Kesmas

Volume 20
Issue 1 *February 2025*

Article 2

2-28-2025

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Recommended Citation

Talib SR , Siswanto JE , Djer MM , et al. Characteristic and Survival Analysis of Infants with Critical Congenital Heart Disease. *Kesmas*. 2025; 20(1): 8-14
DOI: 10.7454/kesmas.v20i1.2041
Available at: https://scholarhub.ui.ac.id/kesmas/vol20/iss1/2

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Talib *et al. Kesmas: Jurnal Kesehatan Masyarakat Nasional (National Public Health Journal)*. 2025; 20 (1): 8-14
DOI: 10.7454/kesmas.v20i1.2041

Kesmas: Jurnal Kesehatan Masyarakat Nasional (National Public Health Journal)

Characteristic and Survival Analysis of Infants with Critical Congenital Heart Disease

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Abstract

Congenital heart disease (CHD) is a major health concern worldwide. This study focused on survival analysis and the factors influencing survival in infants with critical congenital heart disease (CCHD). A total of 79 infants diagnosed with CCHD were identified, with 48.1% (n=38) exhibiting duct-dependent pulmonary circulation, 35.6% (n=28) exhibiting duct-dependent systemic circulation, 6.3% (n=5) exhibiting critical non-duct-dependent, and 10.2% (n=8) exhibiting parallel circulation issues. Of the infants studied, 55.7% (n=44) were male, 78.5% (n=62) had a gestational age of ≥37 weeks, 62% (n=49) had a birth weight of ≥2,500 grams, 59.5% (n=47) exhibited normal fetal growth, 93.7% (n=74) experienced no asphyxia, 91.1% (n=72) had no other congenital disabilities, 87.3% (n=69) had no history of fetal distress, 58.2% (n=46) maintained normal oxygen saturation, and 88.6% (n=70) had an extended stay in the neonatal intensive care unit. The survival analysis indicated that the prognosis of newborns with CCHD was markedly affected by gestational age, birth weight, desaturation, respiratory distress, and hereditary abnormalities. Additional study is required to assess the risk factors influencing the survival of newborns with CCHD.

Keywords: critical congenital heart disease, newborn infant, survival analysis

Introduction

The majority of newborn deaths occur within the first week after birth, primarily due to premature birth, birth asphyxia, infections, and congenital disabilities.[1] In the first five years of life, pneumonia, diarrhea, congenital disabilities, and malaria are the leading causes of death.[1] The World Health Organisation (WHO) estimates that around 240,000 newborns die within one month of birth due to congenital abnormalities, with heart defects, neural tube defects, and Down syndrome being the most common severe abnormalities.[2]

Congenital heart disease (CHD) is the most prevalent congenital disability and presents a significant global health issue. According to The European Surveillance of Congenital Anomalies (EUROCAT) Working Group, 28% of significant congenital anomalies are CHD.[3] The impact of CHD extends beyond the mortality and morbidity of infants and affects the financial burden on families, communities, and countries.[4,5] According to the WHO, congenital impairments cause 7% of newborn mortality, with CHD accounting for 25%.[3] The situation poses a high risk of early infant mortality and necessitates prompt actions to mitigate the issue.[3] Thus, gathering data on survival rates and determinants of survival for infants with CHD is crucial for predicting mortality rates of the disease.

The prevalence of critical congenital heart disease (CCHD) is estimated to be 20-25% of the prevalence of structural CHD.[6–8] World Population Data in 2021 shows that Indonesia's population is about 281,600,000, with the crude birth rate (CBR) being 16 births per 1,000 individuals, meaning there are 4,401,600 yearly births.[9] Given the population and yearly birth rate, the projected incidence of CHD in Indonesia is around 40,934 cases per year, based on an incidence rate of 9.3 per 1,000 live births in Asia.[10] According to the aforementioned structural CHD projections, it is estimated that around 10,233

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Received : July 2, 2024
Accepted : July 15, 2024
Published: February 28, 2025

infants with significant CHD will be born annually in Indonesia and require neonatal emergency treatments. This is roughly 20-25% of the overall prevalence of structural CHD.[5] This study aimed to assess the clinical features, survival rates, and main determinants of survival of infants with CCHD.

