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Original Research Article

PERSISTENT LEFT SUPERIOR VENA CAVA AND ITS ASSOCIATION WITH CONGENITAL HEART DISEASE: A CT ANGIOGRAPHY STUDY

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Abstract: *Persistent Left Superior Vena Cava (PLSVC) is a common venous anomaly that is often associated with congenital heart disease (CHD) in pediatric patients. The significance of this anomaly lies in the potential complications that may arise during cardiac procedures. A prospective observational cohort study was conducted at the Peshawar Institute of Cardiology, a tertiary care heart facility in Peshawar, from January 2021 to January 2022. The study used CT angiography to assess the prevalence and characteristics of PLSVC in a cohort of 75 pediatric patients with CHD. The study also intended to provide valuable insights for preoperative planning and procedural success, addressing the challenges posed by PLSVC in the context of congenital heart anomalies. Demographic data, including age, gender, and clinical history, were collected for all 75 pediatric patients with CHD. CT angiography was used to identify PLSVC, and characteristics such as dimensions, trajectory, and drainage patterns were recorded. Data analysis involved descriptive statistics, chi-squared tests, and a significance level of $p < 0.05$. The study found that Tetralogy of Fallot (TOF) was the most prevalent CHD, constituting 26.7% of cases. The prevalence of PLSVC varied between males and females. Furthermore, the analysis of PLSVC drainage patterns demonstrated associations with specific types of CHD, providing a comprehensive understanding of the diverse manifestations of this anomaly. In conclusion, this study contributes valuable insights into the prevalence and characteristics of PLSVC in pediatric patients with CHD. The findings emphasize the importance of considering gender-specific and CHD-specific factors in medical interventions. These results have implications for clinical practice and future research in pediatric cardiology.*

Keywords: Persistent Left Superior Vena Cava, Congenital Heart Disease, CT Angiography, Vascular Anomaly

Introduction

A persistent left superior vena cava (PLSVC) is the most common abnormality in the veins of the chest. It is frequently found in conjunction with complicated heart conditions (Patel and Gupta, 2018). Although often asymptomatic, it can lead to notable complications such as arrhythmias and cyanosis. Moreover, Persistent Left Superior Vena Cava (PLSVC) might present difficulties during vascular interventional procedures or surgical therapies for cardiac abnormalities (CA). The clinical significance of PLSVC depends on its location of drainage and any associated cardiovascular abnormalities. Several methods can assess PLSVC, including perinatal echocardiography, multidetector computed tomography (MDCT), magnetic resonance imaging (MRI), and invasive angiography. The left brachiocephalic vein (PLSVC) is accountable for roughly 20% of the overall venous blood flow from the left arm and the left side of the head and neck (Azizova et al., 2020). Typically, the drainage of this substance occurs in the right atrium in around 80-90% of instances. In the remaining 10-20% of cases, it drains into the left atrium by several routes, such as the left atrial appendage, left pulmonary veins, or the coronary sinus (CS) (Moradian et al., 2018).

The clinical importance of PLSVC is strongly linked to its drainage location and any accompanying abnormalities (Cao et al., 2022). In instances of persistent left superior vena cava (PLSVC) draining into the right atrium, there is a possibility of expansion of the coronary sinus (CS), which can result in the compression of the atrioventricular (AV) node and the His bundle (Kurtoglu et al., 2011). Cardiac enlargement can lead to abnormal heart rhythms, such as atrial or ventricular fibrillation. It can also cause compression of the left atrium, which reduces the amount of blood pumped by the heart. The closeness of CS dilatation to mitral valve surgery might lead to complications (Kowatari et al., 2020).

