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Clinical Spectrum and Frequency of Congenital Heart Diseases in Children with Down Syndrome at the Faisalabad Institute of Cardiology

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ABSTRACT

Background: Children with Down's syndrome are highly predisposed to congenital heart defects (CHDs), which significantly contribute to morbidity and mortality. Early identification of these defects is crucial for effective management and improved survival outcomes.

Objective: This study aimed to determine the frequency and pattern of various congenital heart defects among children with Down's syndrome presenting to a tertiary cardiology center.

Methods: A descriptive study was conducted in the Department of Cardiology at the Faisalabad Institute of Cardiology, Faisalabad. Fifty eight phenotypically confirmed children with Down's syndrome, aged from birth to 13 years, were included using a non-probability convenient sampling technique. After thorough clinical evaluation and history taking, all participants underwent transthoracic two dimensional echocardiography, and findings were recorded on a structured preforma. Data were analyzed using SPSS version 25, and results were expressed as frequencies and percentages.

Results: Congenital heart defects were detected in 29 out of 58 patients (50%), including 16 males and 13 females (male-to-female ratio 1.2:1). Acyanotic lesions were more prevalent (79.3%) than cyanotic lesions (20.7%). The most common isolated defects were ventricular septal defect, patent ductus arteriosus, and complete atrioventricular septal defect (each 20.7%), followed by atrial septal defect (3.4%) and pulmonary atresia (3.4%).

Conclusion: Half of the children with Down's syndrome in this study had congenital heart defects, most frequently acyanotic lesions such as ventricular septal defect, patent ductus arteriosus, and complete atrioventricular septal defect. Routine echocardiographic screening is essential for early detection and timely intervention.

Keywords: Acyanotic Heart Disease, Atrioventricular Septal Defect, Congenital Heart Defects, Down Syndrome, Echocardiography, Patent Ductus Arteriosus, Ventricular Septal Defect.

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Introduction

Down syndrome, also known as trisomy 21, is a congenital chromosomal disorder resulting from the presence of an extra or partial copy of chromosome 21 (1). It represents the most common genetic cause of intellectual disability and is characterized by a distinct constellation of physical, developmental, and systemic abnormalities that vary from person to person (2). Typical clinical features include hypotonia, short stature, delayed motor milestones, a flat nasal bridge, small head size, low set ears, epicanthal folds, and a single palmar crease. These children frequently exhibit open mouths with protruding tongues and wide gaps between the first and second toes, features that facilitate early diagnosis at birth (3). Globally, the reported incidence of Down syndrome ranges between 1 in 700 and 1 in 1000 live births, although regional variations exist due to sociocultural, ethical, and legal differences in pregnancy termination practices (4-6). The likelihood of having a child with Down syndrome increases with maternal age, particularly after 35 years, while translocation forms of the disorder show a distinct inheritance pattern independent of age (7).

Congenital heart disease (CHD) is among the most frequent and life threatening anomalies associated with Down syndrome. It is defined as a structural abnormality of the heart or intrathoracic great vessels that is of actual or potential functional significance (8). CHDs range from simple septal defects to complex malformations involving multiple chambers and great vessels, and they significantly contribute to morbidity and mortality in affected infants (9). The etiology of these malformations is multifactorial, involving genetic predisposition, chromosomal abnormalities, and teratogenic influences during early embryogenesis (10). Echocardiography is the cornerstone for CHD diagnosis, as it provides noninvasive visualization of cardiac anatomy, function, and blood flow patterns, thereby replacing more invasive procedures such as diagnostic catheterization in most cases (11,12). Representative echocardiographic images are shown below to illustrate typical structural defects observed in children with Down syndrome (Figure 1,2).

