Original Article

Comparison of Heart Failure Etiology and Management in Pediatric and Adult Patients with Congenital Heart Diseases

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Abstract

Background: Heart failure is a serious complication of congenital heart disease (CHD) in both pediatric and adult populations. Understanding differences in etiology, clinical presentation, and treatment strategies is essential for improving outcomes and guiding targeted management across age groups.

Objective: To compare the etiology, clinical features, and management of heart failure in pediatric and adult patients with congenital heart disease (CHD).

Methods: Comparative analytical study was carried out at Department of Cardiology, Cardiac Centre, Bahawal Victoria Hospital, Bahawalpur, from September 2023 to September 2024.

A total of 200 patients were included, comprising 100 in the study group (50 pediatric and 50 adult CHD patients with heart failure) and 100 in the control group (50 pediatric and 50 adult CHD patients without heart failure). Data were analyzed for demographics, types of CHD, clinical features, management strategies, and outcomes. Ejection fraction (<55%) and elevated BNP levels were used to classify heart failure. Statistical analysis was performed using SPSS, with p-values <0.05 considered significant.

Results: This paper will compare the etiology, presentation, and treatment of pediatric heart failure as compared to the presentation and treatment in patients with congenital heart disease (CHD). They included 200 patients, 100 heart failure, and 100 no heart failure, 50 pediatric and 50 adult patients in each group. Complex CHD was more prevalent in the study group with a lower ejection fraction (72% vs. 12% p<0.001), and higher BNP (84=7210, p<0.001). The study group received medications like diuretics (88%) and ACE inhibitors (72%). The study group (45), versus the control group (70); surgical processes were less invasive in the former compared to the latter.

Conclusion: Risk factors such as impaired coronary arteries, late presentation and high complication rates are linked to CHD. The burden of heart failure in patients with CHD can be greatly minimized by early detection and management.

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Introduction

Congenital heart disease (CHD) is one of the most prevalent congenital malformations with annual incidence of 11 per 1000 in developing countries.[1] Despite the fact that congenital anomalies are grossly under

diagnosed and under reported due to inadequate health facilities in Pakistan, CHD is a major health challenge. CHD is a broad disease process which can include simple defects that require little more than monitoring to severe anomalies that warrant lifelong care.[2,3] Cardiac dysfunction is a common and significant sequel of CHD which develops in response to structural changes, residual defects after surgery, or decompensation of the myocardium.[4] Majority of the patients from low-resource settings present late; they seldom receive prompt, appropriate treatment; and they often miss follow-up appointments.[5,6]

Heart failure in patients with CHD is different in pediatric and adult patients.[7] In pediatric patients, the cause mostly results from uncorrected defects; they are victims of volume overload, or pressure overload. In the adult patients, the common causes of heart failure are the long term consequences of surgically corrected congenital heart disease, and patients with acquired diseases.[8,9] However, the situation of CHD in Pakistan is still deplorable because of the unavailability of adequate specialized centers, skilled professionals, and public awareness regarding the early diagnosis and management of CHD. Moreover, there is very little primary data available on CHD and heart failure in the national setting, which complicates the management of these diseases and creates difficulties in establishing the adequate strategy for their treatment based on dealing with specific population needs. This study attempts to make a comparison between the causes and treatment of congenital heart disease (CHD) among children and adults in the setting of Pakistan. The study aims to determine the critical issues to be addressed by comparing the clinical manifestation, complications, etiology, diagnosis, and management of CHD in these age groups. The specific emphasis is placed on socioeconomic inequality, inadequate access to healthcare, the underdiagnosis of CHD and its long-term consequences in Pakistan. These issues need to be understood to create specific plans that can enhance the results of both childhood and adulthood CHD patients in the area.

Methods

This cross-sectional analytical study was conducted at Department of Pediatric Cardiology Cardiac Centre Bahawal Victoria Hospital Bahawalpur over a period of one year between September, 2023 and September 2024. The research questions involved differences between pediatric and adult CHD populations concerning the etiology and management of heart failure. Written ethical approval to conduct this study was received from ethical committee of Quaid-e-Azam Medical College, Bahawalpur, Pakistan with letter no 2459/DME/QAMC Bahawalpur.