Method

This study was a retrospective cohort analysis of live-born children diagnosed with severe congenital cardiac disease at the National Women and Children Health Center in Indonesia. Data was obtained from electronic medical records spanning from January 1, 2020, to December 31, 2022. This study encompassed 79 live-born children diagnosed with CCHD. The authors computed Kaplan-Meier survival estimates based on infant characteristics, including sex, gestational age, birth weight, fetal development, fifth-minute asphyxia, other congenital disabilities, history of fetal distress, saturation levels, and duration of stay in the neonatal intensive care unit (NICU).

Results

During the study period, there were 4,397 live births, of which 955 were suspected cases of CHD that underwent neonatal echocardiography. All singleton newborns were incorporated. Cases diagnosed with specific disorders were eliminated from the study, including Persistent Foramen Ovale (PFO), small Atrial Septal Defect (ASD), non-significant Patent Ductus Arteriosus (PDA), Transient Tachypnea of the Newborn (TTN), and Persistent Pulmonary Hypertension of Newborn (PPHN).

Of the 152 newborns who survived CHD, 73 (48%) were classified as non-critical, while 79 (52%) were identified as critical cases at the National Women and Children Health Center. Table 1 outlines the distribution of CHD diagnoses, with pulmonary atresia occurring most frequently at 25.3% (n=20) and Hypoplastic Left Heart Syndrome (HLHS) at 24.1% (n=19). The characteristics of the infants are delineated in Table 2.

Table 1. Total Number of Patients and Time to Life by Diagnosis

Diagnosis	n = 79 (%)	Time to life in days, mean (min-max)	Death (n)
Duct-Dependent Pulmonary Circulation (DDPC)	**38 (48.1)**		
Tricuspid atresia	4 (5.1)	155.3 (3-365)	2
Ebstein anomaly	2 (2.5)	6.5 (3-10)	2
Pulmonary stenosis	3 (3.8)	14.7 (1-28)	1
Severe pulmonary stenosis-IVS	1 (1.3)	(-)	0
TOF	8 (10.1)	81.6 (4-365)	3
Pulmonary atresia	20 (25.3)	100.2 (1-365)	12
Duct-Dependent Systemic Circulation (DDSC)	**28 (35.6)**		
Mitral atresia	4 (5.1)	56.8 (5-208)	3
HLHS	19 (24.1)	10.4 (0-60)	15
IAA	2 (2.5)	8.5 (2-15)	2
IAA, CAVSD, PDA, Dextrocardia Mirror Image	1 (1.3)	(-)	1
Coarctation of aorta, PDA, PH	1 (1.3)	(-)	0
Complex CHD (combination)	1 (1.3)	(-)	1
Critical Non-Duct-Dependent (CNDD)	**5 (6.3)**		
Truncus arteriosus	3 (3.8)	10.7 (2-21)	2
TAPVD	2 (2.5)	33 (6-60)	2
Parallel Circulation (PC)	**8 (10.2)**		
TGA-IVS	1 (1.3)	(-)	0
TGA-VSD	6 (7.6)	51.3 (1-121)	2
DORV-VSD, TGA	1 (1.3)	(-)	0
Total	**79**		**48**

Notes: IVS = Intact Ventricular Septum, TOF = Tetralogy of Fallot, HLHS = Hypoplastic Left Heart Syndrome, IAA = Interrupted Aortic Arch, CAVSD = Complete Atrio-Ventricular Septal Defect, PDA = Patent Ductus Arteriosus, PH = Pulmonary Hypertension, TAPVD = Total Anomalous Pulmonary Venous Drainage, TGA = Transposition of the Great Arteries, VSD = Ventricular Septal Defect, DORV = Double Outlet Right Ventricle.

A total of 79 infants diagnosed with CCHD were identified as having duct-dependent pulmonary circulation (DDPC) of 48.1% (n=38), duct-dependent systemic circulation (DDSC) of 35.6% (n=28), critical non-duct-dependent (CNDD) of 6.3% (n=5), and parallel circulation (PC) of 10.2% (n=8). Most infants, 60.8% (n=48), died within one year of observation. The majority of infants diagnosed with HLHS died before reaching aged three months.