It is crucial to be aware of the presence of Persistent Left Superior Vena Cava (PLSVC) during invasive medical operations such as inserting a central venous catheter (CVC), placement of cardiac resynchronization therapy leads, or installing a pacemaker. Insufficient understanding of PLSVC might complicate these procedures, perhaps resulting in challenges securing the electrode, angina, low blood pressure, or heart perforation after CVC insertion (Rossi et al., 2015). A comprehensive understanding of Persistent Left Superior Vena Cava (PLSVC) is crucial in cardiac operations that involve venous rerouting techniques, cavo-pulmonary anastomosis (Glenn, Fontan), or heart transplantation. If PLSVC is not identified during retrograde cardioplegia in cardiac procedures, the surgery might be unsuccessful. In such cases, clamping of PLSVC is necessary to halt the retrograde flow. During cardiopulmonary bypass, a lack of awareness of persistent left superior vena cava (PLSVC) can lead to excessive blood flowing back into the right atrium and inadequate blood returning to the pump (Boyer et al., 2019).

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The rationale for this prospective study lies in the clinical importance of Persistent Left Superior Vena Cava (PLSVC) in pediatric patients with congenital heart disease (CHD). PLSVC, a common anomaly, can lead to complications during invasive procedures and surgeries, impacting patient outcomes. The study employs CT angiography to comprehensively examine the frequency and characteristics of PLSVC in a cohort of 76 pediatric CHD patients. By correlating the presence of PLSVC with various classifications of CHD, the research aims to provide valuable insights into preoperative planning and surgical outcomes. The study's objective addresses the potential challenges PLSVC poses in medical interventions, emphasizing the need to thoroughly understand this anomaly to enhance the quality of care for pediatric cardiac patients.

Methodology

The study included pediatric children who had been diagnosed with congenital heart disease (CHD) and were scheduled to undergo CT angiography, who consented to be included in the study. Patients without established congenital heart disease (CHD), adults, and those with contraindications for CT angiography or who did not consent to be included in the study were excluded. Patients' age was considered a continuous variable, while gender was regarded as a categorical variable. Congenital heart disease or anomaly was considered independent, while the drainage site was dependent. The identification of Persistent Left Superior Vena Cava (PLSVC) was made by observing an atypical left-sided superior vena cava during the examination of CT angiography. The dimensions, trajectory, and hydrological characteristics of the persistent left superior vena cava (PLSVC) were recorded. The classification of PLSVC involved its drainage into the coronary sinus, the left atrium, or another anatomical site.

The CHD diagnoses were classified based on known classification systems, such as the Tetralogy of Fallot (TOF) classification. The present study aimed to evaluate the correlation between Persistent Left Superior Vena Cava (PLSVC) and several classifications of congenital heart disease (CHD).

Data was collected from the medical records and CT angiography reports after obtaining written informed consent from the patient's guardians.

Only 75 patients who underwent CT angiography and presented with CHD to the hospital were included in the study.

For a sample size of 75, the margin of error was calculated as:

Margin of Error = $Z * \sqrt{((p * (1 - p)) / n)}$

Where:

Z is the Z-score corresponding to the desired confidence level,

p is the estimated prevalence or proportion of the condition in the population,

n is the sample size.

If we use this formula using 95% confidence level, p=0.3698, n=75, we get: Moe≈0.1086

The statistical analysis was conducted using SPSS version 25, and a significance level of $p < 0.05$ indicated statistical significance. Descriptive statistics were used to summarize patient demographics, persistent left superior vena cava (PLSVC) characteristics, and types of congenital heart disease (CHD).

Statistical analyses, specifically chi-squared tests, were employed to evaluate the correlation between persistent left superior vena cava (PLSVC) and various forms of congenital heart disease (CHD). The study aimed to assess the potential influence of Persistent Left Superior Vena Cava (PLSVC) on preoperative planning and surgical results.

The study investigation was carried out strictly following ethical protocols and received approval from the Institutional Review Board (IRB) or Ethics Committee of Peshawar Institute of Cardiology (MTI), Peshawar. The researchers acquired informed consent from the parents or legal guardians of the patients.

