tissue from the incision on the patient's chest. (42)

Research conducted by Ghaderian et al in 2012-2013 in Iran concluded that cardiac catheterization is a safe and effective procedure without serious mortality or morbidity rates. (43) Improvements in nutritional status are also due to improvements in hemodynamics after defect closure. Reduced intake due to heart failure and recurrent respiratory tract infections which will improve after defect closure will also have an impact on improving nutritional status. In univariate analysis, it was found that z-score before closure and age at closure were associated with an increase in z-score 3 months after closure. (42)

Research conducted by Correia Martins et al concluded that accelerated growth in VSD patients who underwent defect closure occurred 3-6 months after the procedure.44Another study conducted by Manso et al in Brazil, of 68 patients undergoing defect closure procedure scatch up growth BB/TB was found in 89% of patients. In this study, catch up growth from undernutrition at the start of observation to good nutrition at evaluation 3-6 months after cardiac catheterization was obtained in 10 children. (45)

Strategy for providing nutrition to children with congenital heart disease and malnutrition

To restore the nutritional condition of children who experience decreased caloric intake and increased energy requirements, it is necessary to achieve catch-up growth as the ultimate goal of providing nutrition to children with congenital heart disease and failure to thrive. (26)

How to feed children with congenital heart disease and malnutrition varies, depending on the degree of malnutrition and the patient's age. Oral feeding is preferred if circumstances permit, however enteral and/or total parenteral feeding may be necessary if there are appropriate indications. Oral administration of solid food can be started when the baby is 4 to 6 months old. If food is given via a nasogastric tube, you can start by giving food with a density of 24kcal/30 ml at a speed of 1mg/ kgBB/hour continuously. Then the food density can be increased by 3-4 kcal/30 ml/day gradually so that the number of calories you want to achieve is obtained. (46)

Post-operative nutritional support

After surgery is carried out, whether palliative or definitive, nutrition must be started immediately or no later than 48 hours after surgery. Total parenteral nutrition or parenteral nutrition via peripheral blood can be given to patients, especially if the patient uses mechanical ventilation for a long period of time. If enteral nutrition cannot be provided for more than one week, total parenteral nutrition via a central vein must be started immediately. (46)

Providing long-term total parenteral nutrition without stimulation of the cerebrospinal tract can result in small intestinal atrophy, erosion of the cerebrospinal tract mucosa, increased bacterial translocation, and increased incidence of morbidity and death. Giving food through a nasoduodenal tube can be a better option if after surgery it turns out that it requires mechanical ventilation for a long period of time and cannot be given food orally. Providing this food still allows the digestive tract to receive stimulation and is more physiological. (46)

Summary

Acyanotic congenital heart disease constitutes the largest proportion of all congenital heart diseases. Children with acyanotic CHD require more nutrients than normal children. Malnutrition in children with CHD can increase morbidity and mortality. There are multifactorial causes of malnutrition, such as congenital heart defects, inadequate calorie intake, hypermetabolism, age at the time of surgery and increased energy consumption. Although the causes and impact of chronic diseases in children and their relationship to nutritional deficiencies are not fully understood

Referencies

1.Zhang M, Wang L, Huang R, Sun C, Bao N, Xu Z. Risk factors of malnutrition in Chinese children with congenital heart defects. BMC Pediatrics. 2020;20(1).

2. Kumala K, Yantie KV, Hartawan B. Characteristics of isolated type acyanotic congenital heart disease and early clinical manifestations in pediatric patients at Sanglah Central General Hospital, E-Jurnal Medika, 2018, vol.7 No.10

3. Vaidyanathan B, Nair SB, Sundaram KR, Babu UK, Shivaprakasha K. Malnutrition in children with congenital heart disease (CHD): determinants and short-term impact of corrective intervention. Indian Pediatrics. 2008; 45:541- 6.

4. Djer MM, Madiyono B. Management of congenital heart disease. Sari Pediatrics. 2000; 2(3):155-62.

5. Alenezil AM, Albawardi NM, Ali A, Househ MS, Elmetwally A. The epidemiology of congenital heart diseases in Saudi Arabia: A systematic review. J Public Health Epidemiol 2015; 7:232-40.

