

Research Article

Association Between Left Ventricular Anatomical Dimensions, Cardiac Function, and Response to Diuretic Therapy in Children with Congestive Heart Failure

Irum Javaid¹, Farman Ullah^{2*}, Muhayyu Din Babar³, Palvesha Amin⁴, Noreen Anwar⁵, Muhammad Atta Ur Rahman Adnan⁶

¹Assistant Professor, Department of Anatomy, Northwest School of Medicine, Peshawar, Pakistan.

^{2*}Assistant Professor, Department of Cardiology, Kalifa Gul Nawaz Teaching Hospital, MTI Bannu, Pakistan.

³Trainee Registrar, Department of Cardiology, Mufti Mehmood Memorial Teaching Hospital, Dera Ismail Khan, Pakistan.

⁴Senior Registrar Paediatric Cardiac Anesthesia, Department of Anesthesia, Rawalpindi Institute of Cardiology, Rawalpindi, Pakistan.

⁵Associate Professor, Department of Anatomy, Bakhtawar Amin Medical College, Multan, Pakistan.

⁶Lecturer Anatomy/ Clinical Skill Tutor, Department of Basic Medical Science, College of Medicine - Dhofar University, Oman.

Corresponding Author: Farman Ullah

Assistant Professor, Department of Cardiology, Kalifa Gul Nawaz Teaching Hospital, MTI Bannu, Pakistan.

Email: farmanwazir9@gmail.com

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ABSTRACT

Background: Congenital and acquired cardiac disease can lead to CHF, which is an important cause of morbidity in children. Changes in the dimensions of the left ventricle and in systolic function can affect systemic perfusion, renal blood flow and diuretic response. A transthoracic echocardiogram can assist in the identification of structural and functional features that are associated with therapeutic results.

Objective: To determine the association between left ventricular anatomical dimensions, cardiac function, and response to diuretic therapy in children with congestive heart failure.

Methods: The analytical observational study was conducted at Khalifa Gul Nawaz Teaching Hospital MTI Bannu between January 2025 and June 2025. The analysis consisted of 77 children with congestive heart failure. Transthoracic echocardiographic measurements included left ventricular end-diastolic dimension (LVEDD), end-systolic dimension (LVESD), and LVEDD Z score, left ventricular ejection fraction (LVEF), and fractional shortening. The clinical improvement, urine output and length of hospital stay were measured to evaluate diuretic response. Comparisons were made between treatment response-groups and correlation analyses were conducted, where appropriate, and a $p < 0.05$ was regarded as statistically significant.

Results: In the analysis of 77 children, 52 (67.5%) were classified as diuretic responders and 25 (32.5%) as non-responders. Mean LVEF was higher among responders than non-responders ($47.0 \pm 8.5\%$ versus $36.2 \pm 7.3\%$), while LVEDD Z-score was lower (2.5 ± 1.0 versus 4.1 ± 0.9). Both differences were statistically significant ($p < 0.001$). Higher LVEDD Z-score was associated with longer hospitalization ($r = 0.475$, $p < 0.001$), whereas higher LVEF was associated with shorter hospitalization ($r = -0.543$, $p < 0.001$).

Conclusion: The analysis suggests that left ventricular enlargement and impaired systolic function may be associated with reduced diuretic responsiveness and prolonged hospitalization in children with congestive heart failure. These potential relationships warrant confirmation using clinical data and standardized treatment-response criteria.

Keywords: Congestive Heart Failure, Children, Left Ventricular Dimensions, Ejection Fraction, Echocardiography, Diuretic Therapy, Treatment Response.

INTRODUCTION

Congestive heart failure (CHF) is a clinically important syndrome defined by the inability to

maintain adequate systemic circulation or to increase venous return without a rise in filling pressures. Pediatric heart failure is very different from adult heart failure with respect to etiology, pathophysiology, clinical presentation and treatment. Some of the most common causes of cardiac dysfunction in children are congenital heart defects, cardiomyopathies, myocarditis and inherited myocardial disorders. Clinical signs are related to age and severity of the disease and can include tachypnea, difficulty eating, decreased appetite, poor growth, exercise intolerance, hepatomegaly and fluid retention. It is therefore important that cardiac issues are recognized early and the cardiac assessment is complete to avoid progressive deterioration, which will lead to better clinical cardiac management [1-3].