The association between Down syndrome and congenital heart disease has been widely documented in both developed and developing countries. Approximately 40 to 60 percent of children with Down syndrome have a cardiac defect, and about 4 to 10 percent of all CHDs occur in patients with Down syndrome (12). The most common anomalies include atrioventricular septal defect (AVSD), ventricular septal defect (VSD), patent ductus arteriosus (PDA), and atrial septal defect (ASD), while more complex lesions such as tetralogy of Fallot (TOF), transposition of great arteries (TGA), double outlet right ventricle (DORV), and pulmonary atresia are observed less frequently (13). VSDs often close spontaneously during infancy, while PDAs and ASDs may persist undetected due to their mild symptomatology and late presentation (8). The prevalence and pattern of these anomalies can vary geographically, reflecting differences in genetic background, maternal factors, and diagnostic facilities. For instance, AVSDs are predominant in the United States and Europe, whereas VSDs are more common in Asian populations and ASDs in Latin America (13).

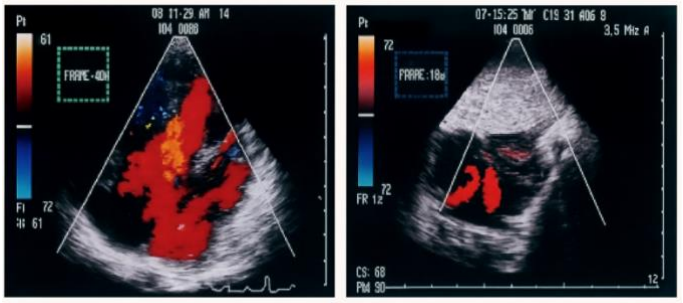

Figure 1: Transthoracic echocardiographic views showing (A) a four chamber view with left-to-right shunt across an atrial septal defect (ASD) and (B) a Doppler image demonstrating combined atrial and ventricular septal defects (AVSD) (12).

Epidemiological studies further illustrate the global variability of CHDs among Down syndrome populations. The prevalence of CHD in Pakistani cohorts is approximately 56 percent (14), comparable to rates observed in Denmark (17), Korea (13), and Mexico (12). However, substantially higher rates have been reported in Brazil (15), while lower frequencies are seen in Libya (16) and Bahrain (18). Differences in diagnostic timing, survival rates, and access to healthcare may explain part of this variation. Despite advances in prenatal screening and early diagnosis, CHDs remain a major determinant of morbidity, hospitalization, and mortality among children with Down syndrome. Studies have also indicated that neonatal mortality in Down syndrome is not solely dependent on cardiac defects but is influenced by concurrent factors such as prematurity, low birth weight, and perinatal asphyxia (12–19).

Given this clinical and epidemiological context, studying the frequency and spectrum of congenital heart defects among children with Down syndrome holds great relevance. The Faisalabad Institute of Cardiology (FIC) serves as a regional referral center where many such cases are encountered. Determining the pattern of cardiac anomalies in this population will not only contribute to local epidemiological data but also help clinicians in early detection, timely referral, and appropriate management planning. By comparing local findings with international literature, this study aims to enhance awareness of the burden of cardiac anomalies among Down syndrome children and to promote strategies that can ultimately reduce morbidity and improve survival in this vulnerable population.

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Materials and Methods

This descriptive study was carried out in the Department of Cardiology at the Faisalabad Institute of Cardiology, Faisalabad, Pakistan. The data collection period extended from July 2020 to September 2020. The study included male and female patients with clinically confirmed Down syndrome who attended the cardiology department for echocardiographic examination. The age range of the participants was from birth to thirteen years. A total of fifty eight patients were included using a convenient non probability sampling technique. Children with other chromosomal or syndromic disorders were excluded from the study to ensure a homogeneous sample.

A structured performa was developed to record all relevant information, including demographic data, clinical findings, and echocardiographic observations. The Performa was pretested and refined before final use. Data were collected by the investigator herself after introducing the purpose of the study to the participants' guardians. Each child underwent transthoracic echocardiography to identify possible congenital heart defects.