Results

The cohort included 75 pediatric patients; the overall gender-based distribution indicated 50.7% females and 49.3% males. Tetralogy of Fallot (TOF) dominates the spectrum, constituting 26.7% of cases, with a notable gender discrepancy — 17.3% in males and 9.3% in females. Atrial Septal Defect (ASD) and Single Ventricular Atrial Septal Defect (SVASD) contribute to 16.0% and 12.0% of cases, respectively, reflecting differing prevalence rates between genders. Coarctation of the Aorta (COA) and Left Atrial Isomerism (LAI) exhibit prevalence rates of 10.7% each. Ventricular Septal Defect (VSD), Transposition of the Great Arteries (TGA), and Right Atrial Isomerism (RAI) display prevalence rates of 4.0% each. The total anomaly distribution encompasses 50.7% in females and 49.3% in males, underlining the gender-specific nuances in the occurrence of congenital heart anomalies within this pediatric cohort *(Table 1)*.

Overall, tetralogy of Fallot (TOF) emerged as the most prevalent, accounting for 20 cases (26.7%). Atrial Septal Defect (ASD) was present in 12 cases (16.0%), Single Ventricular Atrial Septal Defect (SVASD) in 9 cases (12.0%), Coarctation of the Aorta (COA) in 8 cases (10.7%), Left Atrial Isomerism (LAI) in 6 cases (8.0%), Ventricular Septal Defect (VSD) in 3 cases (4.0%), Transposition of the Great Arteries (TGA) in 3 cases (4.0%), Right Atrial Isomerism (RAI) in 3 cases (4.0%), Double Outlet Right Ventricle (DORV) in 2 cases (2.7%), Complete Atrioventricular Septal Defect (CAVSD) in 2 cases (2.7%), Total Anomalous Pulmonary Venous Drainage (TAPVD) in 1 case (1.3%), Total Anomalous Pulmonary Venous Connection (TAPVC) in 1 case (1.3%), Partial Anomalous Pulmonary Venous Connection (PA) in 1 case (1.3%), Double Inlet Right Ventricle (DIRV) in 1 case (1.3%), Double Inlet Left Ventricle (DILV) in 1 case (1.3%), and Atrioventricular Septal Defect (AVSD) in 1 case (1.3%). *(Table 1, Figure 1)*. Moving to the drainage patterns, among the 75 cases analyzed, 67 cases (89.3%) exhibited drainage into the Coronary Sinus (CS). Specifically, within the CS-drained cases, TOF was associated with 16 cases (23.9%), ASD with 12 cases (17.9%), SVASD with 9 cases (13.4%), COA with 8 cases (11.9%), LAI with 2 cases (3.0%), VSD with 3 cases (4.5%), TGA with 3 cases (4.5%), RAI with 3 cases (4.5%), DORV with 2 cases (3.0%), CAVSD with 2 cases (3.0%), TAPVD with 1 case (1.5%), TAPVC with 1 case (1.5%), PMVSD with 1 case (1.5%), PA with 1 case (1.5%), DIRV with 1 case (1.5%), DILV with 1 case (1.5%),

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and AVSD with 1 case (1.5%). Further exploration of drainage patterns revealed that the Left Atrium (LA) was associated with 8 cases (10.7%). All 4 cases (50.0%) were linked to Left Atrial Isomerism (LAI) within the LA-drained cases. *(Table 2)*

Table 1 Distribution of Congenital Heart Anomalies by Gender

Anomaly	Gender					
	Female		Male		Total	
	Count	Table N %	Count	Table N %	Count	Table N %
TOF	7	9.3%	13	17.3%	20	26.7%
ASD	8	10.7%	4	5.3%	12	16.0%
SVASD	4	5.3%	5	6.7%	9	12.0%
COA	6	8.0%	2	2.7%	8	10.7%
LAI	5	6.7%	1	1.3%	6	8.0%
VSD	1	1.3%	2	2.7%	3	4.0%
TGA	0	0.0%	3	4.0%	3	4.0%
RAI	1	1.3%	2	2.7%	3	4.0%
DORV	1	1.3%	1	1.3%	2	2.7%
CAVSD	1	1.3%	1	1.3%	2	2.7%
TAPVD	1	1.3%	0	0.0%	1	1.3%
TAPVC	1	1.3%	0	0.0%	1	1.3%
PMVSD	0	0.0%	1	1.3%	1	1.3%
PA	1	1.3%	0	0.0%	1	1.3%
DIRV	0	0.0%	1	1.3%	1	1.3%
DILV	1	1.3%	0	0.0%	1	1.3%
AVSD	0	0.0%	1	1.3%	1	1.3%
Total	38	50.7%	37	49.3%	75	100.0%

Figure 1 shows the gender-based distribution by Gender Anomaly.