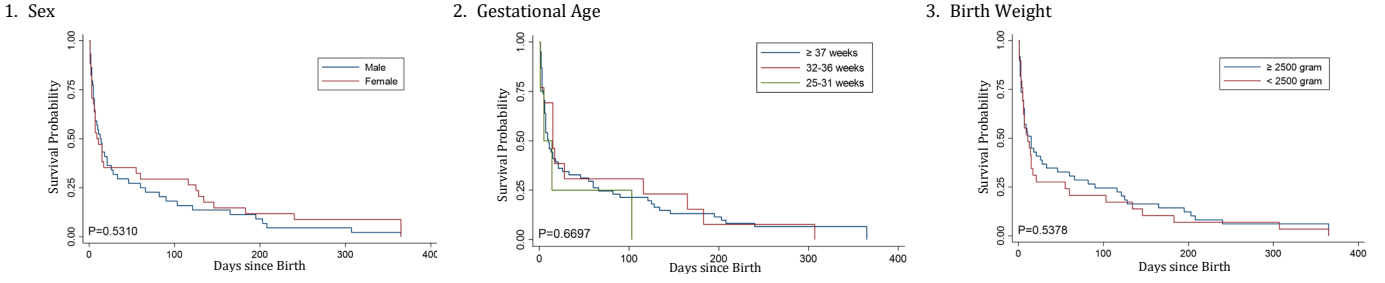
Among the infants, 55.7% (n=44) were male, 78.5% (n=62) had a gestational age of ≥37 weeks, 62% (n=49) infants with birth weight of ≥2,500 grams, 59.5% (n=47) of infants with normal fetal growth, 93.7% (n=74) of infant without asphyxia, 91.1% (n=72) of infants without other congenital disabilities, 87.3% (n=69) of infants without fetal distress, 58.2% (n=46) of infants with normal oxygen saturation, and 88.6% (n=70) of infants with an extended stay in the NICU.

The proportion of infants by characteristics is outlined in Table 2.

Table 2. Characteristics of Infants with Critical Congenital Heart Disease

Characteristic	n = 79 (%)
Sex	
Male	44 (55.7)
Female	35 (44.3)
Gestational age	
≥37 weeks	62 (78.5)
32-36 weeks	13 (16.5)
25-31 weeks	4 (5.0)
Birth weight	
≥2,500 grams	49 (62.0)
<2,500 grams	30 (38.0)
Fetal growth	
Normal	47 (59.5)
IUGR	32 (40.5)
Asphyxia in the fifth minute	
Absent	74 (93.7)
Present	5 (6.3)
Other congenital disabilities	
Absent	72 (91.1)
Present	7 (8.9)
Fetal distress	
Absent	69 (87.3)
Present	10 (12.7)
Saturation	
Normal	46 (58.2)
Abnormal	33 (41.8)
Length of stay in NICU	
<7 days	70 (88.6)
≥7 days	9 (11.4)

Notes: IUGR = Intrauterine Growth Restriction, NICU = Neonatal Intensive Care Unit



No. at risk	0	100	200	300	400
Male	0	36	4	2	2
Female	1	24	6	1	3

No. at risk	0	100	200	300	400
≥37 w	1	48	6	3	4
32-36 w	0	9	3	0	1
23-31 w	0	3	1	0	0

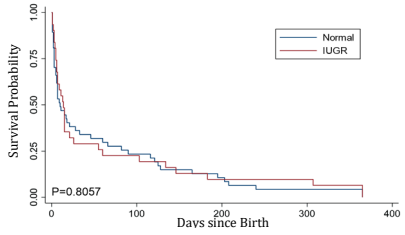
No. at risk	0	100	200	300	400
≥2,500 g	0	37	6	3	3
<2,500 g	1	23	4	0	2

Figure 1. Kaplan-Meier survival analysis showed the impact of sex (1), gestational age (2), and birth weight (3) on the survival of infants with Critical Congenital Heart Disease at the National Women and Children Health Center in Indonesia, 2020-2022.

The Kaplan-Meier survival curve showed that the survival of infants with CCHD varied according to their characteristics (Figure 1). The Kaplan-Meier curve suggests a disparity in survival duration between males and females. The log-rank test results indicated no significant difference (p-value >0.05). The survival probability of infants born at a gestational age of 23-31 weeks was lower than that of infants born at 32-36 weeks and those delivered at 37 weeks or later. Infants aged beyond 37 weeks constituted the largest group (78.5%).

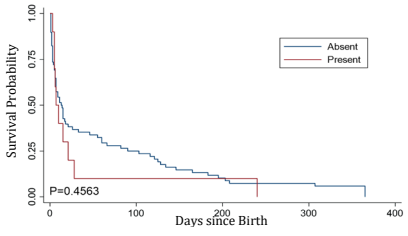
The survival of newborns with CCHD varied according to gestational age. The log-rank test found no significant difference (p-value >0.05). The survival probability based on birth weight showed no significant difference in survival time between infants with a birth weight of ≥2,500 grams and those with a birth weight of <2,500 grams (p-value >0.05).