Echocardiography was performed following standard two dimensional and Doppler imaging procedures (11). Situs was examined in the subcostal view, and pulmonary venous connections to the left atrium were evaluated using apical and suprasternal windows. Ventricular morphology was assessed in apical four chamber and two chamber views, while the great arteries were identified in short axis views at the base of the heart. The pulmonary artery was examined through parasternal long axis and short axis views, and the aortic arch through suprasternal short axis views. The right ventricle and its inflow tracts were evaluated using apical and subcostal four chamber views. Coarctation of the aorta was observed in the suprasternal window. Two dimensional subcostal and apical four chamber views were used to detect atrial and ventricular septal defects. Color Doppler and M mode imaging were applied for further analysis. Follow up evaluations were arranged according to the primary cardiac diagnosis.

All data were entered and analyzed using the Statistical Package for Social Sciences (SPSS) version 25. Categorical variables such as gender and types of congenital heart defects were expressed as frequencies and percentages, while quantitative variables were summarized as mean and standard deviation. The findings were presented through descriptive tables and figures to illustrate the distribution and pattern of cardiac defects among children with Down syndrome.

There were no ethical issues involved in this study, as no experimental intervention or medication was administered to any patient. The procedures performed were routine clinical assessments that formed part of the standard diagnostic evaluation for each participant. Confidentiality of patient data was maintained throughout the study period.

Results

A total of fifty eight consecutive patients with clinically confirmed Down syndrome were included in the study. Echocardiography data were collected prospectively using a structured Performa. After detailed clinical examination, all patients underwent transthoracic echocardiography to identify congenital heart defects (CHDs). The detected anomalies included patent ductus arteriosus (PDA), atrioventricular septal defect (AVSD), ventricular septal defect (VSD), atrial septal defect (ASD), tetralogy of Fallot (TOF), coarctation of the aorta (CoA), transposition of great arteries (TGA), double outlet right ventricle (DORV), pulmonary atresia or stenosis, and univentricular heart malformation. Out of the 58 patients, 63.793% (n=37) were males and 36.206% (n=21) were females, giving a male to female ratio of 1.7:1. Among the 29 patients diagnosed with congenital heart defects, 55.171% (n=16) were males and 44.827% (n=13) were females, yielding a male to female ratio of 1.2:1 (Figure 2).

Figure 3 illustrates the distribution of isolated congenital heart defects with gender comparison. In males, the most common isolated lesion was patent ductus arteriosus (13.793%), followed by ventricular septal defect (10.171%) and complete atrioventricular septal defect (10.171%). The least frequent lesions were transposition of great arteries (3.448%), double outlet right ventricle (3.448%), and pulmonary atresia (3.448%). In females, ventricular septal defect (10.171%) and complete atrioventricular septal defect (10.171%) were the most common, followed by patent ductus arteriosus (6.896%), while atrial septal defect, tetralogy of Fallot, and pulmonary atresia were each observed in 3.448% of cases.

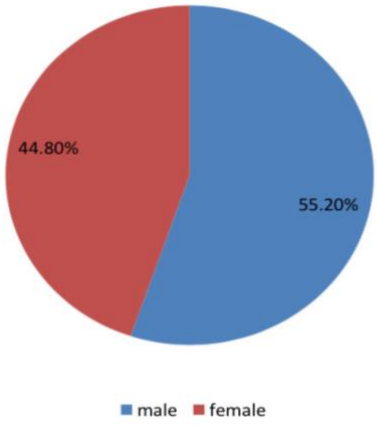

Figure 2: Distribution of congenital heart defects by gender among children with Down syndrome (n=58).

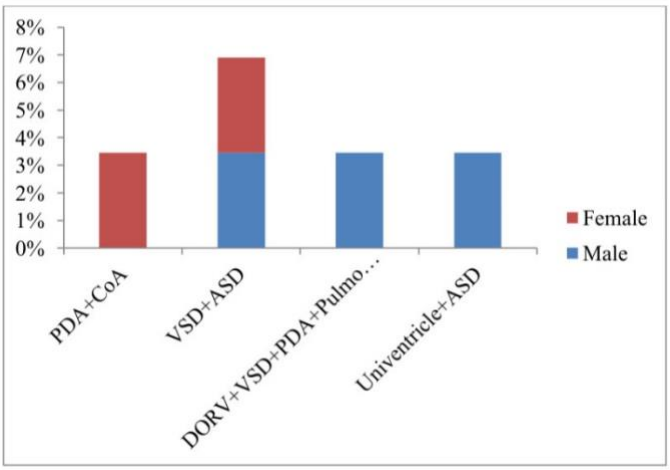

Figure 3: Percentages of isolated congenital heart defects and gender distribution among 58 children with Down syndrome.