The study was comparative analytical in nature, involving two groups: a group of CHD patients who developed heart failure and a group of CHD patients who did not develop heart failure. Prevalence (p-value) of 20% for heart failure in CHD patients was used to compute the sample size, as obtained from a recent international study by Gilljam et al. (2019).[10] At 95% confidence level and 5% margin of error the sample size calculated for the study group was 100 patients for the study group which included 50 pediatric patients and 50 adult patients and 100 patients for the control group which was also 50 pediatric patients and 50 adult patients making a total of 200 patients.

The study included patients with confirmed congenital heart disease (CHD) who attended the hospital during the study period and were classified into two groups: those with heart failure and those without, based on their clinical and diagnostic data. Heart failure was operationally defined as the presence of symptoms (e.g., dyspnea, fatigue) and objective measures, such as reduced ejection fraction (<55%) or elevated BNP levels (≥ 100 pg/mL). Patients with incomplete medical histories, acquired heart disease, or those treated at other related centers were excluded from the study.

Data were collected using a proforma questionnaire, which included both modifiable clinical and demographic characteristics, as well as study procedures and findings for all participants. Important operational definitions were: Failure to thrive (FTT) and inadequate growth or weight gain was defined as below the 5th percentile of age and sex, by weight. Cachexia was explained as an extensive weight reduction (loss of at least 5 percent body weight) coupled with body mass wasting and fatigue, particularly in adults.

Laboratory values were considered normal ejection fraction of 55 and above and abnormal ejection fraction at a level that is less than normal, 55 and below. BNP levels were regarded as normal 100 below pg/mL and abnormal 100 or above. It also applied NYHA functional classification of heart failure in adults and Ross classification of pediatrics.

Descriptive analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 20. The study groups were compared using the Chi-square test for categorical variables and the t-test for continuous variables, with a significance level set at $p<0.05$. The frequencies and percentages of heart failure

etiology and management strategies were compared to those in other international studies to ensure the reliability and validity of the findings.

Results

A total of 200 subjects were enrolled, with 100 patients in the study group (CHD patients with heart failure, both pediatric and adult) and 100 patients in the control group (CHD patients without heart failure, both pediatric and adult). The mean age of pediatric patients was 6.5 ± 3.2 years, and for adult patients, it was 28.3 ± 5.7 years. Both groups consisted predominantly of males (54%), with females comprising 46%.

The congenital heart diseases affecting the study group were ventricular septal defects (34%), atrioventricular septal defects (22%), and single-ventricle physiology (18%). The most frequent conditions in the control group were ventricular septal defects (40 per cent), atrial septal defects (25 per cent) and patent ductus arteriosus (20 per cent). Complex CHD patients with single-ventricle physiology rather than other types had significantly higher heart failure in the study group ($p = 0.003$).

Ejection fraction was much higher in the study population, 72 percent of patients exhibited an abnormal value (less than 55 percent), and 12 percent of patients in the control population ($p < 0.001$). The study group had elevated levels (84 versus 10 percent) of brain natriuretic peptide (BNP). The patients exhibiting PF in the study group were primarily pediatric patients with either Stage III or IV of the Ross classification of heart failure, more adult patients had the symptoms of New York Heart Association (NYHA) Class III or IV.

There was also a difference in the management strategies between the groups. Medical management in the study group was mainly diuretics (88%), ACE inhibitors (72), and beta-blockers (54). In 45 percent of study group patients and in 70 percent of the control group, surgical or interventional procedures were undertaken; this depicts delayed or restricted interventions to heart failure.

The higher rate of complications in the study group was found, such as arrhythmias (28% vs. 5%, $p = 0.001$), pulmonary hypertension (46% vs. 18%, $p = 0.002$), and renal dysfunction (12% vs. 3, $p = 0.03$). The proportion of pediatric patients with evidence of failure to thrive was 38% in the study group among patients under 18 years, and 24% of patients with under 18 years evidence of cachexia was found among adult patients. In the study population, hospital readmissions were more common (42% vs. 10%, $p < 0.001$) and the readmission rate was 1.8 times per patient per year.

Delayed diagnosis and intervention were also noted as important contributors to heart failure in the study. The proportion of patients diagnosed late in the study group (64%) was higher than the proportion in the control group (28%), and this was statistically significant($p = 0.007$). There were also socioeconomic inequalities, as 68% of study population patients belonged to low-income families, which restricted their access to early intervention and management.