Changes in LV dimensions are critical in the pathogenesis of cardiac failure. Prolonged pressure or volume stress can result in ventricular dilatation, myocardial hypertrophy and gradual structural remodeling. These adaptive remodelling changes are initially beneficial to maintain the cardiac output, however they can also lead to an increase in myocardial wall tension, decline in mechanical efficiency and affect ventricular function. Left ventricular end-diastolic dimension and end-systolic dimension are valuable pieces of information about chamber enlargement and contractile abnormalities. But in children, measurements of the ventricles are strongly related to body size and somatic growth and therefore should be standardized for interpretation. The use of paediatric echocardiographic Z-scores is a useful tool to compare the size of the ventricles with expected values and may enhance detection of pathological ventricular enlargement [4-6]

Another major factor in the clinical condition of children with heart failure is cardiac systolic function. Ventricular contractility can be evaluated echocardiographically and this is important in monitoring myocardial dysfunction using indices such as left ventricular ejection fraction and fractional shortening. A decrease in systolic function can result in decreased forward flow, elevated filling pressures, and decreased organ perfusion. However, the relationship between ventricular structure and functional impairment can be non-linear, as hemodynamic loading, myocardial disease and congenital abnormalities may influence cardiac function independently. This makes it easier to evaluate cardiac dysfunction through simultaneous measurement of ventricular

dimensions and functional parameters, compared to either measurement alone [7-9]. Diuretic therapy is part of the symptomatic treatment that is a key treatment strategy for children who come in with pulmonary/systemic congestion. Loop diuretics stimulate sodium and water diuresis, thus decreasing circulating volume and filling pressures of ventricles. Diuresis may be appropriate and can help to reduce respiratory symptoms, oedema, feeding tolerance and clinical stability. But, the effect of diuretics on children can be highly variable. Affected by reduced cardiac output, renal perfusion, neurohormonal activation, advanced myocardial dysfunction and differences in underlying cardiac diagnosis, there may be inadequate diuresis. Furthermore, overuse of a diuretic can lead to electrolyte disturbances, intravascular volume depletion and renal impairment. Assessment of clinical congestion, urine output, fluid balance, and cardiac function is thus essential to determine the efficacy of therapy and to make tailored decisions [10-12]. Although echocardiography is routinely used to evaluate cardiac structure and function, the relationship between ventricular dimensions, systolic performance, and diuretic responsiveness in children remains insufficiently characterized. Identifying anatomical and functional parameters associated with clinical response may help clinicians recognize patients at increased risk of persistent congestion, inadequate diuresis, and prolonged hospitalization. Integration of echocardiographic findings with objective treatment-response measurements may also contribute to improved risk stratification and therapeutic decision-making. Further clinical investigation is required to clarify these relationships across the diverse causes of pediatric heart failure. Therefore, the present study aimed to determine the association between left ventricular anatomical dimensions, cardiac functional parameters, and response to diuretic therapy among children diagnosed with congestive heart failure.

MATERIALS AND METHODS

This hospital-based analytical observational study was conducted at Khalifa Gul Nawaz Teaching Hospital, MTI Bannu, over six months, from January 2025 to June 2025. The study was designed to evaluate the association between left ventricular anatomical dimensions, cardiac systolic function, and clinical response to diuretic therapy among children diagnosed with congestive heart failure (CHF).

Echocardiographic parameters were assessed in relation to clinical characteristics and treatment outcomes to identify potential indicators of diuretic responsiveness.