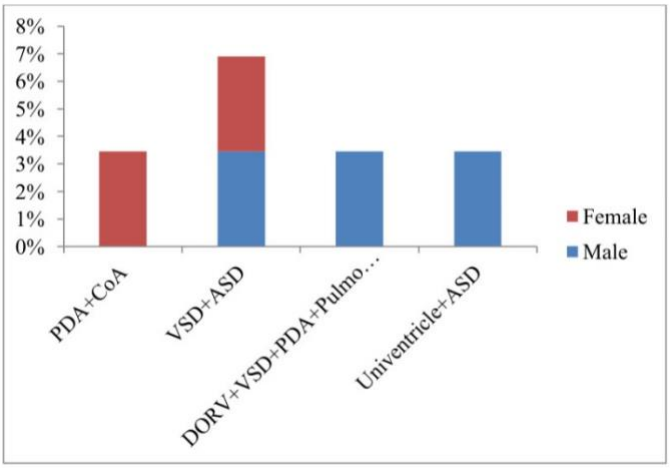

Figure 4: Percentages of mixed congenital heart defects with gender distribution among 58 cases.

Figure 4 shows the percentages of mixed congenital heart defects by gender. Among males, combinations such as VSD+ASD, DORV+VSD+PDA+pulmonary atresia, and univentricular heart with ASD were observed in 3.448% each. Among females, combinations such as PDA+CoA and VSD+ASD were each seen in 3.448% of cases. Patients were categorized into four age groups: below 1 year, 1–5 years, 6–10 years, and above 10 years. The majority of CHDs were detected in the 1–5 years age group (51.724%), followed by those below 1 year (41.379%), while only 6.896% of cases were between 6 and 10 years of age. No cardiac defects were identified in patients older than 10 years (Figure 5).

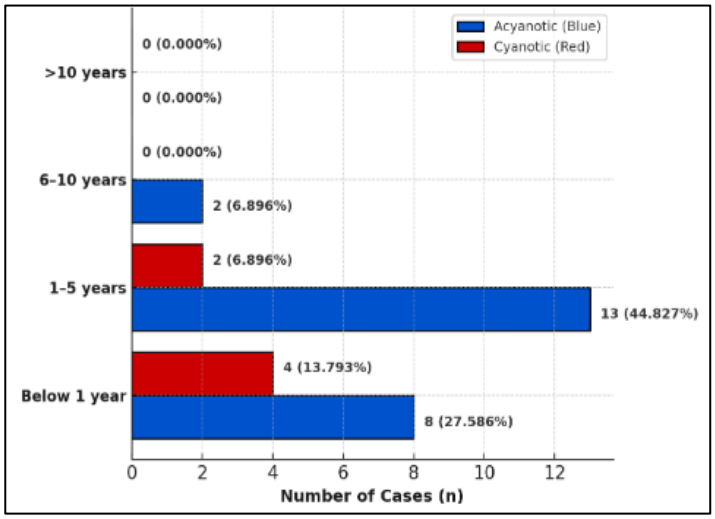

Figure 5: Age-wise Distribution of CHDs in Down Syndrome (n=58).

Table 1: Frequency distribution of isolated congenital heart lesions (n=24).

Acyanotic Lesions (n=20)	Percentage	Cyanotic Lesions (n=4)	Percentage
VSD	20.989%	Pulmonary atresia	6.896%
PDA	20.989%	TGA	3.448%
CAVSD	20.989%	TOF	3.448%
ASD	3.448%	—	—
DORV + VSD	3.448%	—	—

Table 2: Frequency distribution of mixed congenital heart lesions (n=5).