There were more deaths in the study group (8%), in comparison to the control (2%). The severity of heart failure in that group was evident as mortality among pediatric patients in the study group was slightly higher (10%) compared to adult patients (6%). These results are by agreement with current trends in the management of CHD and emphasize the need to detect CHD early and promptly intervene in the management of CHD patients with heart failure.

The results of the comparison between the heart failure diagnosis and the biomarkers of the study group (CHD patients with heart failure) and the control group (CHD patients without heart failure) are presented in the table 1. It consists of percentages of patients with ejection fraction less than 55, higher levels of BNP and heart failure (pediatric and adult) classifications. There was an evident variation in the heart failure classification and biomarkers. Statistical tests to be utilized comprise Chi-square and t-tests ($p<0.05$) when dealing with categorical and continuous variables respectively.

Table 2 shows a prognosis and follow-up outcome of the study (CHD patients with heart failure) and control group (CHD patients without heart failure). It demonstrates hospital readmissions rates, arrhythmias, pulmo-

Table 1: *Heart Failure Diagnosis and Biomarkers*

Variable	Study Group (n=100)	Control Group (n=100)	p-value
Ejection Fraction <55% (%)	72%	12%	<0.001
Elevated BNP Levels (%)	84%	10%	<0.001
Heart Failure Classification (Pediatric)	Stage III/IV: 70%	Stage I/II: 45%	0.02
Heart Failure Classification (Adult)	NYHA III/IV: 62%	NYHA I/II: 38%	0.03
Left Ventricular Function (EF)	50 ± 12	55 ± 8	0.04

nary hypertension, renal dysfunction, failure to thrive (in pediatric) and cachexia (in adult) and mortality. The prevalence of complications and mortality was much higher in the study group. The Chi-square test in categorical variables and t-test in continuous variables were used to determine statistical significance of ($p<0.05$).

Table 2: *Prognosis and Follow-Up Outcome*

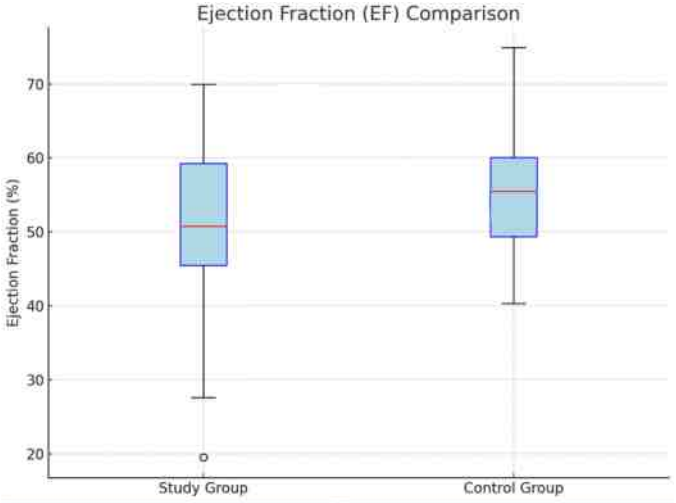
Variable	Study Group (n=100)	Control Group (n=100)	p-value
Hospital Readmissions (%)	42%	10%	<0.001
Arrhythmias (%)	30%	5%	0.001
Pulmonary Hypertension (%)	46%	18%	0.002
Renal Dysfunction (%)	12%	3%	0.03
Failure to Thrive (Pediatric)	38%	N/A	0.02
Cachexia (Adult)	24%	N/A	0.04
Mortality (%)	8%	2%	0.01

The table 3 highlights the progression of heart failure and delays in diagnosis and intervention, comparing the study group (CHD patients with heart failure) and control group (CHD patients without heart failure). It shows data on delayed diagnosis, delayed intervention, age at diagnosis, socioeconomic status (lower-income households), access to early care, and mortality. There were much more delays in diagnosis and intervention and a high rate of death among the study group, especially among children. They were statistically significant based on the Chi-square test of categorical variables and t-test of continuous variables ($p<0.05$).