A total of 77 pediatric patients diagnosed with congestive heart failure were included in the study through a non-probability consecutive sampling technique. Children aged 1 month to 18 years with a clinical diagnosis of CHF, confirmed by echocardiographic and/or clinical features, were eligible for inclusion. The diagnosis was established based on clinical manifestations, including tachypnea, tachycardia, feeding difficulties, hepatomegaly, pulmonary congestion, and evidence of cardiac dysfunction. Children with congenital heart disease, cardiomyopathy, myocarditis, or other structural and functional cardiac abnormalities associated with CHF were eligible. Confounding factors that might affect diuretic response were minimized by excluding patients with significant renal dysfunction, severe dehydration, pre-existing electrolyte disturbances, and incomplete clinical or echocardiographic records.

A structured proforma was used to collect demographic and clinical information. The variables recorded included age, gender, body weight, underlying cardiac diagnosis, duration of symptoms, heart rate, respiratory rate, oxygen saturation, and clinical characteristics of heart failure. The severity of heart failure was evaluated using the modified Ross classification. Transthoracic echocardiography was performed to assess left ventricular anatomical dimensions and systolic function. Echocardiographic parameters included left ventricular end-diastolic dimension (LVEDD), left ventricular end-systolic dimension (LVESD), left ventricular ejection fraction (LVEF), and fractional shortening (FS). Left ventricular dimensions were recorded in millimeters, whereas LVEF and FS were expressed as percentages. Pediatric reference values were adjusted for body size to calculate LVEDD Z-scores. Ventricular enlargement and systolic dysfunction were evaluated according to standard pediatric echocardiographic principles. Diuretic therapy was administered according to the clinical condition, hemodynamic status, and severity of fluid overload. The medications included furosemide and spironolactone, administered individually or in combination according to clinical requirements. The pediatric dosing regimens described for this treatment approach included intravenous furosemide at 0.5–1 mg/kg/dose every 6–12 hours or oral

furosemide at 1–2 mg/kg/dose every 12 hours. Spironolactone was considered as adjunctive oral therapy at 1–3 mg/kg/day in one or two divided doses. The route of administration was selected according to the severity of congestion, hemodynamic stability, and ability to tolerate oral medication. Drug doses and administration frequency were adjusted according to body weight, clinical response, renal function, and serum electrolyte concentrations. The duration of treatment depended on improvement in fluid overload, resolution of clinical congestion, and overall clinical stability. The type of diuretic, dose, route, frequency of administration, and duration of treatment were recorded from the patients' clinical treatment charts.

Clinical response to diuretic therapy was assessed through changes in urine output, respiratory symptoms, peripheral edema, pulmonary congestion, and overall clinical condition. Urine output was calculated in mL/kg/hour using the recorded urine volume, body weight, and duration of urine collection. Baseline urine output was compared with post-treatment measurements to evaluate the diuretic response. Patients demonstrating improvement in diuresis and reduction in clinical signs of congestion were classified as responders, whereas those with persistent congestion and inadequate diuresis were classified as non-responders. Clinical assessment also included changes in respiratory status and the requirement for additional therapeutic interventions. Renal function and serum electrolyte measurements, particularly sodium and potassium concentrations, were reviewed where available to identify potential complications associated with diuretic therapy. Secondary clinical outcomes included duration of hospitalization, electrolyte abnormalities, and the requirement for escalation or modification of diuretic treatment.

All data were analyzed using IBM SPSS Statistics version 26.0. Continuous variables, including age, LVEDD, LVESD, LVEDD Z-score, LVEF, fractional shortening, urine output, and length of hospital stay, were summarized as mean and standard deviation. Categorical variables, including gender, underlying cardiac diagnosis, and response to diuretic therapy, were presented as frequencies and percentages. The normality of continuous variables was assessed using the Shapiro–Wilk test. Independent-samples t-tests were used to compare normally distributed continuous

variables between diuretic responders and non-responders, with Welch's t-test applied when the assumption of equal variances was violated. For variables that were not normally distributed, the Mann–Whitney U test was used. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Pearson correlation analysis was performed to evaluate associations between left ventricular dimensions, cardiac functional parameters, urine output, and duration of hospitalization. Spearman correlation was used when parametric assumptions were not

satisfied. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study comprised 77 children, including 50 (64.9%) males and 27 (35.1%) females. The mean age was 57.6 ± 33.3 months. The most common age category was 6–12 years (46.8%), followed by 1–5 years (44.2%). The most common underlying diagnosis was congenital heart disease (62.3%) and cardiomyopathy (23.4%).