Acyanotic Lesions (n=3)	Percentage	Cyanotic Lesions (n=2)	Percentage
VSD + ASD	6.896%	DORV + VSD + PDA + Pulmonary atresia	3.448%
PDA + CoA	3.448%	Univentricular + ASD	3.448%

Congenital heart defects were found in 50% (n=29) of the total study population. These were categorized into **acyanotic** and **cyanotic** groups, as well as **isolated** and **mixed** lesions. Acyanotic lesions were more prevalent (79.310%, n=23) than cyanotic lesions (20.689%, n=6). Among acyanotic lesions, the most common isolated defects were VSD, PDA, and complete AVSD (each 20.689%, n=6). Mixed lesions included ASD+VSD (6.896%, n=2), and isolated ASD, DORV, and PDA+CoA (each 3.448%, n=1). These distributions are shown in Table 1. Among the mixed lesions (n=5), acyanotic combinations such as VSD+ASD and PDA+CoA were observed, while cyanotic combinations included DORV+VSD+PDA+pulmonary atresia and univentricular

heart with ASD. Their frequencies are detailed in Table 2. Among the cyanotic lesions (n=6), isolated pulmonary atresia was the most common (6.896%), followed by tetralogy of Fallot and transposition of great arteries (3.448% each). Mixed cyanotic defects, including univentricular heart with ASD and DORV+VSD+PDA+pulmonary atresia, were also found in 3.448% of cases each. Overall, acyanotic lesions were predominant among children with Down syndrome, and VSD, PDA, and CAVSD represented the most frequently encountered cardiac defects in this population.

Discussion

The present study demonstrated that congenital heart defects were identified in 50% of children with Down's syndrome examined at the Faisalabad Institute of Cardiology. This proportion aligns with several previous studies reporting a prevalence between 35% and 65% (22). The frequency observed in this cohort was comparable to that reported in Korea (56.9%) (13) and Khyber Pakhtunkhwa, Pakistan (56.36%) (14). However, it was lower than the 81% reported in Brazil (15), while studies from Libya (16) and the Netherlands (28) showed relatively lower rates. These regional variations may be attributed to genetic heterogeneity, maternal age distribution, differences in prenatal diagnosis, and embryological factors influencing cardiac development. Among the 58 participants, the male to female ratio was 1.7:1, and among those with congenital heart defects, it was 1.2:1, suggesting a slight male predominance. This finding is consistent with Khan and Muhammad (14), who reported a 1.5:1 ratio, while Mourato et al. (15) observed a female predominance in Brazil with a ratio of 1:1.3. Such gender differences could be due to population selection or referral patterns rather than biological disparity.

In the present study, isolated cardiac lesions were more frequent than mixed lesions, representing 82.8% of all congenital heart defects. These findings were comparable to those of Khan and Muhammad (14), who reported 90.3% isolated lesions, and were also in agreement with data from Libya, Guatemala, Mexico, and Turkey, where isolated lesions accounted for 65%, 80%, 74%, and 78%, respectively (16). This predominance of isolated defects may be related to survival bias, as children with complex or mixed lesions often die before diagnosis. The most common isolated acyanotic defects were ventricular septal defect, patent ductus arteriosus, and complete atrioventricular septal defect, each found in 20.7% of patients, followed by mixed defects such as atrial septal defect combined with ventricular septal defect (6.9%). Less frequent anomalies included isolated atrial septal defect, double outlet right ventricle, and patent ductus arteriosus with coarctation of the aorta, each in 3.4% of patients. Among cyanotic lesions, pulmonary atresia was the most common (6.9%), followed by tetralogy of Fallot and transposition of the great arteries (3.4% each). These results highlight the dominance of acyanotic lesions in Down's syndrome, consistent with the global trend (13–16, 24).