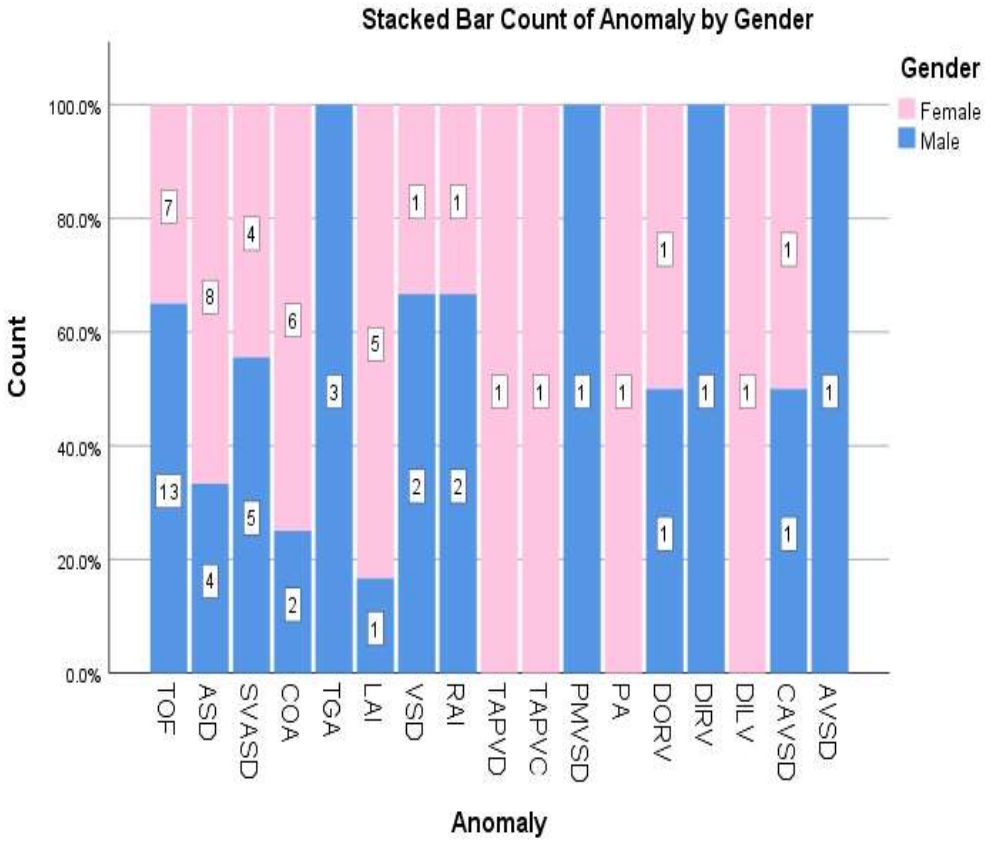

Table 2 Cross-tabulation of drainage patterns about different congenital heart anomalies (Anomaly)

Anomaly	CS			
	Coronary Sinus		Left Atrium	
	Count	Table N %	Count	Table N %
TOF	16	21.3%	4	5.3%
ASD	12	16.0%	0	0.0%
SVASD	9	12.0%	0	0.0%
COA	8	10.7%	0	0.0%
LAI	2	2.7%	4	5.3%
VSD	3	4.0%	0	0.0%
TGA	3	4.0%	0	0.0%
RAI	3	4.0%	0	0.0%
DORV	2	2.7%	0	0.0%
CAVSD	2	2.7%	0	0.0%
TAPVD	1	1.3%	0	0.0%
TAPVC	1	1.3%	0	0.0%
PMVSD	1	1.3%	0	0.0%
PA	1	1.3%	0	0.0%
DIRV	1	1.3%	0	0.0%
DILV	1	1.3%	0	0.0%
AVSD	1	1.3%	0	0.0%
Total	67	89.3%	8	10.7%