Table 1. Demographic and Baseline Clinical Characteristics of Children with Congestive Heart Failure (N=77)

Characteristics	Frequency (%)
Age (months), mean $\pm$ SD	57.6 $\pm$ 33.3
Age group	
<1 year	7 (9.1)
1–5 years	34 (44.2)
6–12 years	36 (46.8)
Gender	
Male	50 (64.9)
Female	27 (35.1)
Underlying cardiac diagnosis	
Congenital heart disease	48 (62.3)
Cardiomyopathy	18 (23.4)
Myocarditis	7 (9.1)
Other cardiac conditions	4 (5.2)

The mean left ventricular end-diastolic dimension (LVEDD) was 44.9 ± 7.7 mm and the mean left ventricular end-systolic dimension (LVESD) was 35.3 ± 6.9 mm. Left ventricular

enlargement was present with an LVEDD Z score of 3.0 ± 1.2 . The average left ventricular ejection fraction was $43.5 \pm 9.5\%$ and fractional shortening was $21.6 \pm 4.3\%$.

Table 2. Left Ventricular Anatomical Dimensions and Cardiac Functional Parameters (N=77)

Echocardiographic variable	Mean $\pm$ SD
LVEDD (mm)	44.9 $\pm$ 7.7
LVESD (mm)	35.3 $\pm$ 6.9
LVEDD Z-score	3.0 $\pm$ 1.2
LVEF (%)	43.5 $\pm$ 9.5
Fractional shortening (%)	21.6 $\pm$ 4.3

Of the 77 children, 52 (67.5%) responded to diuretic therapy and 25 (32.5%) were non-responders. Before treatment, mean urine output was 0.7 ± 0.2 mL/kg/hour and after treatment, it was 2.0 ± 0.6 mL/kg/hour. The average length of hospitalization was 6.6 ± 2.6 days.

Table 3. Clinical Response to Diuretic Therapy and Hospitalization Outcomes (N=77)

Treatment response variable	Result
Response to diuretic therapy	
Responders	52 (67.5%)
Non-responders	25 (32.5%)
Baseline urine output (mL/kg/hour), mean $\pm$ SD	0.7 $\pm$ 0.2

Post-treatment urine output (mL/kg/hour), mean $\pm$ SD	2.0 $\pm$ 0.6
Hospital stay (days), mean $\pm$ SD	6.6 $\pm$ 2.6

Left ventricular dimensions were significantly smaller and systolic function was significantly improved in children who were classified as diuretic responders compared to non-responders. Mean LVEDD was 42.2 $\pm$ 7.0 mm among responders compared with 50.3 $\pm$ 6.3

mm among non-responders ($p < 0.001$). LVEF was also significantly higher among responders (47.0 $\pm$ 8.5% versus 36.2 $\pm$ 7.3%, $p < 0.001$). Post-treatment urine output was greater and hospitalization was shorter among responders.

Table 4. Comparison of Left Ventricular Dimensions and Cardiac Function Between Diuretic Responders and Non-Responders

Variable	Responders (n=52)	Non-responders (n=25)	p-value
Age (months)	55.3 $\pm$ 31.6	62.3 $\pm$ 36.8	0.421
LVEDD (mm)	42.2 $\pm$ 7.0	50.3 $\pm$ 6.3	<0.001
LVESD (mm)	32.5 $\pm$ 5.8	41.1 $\pm$ 5.1	<0.001
LVEDD Z-score	2.5 $\pm$ 1.0	4.1 $\pm$ 0.9	<0.001
LVEF (%)	47.0 $\pm$ 8.5	36.2 $\pm$ 7.3	<0.001
Fractional shortening (%)	23.1 $\pm$ 3.8	18.3 $\pm$ 3.3	<0.001
Baseline urine output (mL/kg/hour)	0.7 $\pm$ 0.2	0.8 $\pm$ 0.2	0.294
Post-treatment urine output (mL/kg/hour)	2.3 $\pm$ 0.4	1.3 $\pm$ 0.4	<0.001
Hospital stay (days)	5.4 $\pm$ 1.7	9.0 $\pm$ 2.4	<0.001

Values are presented as mean $\pm$ SD. P-values were calculated using Welch's independent-samples t-test.