Geographical comparisons revealed partial overlap but also some distinct differences in lesion distribution. Kim et al. (13) reported atrial septal defect as the most frequent lesion in Korean children (30.5%), followed by ventricular septal defect (19.3%), patent ductus arteriosus (17.5%), and atrioventricular septal defect (9.4%). Mourato et al. (15) in Brazil found the secundum type of atrial septal defect most prevalent (51.8%), followed by atrioventricular septal defect (46.6%), ventricular septal defect (27.7%), and tetralogy of Fallot (6.3%). Elmagrpy et al. (16) in Libya observed atrial septal defect (23%) as the most common, followed by atrioventricular septal defect (19%) and ventricular septal defect (14%). Weijerman et al. (28) in the Netherlands identified atrial septal defect (54%), ventricular septal defect (33.3%), and patent ductus arteriosus (5.8%) as the leading anomalies, while Ali (24) in Sudan found atrioventricular septal defect (48%) to be the most common, followed by atrial septal defect (23%) and tetralogy of Fallot (6%). The current findings most closely resemble those of Khan and Muhammad (14) in Pakistan, where ventricular septal defect (22.6%) and patent ductus arteriosus (19.4%) were predominant, followed by atrioventricular septal defect (19.4%) and atrial septal defect (16.1%), indicating regional consistency in South Asian populations.

Acyanotic lesions (79.3%) were significantly more frequent than cyanotic lesions (20.7%), a distribution consistent with the pathophysiological mechanisms of Down's syndrome, where endocardial cushion defects and incomplete septation account for most anomalies (8, 13, 14, 25). The predominance of ventricular and atrioventricular septal defects supports the embryological theory that gene overexpression on chromosome 21 interferes with endocardial cushion formation, leading to these characteristic defects (9, 25). The relatively lower frequency of cyanotic lesions such as tetralogy of Fallot, transposition of the great arteries, and pulmonary atresia in this cohort also corresponds with previous regional findings (14, 24, 28). Despite the clinical importance of these findings, this study was limited by its small sample size, which reduces generalizability. The use of convenience sampling could have introduced selection bias, and reliance on transthoracic echocardiography alone may have led to operator dependent variations in diagnosis. The short study duration restricted longitudinal follow up, preventing assessment of natural progression. Nonetheless, this study provides valuable baseline data for the Pakistani pediatric population and contributes to the limited local evidence base on cardiac anomalies in children with Down's syndrome.

From a clinical standpoint, these results emphasize the critical importance of early echocardiographic screening in all infants with Down's syndrome, as undiagnosed

congenital heart defects significantly contribute to morbidity and mortality. Strengthening pediatric cardiac services and enhancing pediatrician training in early diagnosis and management of congenital cardiac anomalies are vital steps. Regular echocardiographic evaluations throughout early life should be standardized to prevent late complications such as pulmonary hypertension and Eisenmenger's physiology. Further multicenter, population based studies are needed across Pakistan to investigate maternal and neonatal factors associated with congenital heart defects in Down's syndrome and to guide evidence based preventive and diagnostic strategies (23–28).

Conclusion

Congenital heart defects were found to be highly prevalent among children with Down's syndrome, with isolated acyanotic lesions particularly ventricular septal defect (VSD), patent ductus arteriosus (PDA), and complete atrioventricular septal defect (CAVSD) being the most frequent in this population. These findings emphasize the critical need for early cardiac screening and echocardiographic evaluation in all newborns with Down's syndrome to enable prompt diagnosis and management, thereby reducing preventable morbidity and mortality. Strengthening pediatric cardiology services, improving access to specialized care, and promoting awareness among healthcare professionals and families are essential steps to enhance the quality of life and long term outcomes of affected children in resource limited healthcare systems.

Authors' Contributions

ICMJE authorship criteria	Detailed contributions	Authors
Substantial Contributions	Conception or Design of the work	1, 2
	Data acquisition	1, 2
	Data analysis or interpretation	1, 2
Drafting or Reviewing	Draft the work	1
	Review critically	1, 2
Final approval	Final approval of the version to be published.	1, 2
Accountable	Agreement to be accountable for all aspects of the work.	1, 2

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