1. Fetal Growth



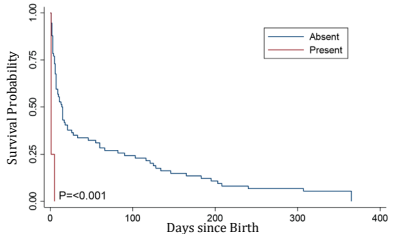
No. at risk	0	100	200	300	400
Normal	0	36	6	3	2
IUGR	1	24	4	0	3

2. Fetal Distress History



No. at risk	0	100	200	300	400
Absent	1	51	10	2	5
Present	0	9	0	1	0

3. Asphyxia

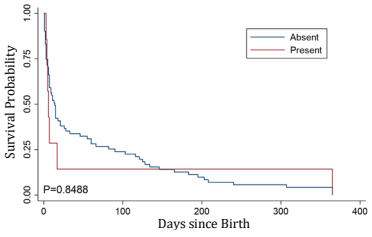


No. at risk	0	100	200	300	400
Absent	0	56	10	3	5
Present	1	4	0	0	0

Figure 2. The Kaplan-Meier survival analysis showed the impact of fetal growth (1), fetal distress history (2), and asphyxia (3) on the survival of infants with Critical Congenital Heart Disease at the National Women and Children Health Center in Indonesia, 2020-2022

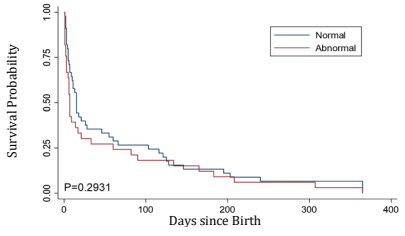
A Kaplan-Meier curve on fetal growth indicates no significant difference in survival time between infants with normal growth and those with Intrauterine Growth Restriction (IUGR) (p-value >0.05). In cases of fetal distress, a disparity in survival duration was observed between infants experiencing fetal distress and those not affected by it. The log-rank test found no significant difference (p-value >0.05). Asphyxia demonstrated a disparity in survival duration between infants born with asphyxia and those without. The log-rank test recorded a significant difference (p-value <0.05) in newborns with asphyxia. Kaplan-Meier curves for other congenital disabilities, oxygen saturation, and length of stay in the NICU indicated no difference in survival time for infants with CCHD. The log-rank test indicated no significant differences in other congenital disabilities, oxygen saturation, and length of stay in the NICU (p-value >0.05).

1. Other Congenital Defect



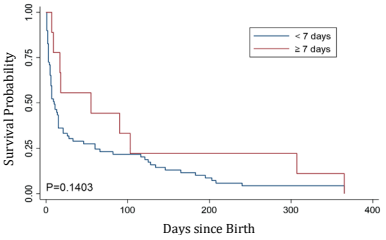
No. at risk	0	100	200	300	400
Absent	1	54	10	3	4
Present	0	6	0	0	1

2. Saturation



No. at risk	0	100	200	300	400
Normal	1	33	7	2	3
Abnormal	0	27	3	1	2

3. Length of Stay in NICU



No. at risk	0	100	200	300	400
<7 days	1	54	9	3	3
≥7 days	0	6	1	0	2

Figure 3. The Kaplan-Meier survival analysis showed the impact of another congenital disability (1), oxygen saturation (2), and length of stay in the Neonatal Intensive Care Unit (3) on the survival of infants with Critical Congenital Heart Disease at the National Women and Children Health Center in Indonesia, 2020-2022.