Pearson correlation analysis showed a significant correlation between LVEDD Z-score and LVEF ($r = -0.306$, $p = 0.007$). There was a negative correlation between higher LVEDD Z-scores and lower post-treatment urine output ($r = -0.382$, $p = 0.001$) and longer hospitalization

($r = 0.475$, $p < 0.001$). On the other hand, urine output was positively related to LVEF ($r = 0.327$, $p = 0.004$) and hospitalization time was negatively related to LVEF ($r = -0.543$, $p < 0.001$).

Table 5. Correlation of Left Ventricular Anatomical Dimensions and Systolic Function with Diuretic Response Parameters

Variables	Pearson r	p-value
LVEDD Z-score vs. LVEF	-0.306	0.007
LVESD vs. LVEF	-0.501	<0.001
LVEDD Z-score vs. post-treatment urine output	-0.382	0.001
LVEF vs. post-treatment urine output	0.327	0.004
LVEDD Z-score vs. hospital stay	0.475	<0.001
LVEF vs. hospital stay	-0.543	<0.001

Pearson correlation analysis was applied; $p < 0.05$ was considered statistically significant.

Fig. 1. Cardiac function and ventricular size by diuretic response

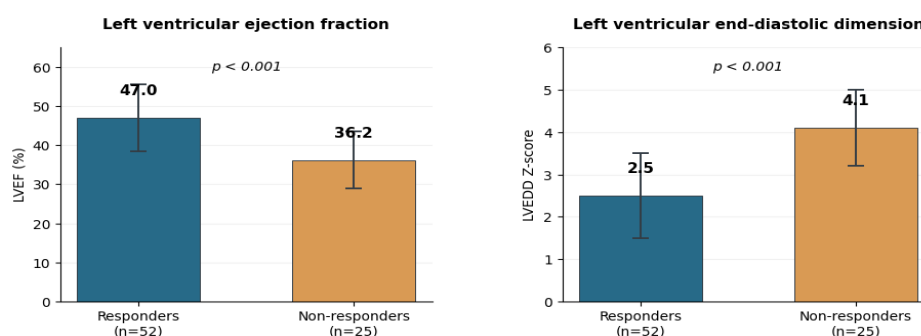


Fig. 1: Comparison of Mean Left Ventricular Ejection Fraction and LVEDD Z-Score Between Diuretic Responders and Non-Responders Among Children with Congestive Heart Failure.

DISCUSSION

Congestive heart failure in children represents a complex clinical condition characterized by impaired cardiac performance, circulatory congestion, and progressive alterations in ventricular structure and function. Unlike adult heart failure, pediatric heart failure develops from diverse etiologies, including congenital cardiac abnormalities, cardiomyopathies, myocarditis, and other acquired myocardial disorders. These conditions may produce ventricular remodeling, increased cardiac workload, and compromised systemic perfusion. The relationship between anatomical ventricular dimensions and functional impairment is particularly important because progressive ventricular enlargement may reflect worsening myocardial dysfunction and increased hemodynamic stress. Early identification of structural abnormalities through echocardiography facilitates appropriate clinical assessment, risk stratification, and individualized therapeutic management. Furthermore, integrating anatomical and functional parameters provides a more comprehensive understanding of disease severity than reliance on clinical manifestations alone [13-15].