6. Maramis PP, Kaunang ED, Rompis J. The relationship between congenital heart disease and nutritional status in children at RSUP Prof. Dr. RD Kandou Manado 2009-2013. eCl. 2014;2(2).

7. Blasquez A, Clouzeau H, Fayon M, Mouton JB, Thambo JB, Enaud R, Lamireau T. Evaluation of nutritional status and support in children with congenital heart disease. Eur J Clin Nutr 2016; 70:528-31.

8. Ratanachu-ek S and Pongdara A. Nutritional Status of Pediatric Patients with Congenital Heart Disease: Pre- and Post Cardiac Surgery. J Med Assoc Thai 2011;94: S133-7.

9. Tokel K, Azak E, Ayabakan C, Varan B, Aslamaci SA, Mercan S Somatic growth after corrective surgery for congenital heart disease. Turk J Pediat. 2010; 52:58-67.

10. Okoromah CA, Ekure EN, Lesi FE, Okunowo WO, Tijani BO, Okeiyi JC. Prevalence, profile and predictors of malnutrition in children with congenital heart defects: A case-control observational study. Arch Dis Childhood. 2011;96(4):354-60.

11. Artiko B, Salimo H, Lilijanti S. Accelerated growth of children with patent ductus arteriosus before and after closure catheterization [thesis]. Surakarta: Faculty of Medicine, Sebelas University March, 2015.

12. Sahan YO, Kilicoglu E, Tutar ZU. Evaluation of children with congenital heart disease hospitalized with diagnosis of lower respiratory tract infection. J Pediatr Res 2018;5(1):32-6.

13. Nydegger A, Bines JE. Applied nutritional investigation: energy metabolism in infants with congenital heart disease. Nutrition 2006; 22:697- 704.

14. Wahab AS Pediatric Cardiology: Non-Cyanotic Congenital Heart Disease. Jakarta: EGC. 2009.pp: 37-51.

15. Park MK. Pediatric cardiology for practitioners, 5th Edition. Philadelphia: Mosby; 2008.

16. Naqvi N, McCarthy KP, Ho SY. Anatomy of the atrial septum and interatrial communications. J Thorac Dis. 2018;10(Suppl 24): S2837-S2847

17. Muresan D, Marginean C, Zaharie G, Stomatian F, Rotar IC. Complete atrioventricular septal defect in the era of prenatal diagnosis. Medultrason.2016:18;500-7.

18. Schneider DJ, Moore JW. Patent ductus arteriosus. Circulation 2006. 114:1873-82.

19. DiLorenzo MP, Santo A, Rome JJ, Zhang H, Faerber JA, Mercer-Rosa L, Hopper RK. Pulmonary Vein Stenosis: Outcomes in Children With Congenital Heart Disease and Prematurity. Semin Thorac Cardiovasc Surg. 2019;31(2):266-73.

20. Bernstein D. Acyanotic Congenital Heart Disease: Left-to-Right Shunt Lesions, 2015; p.2189-2196.

22. World Food Programme. Defining and measuring malnutrition. In: A manual: measuring and interpreting malnutrition and mortality. Rome: CDC and WFP; 2005. p.15-22

23. Pierre AS, Khattra P, Johnson M, Cender L, Manzano S, Holsti L. Content validation of the infant malnutrition and feeding checklist for congenital heart disease: a tool to identify risk of malnutrition and feeding difficulties in infants with congenital heart disease . Journal of pediatrics. 2010; 25:367-74.

24. Vigneswaran TV, Sinha MD, Valverde I, Simpson JM, Charakida M. Hypertension in Coarctation of the Aorta: Challenges in Diagnosis in Children. Pediatr Cardiol. 2018;39(1):1-10.

25. Sjarif DR, Anggiawan SL, Putra ST, Djer MM. Anthropometric profiles of children with congenital heart disease. Med J Indonesia. 2011; 20:40-5.