Discussion

A total of 79 infants diagnosed with CCHD were identified with developmental disorders: DDPC of 48.1% (n=38), DDSC of 35.6% (n=28), CNDD of 6.3% (n=5), and PC of 10.2% (n=8). The majority of diagnoses for live-born infants with CCHD were pulmonary atresia at 25.3% (n=20), followed by HLHS at 24.1% (n=19). The one-year survival probability of newborns with CCHD was 39.2%. The majority of deaths occur before three months of age. This data aligned with a study conducted in Beijing, which revealed that deaths among newborns with CCHD predominantly occur within the first-week post-birth.[11] Previous studies indicated that newborn survival diminished by 70% by 28 days of age.[12,13] A study in developing countries determined that the survival rate for CCHD was 90.4% (95% CI 89–91.8%) at one month and 69.3% (95% CI 67.2–71.4%) at one year.[14]

This study, based on the Kaplan-Meier curve on sex, showed a difference in survival time between males and females. Using the Kaplan-Meier curve concerning sex demonstrated a disparity in survival duration between males and females.[15] Additionally, the log-rank test results indicated no statistically significant difference (p-value >0.05). The survival probability of infants born at a gestational age of 23-31 weeks was lower than that of infants born at 32-36 weeks and those delivered at ≥37 weeks. Infants with a gestational age ≥37 weeks constituted the largest group (78.5%). Infants with a birth weight of >2,500 grams were the highest proportion (62%). Infants born before 39 weeks of gestation have a

greater death and morbidity rate than term infants. Premature newborns with CHD had worse outcomes than full-term infants.[16] According to one study, the one-year survival rate for babies born before 28 weeks was 79.4%, and the one-year survival rate for those born after 37 weeks was 97.1%.[17] The ≥39-week group showed substantial evidence of improved survival, followed by lower evidence at 24–31 and 37–38 weeks, and no evidence at 32–36 weeks, according to another study.[18]

PA-IVS is a critical congenital heart defect characterized by ductal-dependent pulmonary circulation. This study found the highest prevalence of pulmonary atresia with an intact interventricular septum, pulmonary atresia with ventricular septal defect, and its combination with Tetralogy of Fallot was observed among cases of CCHD. The previous study found that 142 of the 491 tested subjects were affected with CCHD.[14] Infants with pulmonary atresia frequently die before one year of age.[19]

HLHS is a form of CCHD disease that causes structural underdevelopment of the left side of the heart, encompassing the mitral valve, left ventricle, aortic valve, ascending aorta, and aortic arch.[20] The mortality rate in this study was highest among newborns diagnosed with HLHS, at 24.1%. Moreover, the majority of infants died before reaching 28 days of age. This finding aligned with the study in Türkiye, which indicated that the death rate escalated to 80% within three months.[13]

In comparison, studies in metropolitan Atlanta discovered that the survival rates of newborns with HLHS into adolescence have markedly improved in recent years.[15–18] This study found that the largest mortality rate occurred in newborns with HLHS within the first week of life. The reason is that these infants did not receive intervention, surgery, or subsequent Norwood treatment in underdeveloped countries such as Indonesia.

Low birth weight significantly increases the risk of mortality in newborns with CCHD.[12,14] Gestational age significantly influences the survival of infants with CCHD.[21] Small for gestational age (SGA) is the primary cause of postnatal mortality in newborns with CCHD.[21] This study discovered that most newborns with CCHD exhibited normal gestational age and birth weight.

The CHD can significantly impact the entire family unit and influence not only the patient's quality of life but also the physical, emotional, and occupational well-being of their loved ones.[22–24] Despite advancements in therapies, numerous patients with CCHD remain uncured and require lifelong management.[22,25,26] Parents of children with CCHD may encounter psychological issues, including anxiety, depression, and hopelessness. They may also encounter stress responses, including acute stress disorder or post-traumatic stress disorder.[23,24,27] In addition to the elevated mortality and morbidity associated with CCHD, surgical procedures and interventions can adversely impact family finances and increase the load on the state.[28–31]

Conclusion

In this study, the survival rate of newborns with CHD is 39.2% after one year of surveillance. The Kaplan-Meier curves reveal disparities in survival time between males and females for gender, gestational age, and asphyxia. More research is needed to determine the risk factors influencing the survival of neonates with IUGR. These findings give evidence for doctors, health workers, researchers, and legislators to enhance services and develop CHD preventive policies.

Abbreviations

WHO: World Health Organization; CHD: Congenital Heart Disease; CCHD: Critical Congenital Heart Disease; NICU: Neonatal Intensive Care Unit; HLHS: Hypoplastic Left Heart Syndrome; DDPC: Duct-Dependent Pulmonary Circulation; DDSC: Duct-Dependent Systemic Circulation; CNDD: Critical Non-Duct-Dependent; PC: Parallel Circulation; IUGR: Intrauterine Growth Restriction.

Ethics Approval and Consent to Participate

The hospital's ethical committee at the Harapan Kita National Women and Children Health Center reviewed and approved the study.