Anatomical parameters of the left ventricle are significant markers of myocardial remodeling and the course of cardiac dysfunction in children. Left ventricular end-diastolic and end-systolic dimensions can become enlarged due to chronic volume overload or due to decreased myocardial contractility or to changes in ventricular loading. Ventricular dilatation can lead to higher wall stress, mechanical inefficiency and worsen the symptoms of heart failure. Measurements obtained by echocardiogram can offer useful information about the structure and contractile function of the heart, including left ventricular end-diastolic dimension, end-systolic dimension, ejection fraction and fractional shortening. Absolute ventricular measurements, however, must be interpreted with age, body size and developmental changes in mind when evaluating children. Normal ranges can be compared and abnormal ventricular enlargement identified with the use of body surface area adjusted Z-scores. These measurements could help identify children who are at risk of clinical deterioration and length of hospital stay [16-18].

Diuretic therapy is a mainstay of the treatment of children with CHF, especially in the setting of pulmonary or systemic congestion. Diuretics, such as loop diuretics like furosemide, increase sodium and water output and decrease intravascular volume and ventricular filling pressures. The decrease in congestion can lead to a decrease in respiratory symptoms, peripheral edema, feeding tolerance, and clinical stability. However, diuretic effectiveness depends on the nature of the cardiac disease, renal blood flow, and amount of neurohormonal activation and/or the extent of ventricular dysfunction. In children with severe myocardial function abnormalities, renal blood flow may also be compromised, as may be renal delivery of diuretics to their target sites, thereby limiting the therapeutic response. Therefore, the effects of diuretic use must be evaluated by measuring urine output, clinical congestion, fluid balance and renal function in addition to the dose used. It is also important to carefully monitor to reduce electrolyte disturbances, dehydration, and renal complications [19, 20].

It is important to note and understand the relationship between left ventricular functional parameters and diuretic responsiveness for pediatric heart failure management. Reduced forward cardiac output, reduced renal perfusion and a fluid overload may be the result of impaired ejection fraction and reduced fractional shortening, reflecting impaired systolic function. On the other hand, when children have relatively normal ventricular function, they might have better renal hemodynamics and have a better response to the common decongestive therapy. Nevertheless, the hemodynamic status of children with heart failure cannot be completely defined by VEF, especially children with CHD or predominant diastolic dysfunction. A variety of structural abnormalities, ventricular loading conditions, valvular lesions, pulmonary vascular resistance and renal function can have a separate effect on clinical results. Thus, a comprehensive assessment of ventricular dimensions, systolic function, and treatment response may help the clinician identify individuals that need more monitoring, treatment modifications, or cardiac support.

Echocardiography is clinically relevant, but there are several caveats to consider when interpreting echocardiographic measures of diuretic responsiveness. Causality between the

enlargement of the ventricles and impaired systolic function and treatment results cannot be proven by observational research. Confounding effects may be introduced by differences in underlying cardiac diagnoses, severity of the disease, diuretic regimens, and concurrent medications, and renal function. In addition, a single measurement of urine output or fluid balance may be difficult in younger children and echocardiographic measurements of ventricles may not capture the changes in performance. In addition, findings may be limited in generalizability due to the small sample size and single center enrollment. Multicenter prospective study with standardized echocardiographic parameters, sequential evaluation of ventricular function, objective data regarding congestion and well defined diuretic response criteria are recommended for future study. These studies can contribute to the creation of accurate predictive models and assist in the creation of better treatment plans for children with congestive heart failure.

CONCLUSION

Left ventricular anatomical dimensions and cardiac functional parameters are important components of the clinical assessment of children with congestive heart failure. Ventricular enlargement and impaired systolic function may be associated with reduced responsiveness to diuretic therapy, persistent congestion, and prolonged hospitalization. Echocardiographic evaluation using left ventricular end-diastolic and end-systolic dimensions, ejection fraction, fractional shortening, and age-appropriate Z-scores may support risk stratification and therapeutic decision-making. Integration of cardiac imaging with clinical assessment and objective measures of diuretic response is essential for optimizing the management of pediatric heart failure. Further prospective investigations are required to determine the independent predictive value of these parameters and their potential contribution to improved clinical outcomes.

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