26. Parrish CR. Nourishing little hearts: Nutritional implications for congenital heart disease. Practical Gastroenterology August 2011; 98:11- 34.

27. Sari NK, Soetadji A, Kosim MS The Relationship between the Size of Ventricular Septal Defect and Lung Function Sari Pediatrics 2014;16(3):189-94

28. Tokel K, Azak E, Ayabakan C, Varan B, Aslamaci SA, Mercan S Somatic growth after corrective surgery for congenital heart disease. Turk J Pediat. 2010; 52:58-67.

29. Leite HP, de Camargo Carvalho AC, Fisberg M. Nutritional status of children with congenital heart disease and left-to-right shunt. The importance of the presence of pulmonary hypertension. Arg Bras Cardiol. 2005;65(5):403–7.

30. Salih AF. Effects of ventricular septal defect on children's growth pattern in Slemani Pediatric Teaching hospital. Pediatr. Ther. 2015;5: 1–6.

31. Gunawan H, Kaban RK. Pharmacological Therapy of Patent Ductus Arteriosus in Premature Infants: Indomethacin or Ibuprofen?. Sari Pediatrics 2010;11(6):401-8.

32. Shchekochikhin D. Role of Diuretics and Ultrafiltration in Congestive Heart Failure. Pharmaceuticals. 2013; 6:851-66.

33. Ardehali H, Sabbah HN, Burke MA, Sarma S, Liu PP, Cleland JG, et al. Targeting myocardial substrate metabolism in heart failure: potential for new therapies. Eur J Heart Fail 2012;14(2):120–9.

34. Laskowski KR, Russell RR. Uncoupling Proteins in Heart Failure. Curr Heart Fail Rep. 2008; 5(2): 75–9.

35. Stephen C, Kolwicz, Tian R. Glucose metabolism and cardiac hypertrophy. Cardiovascular research 2011; 90:194–201.

36. Shrafian H, Frenneaux P, Opie LH. Metabolic mechanisms in heart failure. Circulation. 2007; 116:434–48.

37. Harelina T, Setyoningrum RA, Sembiring YE Risk Factors for Pneumonia in Children with Congenital Heart Disease. Sari Pediatrics. 2020;21(5):276-81.

38. Hubschman L. Malnutrition in congenital inherited disease. ICAN 2013;5;170-6.

39. Masood, N., Sharif, M., Asghar, RM, Qamar, M., Hussain, I. Frequency of Congenital Heart Diseases at Benazir Bhutto Hospital Rawalpindi. Annals of Pakistan Institute of Medical Sciences. 2010; 6(2):120- 3.

40. Abad-Sinden A, Sutphen Jl. Growth and Nutrition.In: Allen HD, Clark EB, Gutgesell HP, Driscoll DJ, editors. Moss and Adams' heart disease in infants, children, and adolescents. Including the fetus and young adults. 6th ed.vol 1. Philadelphia: Lippincott Wiliams & Wilkins, 2010: p.325-32.

41. Hartaty D, Noormanto, Haksari EL Weight Gain After Transcatheter Closure of Patent Ductus Arteriosus. Sari Pediatrics. 2015;17(3):180-4.

42. Sukandar A, Lilijanti S. Impact of Ventricular Septal Defect Closure using the Cardiac Catheterization Method on Echocardiography and Anthropometric Nutritional Status. Sari Pediatrics. 2020;22(1):43-8.

Univ Heart Ctr 2015;10:182-7.

44. Correia Martins L, Lourenco R, Cordeiro S, et al. Cath-up growth in term and preterm infants after surgical closure of ventricular septal defect in the first year of life. Eur J Pediatr 2016 ;175:573-9.

45. Manso PH, Carmona F, Jacomo AD, Bettiol H, Barbieri MA, Carloti AP. Growth after ventricular septal defect repair: does defect size matter? A 10 years experience. Acta Pediatr 2010;991356-60.

46. Mehta NM, Duggan CP. Nutritional deficiencies during critical illness. Pediatr Clin N Am 2009; 56:1143-60.