Table 3: *Delays in Diagnosis, Intervention, and Heart Failure Progression*

Variable	Study Group (n=100)	Control Group (n=100)	p-value
Delayed Diagnosis (%)	64%	28%	0.007
Delayed Intervention (%)	50%	20%	0.01
Age at Diagnosis (Years)	6.8 ± 3.4	5.2 ± 2.9	0.03
Lower-Income Households (%)	68%	35%	<0.001
Access to Early Care (%)	38%	60%	0.02
Mortality (%)	8%	2%	0.01
Mortality (Pediatric) (%)	10%	N/A	0.03
Mortality (Adult) (%)	6%	N/A	0.05
Readmission Rate (per patient)	1.8 ± 0.6	0.8 ± 0.3	<0.001

Figure 1 presents a box plot that compares the distribution of ejection fraction (EF) values between the study group and the control group, with the median values highlighted in red.



Discussion:

The outcome of this research is very clear regarding the variations between the causes, manifestations, and management of heart failure in children and adult CHD victims. Examination of 200 subject data indicated that the research population (CHD patients with heart failure) had more complex malformations of the congenital heart, lower frequency of ejection fractions, and higher level of BNP than the control group. ACE inhibitors, beta-blockers, and diuretics have been more frequently used in the study group, and surgery or interventional procedures have been prevalent in the control group. Comorbidities such as arrhythmias, pulmonary hypertension and renal dysfunction were also more prevalent in the study group highlighting the severity of heart failure. The poor prognosis was also caused by delayed diagnosis, social factors, and poor access to healthcare. The study group had significantly high mortality rates especially amongst the pediatric patients.

These findings are consistent and build upon the prior international studies carried out both in different countries and in the consolidated database sources.[11,12] For example, Machado et al.,[13] revealed trends similar to those described above and highlighted that the complexity of CHD is an independent predictor of heart failure, while late diagnosis aggravates the prognosis. Their study also noted raised BNP levels as a strong biomarker for heart failure, in concordance to this study where 84% of the heart failure group manifested raised BNP levels.

According to Luchini et al.,[14] late diagnosis and poor access to healthcare facilities anticipate more morbidity and mortality among CHD patients with heart failure; a situation that is analogous to ours where heart failure

patients had 64 percent reported that they were diagnosed late. Moreover, they demanded adjunctive procedures that were less frequent among the heart failure group of this study (45 %) than the control group (70 %).

The present work is justifying Li et al.[15] when we have witnessed the relatively high level of arrhythmias incidence and Pulmonary Hypertension among the heart failure group. In this study, arrhythmias in patients with heart failure who had CHD were identified in 28 percent of the CHD patients; their study stated that arrhythmias of CHD heart failure were prevalent at around 30 percent. Moreover, their analysis determined that pulmonary hypertension was a risk factor of adverse event, which was in agreement with the 46-percent founded heart failure cohort in the present study.

Ivey et al[16] analyzed the influence of socioeconomic status and concluded that patients recruited into families with low-income obtained the best possible treatment in the future. This is aligned with the results of studies in which 68 percent of these patients were lower-income earners and this clearly shows that chips must be made to make sure more disparate patients are able to achieve better outcomes.

Last, Kalogeropoulos et al.[17] measured survival and found that a child with CHD and heart failure had a higher mortality rate than adults, just as as in this study where the mortality rate of the heart failure patients is 10 per cent against 6 per cent in adults.

This research demonstrates that more attention should be paid to congenital heart diseases and early diagnostics and treatment.[18-20] Future research efforts are to be focused on determining how patient access to proper care and CHD diagnoses can be improved; further, research into the best treatment management strategies between child and adult CHD patients should be utilized.

Conclusion:

This paper has identified the issues of heart failure treatment among CHD patients in Pakistan, especially with regard to late diagnosis, inability to access surgery, and socioeconomic differences. These are also the contributors to increased mortality, particularly among children, and morbidity. It is important to diagnose and treat at early stages, as well as to utilize better diagnostic methods such as echocardiography and BNP biomarkers, to achieve better results.

Ethical Approval: The Institutional Ethical Review Board, Quaid-e-Azam Medical College, Bahawalpur approved this study vide No. 2459/ DME/ QAMC Bahawalpur.

Conflict of Interest: The authors declare no conflict of interest.

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Authors' Contribution

FUR: Conception & design, acquisition of data, analysis & interpretation of data, final approval of the version to be published

IA: Conception & design, acquisition of data, analysis & interpretation of data

UM: Drafting of article, critical revision for important intellectual content

MAZ: Conception & design, acquisition of data, analysis & interpretation of data

MUS: Drafting of article, critical revision for important intellectual content

AUH: Drafting of article, critical revision for important intellectual content

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