Competing Interest

All the authors declare that there are no conflicts of interest.

Availability of Data and Materials

All data generated or analyzed during this study are included in this published article (and its supplementary information files).

Authors' Contribution

All individuals, including SRT, JES, MMD, NS, SN, KAKT, and AA, who meet the criteria for authorship have been listed as authors. It is worth noting that all authors have contributed equally to this work, ensuring transparency and accountability for the content, including participation in the concept and design. Specifically, SRT, NS, SN, and KAKT analyzed and interpreted the data, while JES and MMD contributed valuable insights to the discussion during

the writing process. AA conducted the final revision of the manuscript, which SRT, JES, and MMD acknowledged. Additionally, each author certifies that this or similar material has not been submitted or published in any other publication.

Acknowledgment

The authors thank all the Cardiology and Neonatology Working Group staff at Harapan Kita National Women and Children Health Center for their support and cooperation.

References

1. World Health Organization. Newborn mortality. Geneva: World Health Organization; 2024.
2. World Health Organization. Congenital disorders. Geneva: World Health Organization; 2023.
3. Bergman JEH, Perraud A, Barišić I, et al. Updated EUROCAT guidelines for classification of cases with congenital anomalies. Birth Defect Res. 2024; 116 (2): e2314. DOI: 10.1002/bdr2.2314.
4. Wu Z, McGoogan JM. Characteristics of and important lessons from the Coronavirus Disease 2019 (COVID-19) outbreak in China: Summary of a report of 72,314 cases from the Chinese Center for Disease Control and Prevention. JAMA. 2020; 323 (13): 1239–1242. DOI: 10.1001/jama.2020.2648.
5. Hwang IC, Sisavanh M, Billamay S, et al. Congenital heart disease at Laos Children's Hospital: Two-year experience. Pediatr Int. 2017; 59 (3): 271–279. DOI: 10.1111/ped.13156.
6. Bravo-Valenzuela NJ, Peixoto AB, Araujo Júnior E. Prenatal diagnosis of congenital heart disease: A review of current knowledge. Indian Heart J. 2018; 70 (1): 150-164. DOI: 10.1016/j.ihj.2017.12.005.
7. Bakker MK, Bergman JEH, Krikov S, et al. Prenatal diagnosis and prevalence of critical congenital heart defects: An international retrospective cohort study. BMJ Open. 2019; 9 (7): e028139. DOI: 10.1136/bmjopen-2018-028139.
8. Çaylan N, Yalçın SS, Tezel B, et al. Evaluation of critical congenital heart disease from 2018 to 2020 in Turkey: A retrospective cohort study. BMC Pregnancy Childbirth. 2023; 23: 871. DOI: 10.1186/s12884-023-06193-1.
9. Kaneda T, Greenbaum C, Haub C. World population data sheet 2021. Washington, DC: Population Reference Bureau; 2021.
10. Liu Y, Chen S, Zühlke L, et al. Global birth prevalence of congenital heart defects 1970-2017: Updated systematic review and meta-analysis of 260 studies. Int J Epidemiol. 2019; 48 (2): 455-463. DOI: 10.1093/ije/dyz009.
11. Zhang W, Xu HY, Zhang YC, et al. Delayed diagnosis of critical congenital heart defects predicting risk factors and survival rate in newborns in Beijing: A retrospective study. J Int Med Res. 2021; 49 (7): 1–10. DOI: 10.1177/03000605211028028.
12. Lopes SAVDA, Guimarães ICB, Costa SF de O, et al. Mortality for critical congenital heart diseases and associated risk factors in newborns: A cohort study. Arq Bras Cardiol. 2018; 111 (5): 666-673. DOI: 10.5935/abc.20180175.
13. Çaylan N, Yalçın SS, Tezel B, et al. Investigation of infant deaths associated with critical congenital heart diseases: 2018–2021, Türkiye. BMC Public Health. 2024; 24: 441. DOI: 10.1186/s12889-024-17966-4.
14. Mat Bah MN, Sapian MH, Jamil MT, et al. Survival and associated risk factors for mortality among infants with critical congenital heart disease in a developing country. Pediatr Cardiol. 2018; 39 (7): 1389–1396. DOI: 10.1007/s00246-018-1908-6.
15. Meyer SL, Wolff D, Ridderbos FJS, et al. Sex differences in cardiac function and clinical outcome in patients with a Fontan circulation. Int J Cardiol Congenit Hear Dis. 2021; 5: 100197. DOI: 10.1016/J.IJCCHD.2021.100197.
16. Cheung PY, Hajihosseini M, Dinu IA, et al. Outcomes of Preterm Infants with Congenital Heart Defects After Early Surgery: Defining Risk Factors at Different Time Points During Hospitalization. Front Pediatr. 2021; 8: 616659. DOI: 10.3389/FPED.2020.616659.
17. Benjamin RH, Nguyen JM, Canfield MA, et al. Survival of neonates, infants, and children with birth defects: A population-based study in Texas, 1999–2018. Lancet Reg Heal - Am. 2023; 27: 100617. DOI: 10.1016/J.LANA.2023.100617.
18. Gimeno L, Brown K, Harron K, et al. Trends in survival of children with severe congenital heart defects by gestational age at birth: A population-based study using administrative hospital data for England. Paediatr Perinat Epidemiol. 2023; 37 (5): 390. DOI: 10.1111/PPE.12959.
19. Levine J, Mayer JE, Pulmonary Atresia With Intact Ventricular Septum. In: Walsh EP, Teele SA, Mayer JE, Brown DW, editors. Nadas' Pediatr Cardiol. 3rd ed. Elsevier; 2025. p. 471-477. DOI: 10.1016/B978-1-4557-0599-3.00046-6
20. Kritzmire SM, Cossu AE. Hypoplastic left heart syndrome. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023.
21. Steurer MA, Peyvandi S, Baer RJ, et al. Impaired fetal environment and gestational age: What is driving mortality in neonates with critical congenital heart disease? JAHA J Am Heart Assoc. 2019; 8 (22): e013194.
22. Azhar AS, Al Shammasi ZH, Higgi RE. The impact of congenital heart diseases on the quality of life of patients and their families in Saudi Arabia: Biological, psychological, and social dimensions. Saudi Med J. 2016; 37 (4): 392–398. DOI: 10.15537/smj.2016.4.13626.
23. Zych-Krekora K, Sylwestrzak O, Grzesiak M, et al. Impact of prenatal and postnatal diagnosis on parents: Psychosocial and economic aspects related to congenital heart defects in children. J Clin Med. 2023; 12 (18): 5773. DOI: 10.3390/jcm12185773.
24. Sprong MCA, Zwagerman IR, Soeters L, et al. Prioritizing family-centered developmental care: Insights from parents of children with critical congenital heart disease: A qualitative study. Eur J Pediatr. 2024; 183 (9): 3863-3876. DOI: 10.1007/s00431-024-05600-9.
25. Centers for Disease Control and Prevention. Living with a congenital heart defect | Congenital heart defects (CHDs). Atlanta, GA: Centers for Disease Control and Prevention; 2024.
26. Marelli A, Miller SP, Marino BS, et al. Brain in congenital heart disease across the lifespan: The cumulative burden of injury. Circulation. 2016; 133 (20): 1951–1962. DOI: 10.1161/CIRCULATIONAHA.115.019881.
27. Lisanti AJ. Parental stress and resilience in congenital heart disease: A new frontier for health disparities research. Cardiol Young. 2018; 28 (9): 1142-1150. DOI: 10.1017/S1047951118000963.
28. Grosse SD, Peterson C, Abouk R, et al. Cost and cost-effectiveness assessments of newborn screening for critical congenital heart disease using pulse oximetry: A review. Int J Neonatal Screen. 2017; 3 (4): 34. DOI: 10.3390/ijns3040034.
29. Chamorro Velásquez CL, Sandoval Reyes NF, Taborda Restrepo A, et al. The economic impact of critical congenital heart disease to the health system and families in Colombia. F1000Res. 2019; 8: 92. DOI: https://f1000research.com/articles/8-92/v1.

30. Su Z, Zou Z, Hay SI, et al. Global, regional, and national time trends in mortality for congenital heart disease, 1990–2019: An age-period-cohort analysis for the Global Burden of Disease 2019 study. EClinicalMedicine. 2022; 43: 101249. DOI: 10.1016/j.eclinm.2021.101249.
31. Bai Z, Han J, An J, et al. The global, regional, and national patterns of change in the burden of congenital birth defects, 1990–2021: An analysis of the Global Burden of Disease Study 2021 and forecast to 2040. EClinicalMedicine. 2024; 77: 102873. DOI: 10.1016/j.eclinm.2024.102873.