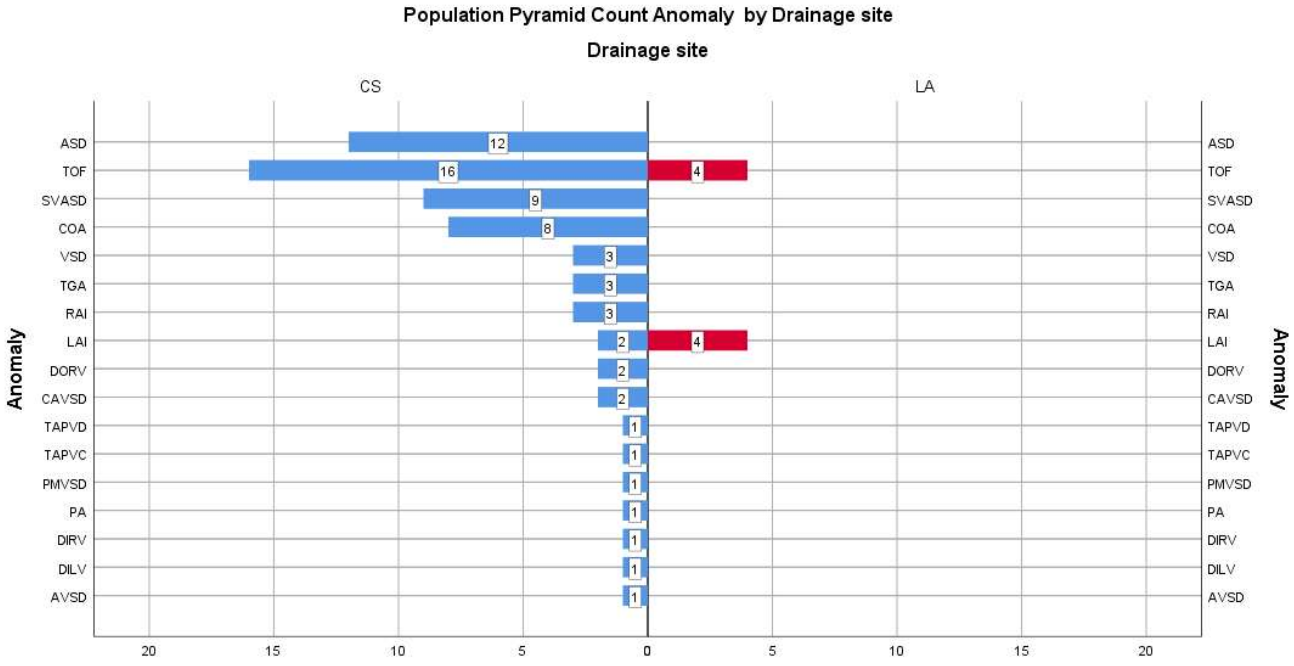

Figure 2 Bar chart showing the distribution of Anomaly by Drainage site

The Pearson Chi-Square test yielded a value of 27.425 with 16 degrees of freedom and a two-sided significance level of 0.037. This suggests a statistically significant association between the studied population's drainage patterns and CHD types. However, it's crucial to note that in 29 out of 34 cells (85.3%), the expected count was less than 5. This raises concerns about the reliability of the results, as such low expected counts can affect the validity of the chi-square test. The minimum expected count in the cells was 0.11, indicating potential limitations in the interpretability of the findings. *(Tables 2 and 3)* The study investigated the cohort's characteristics of Persistent Left Superior Vena Cava (PLSVC) drainage patterns. Among the patients, 17.11% exhibited drainage into the Coronary Sinus, while 19.74% showed drainage into the Right Atrium. Another 19.74% presented with alternative drainage patterns, and 7.89% lacked detailed information on drainage. These findings provide a comprehensive understanding of the diverse drainage patterns associated with PLSVC in the studied pediatric population, as detailed in Table 2

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Table 3 Chi-square analysis.

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	27.425[a]	16	.037
Likelihood Ratio	23.269	16	.107
N of Valid Cases	75		
a. 29 cells (85.3%) have an expected count of less than 5. The minimum expected count is .11.			

.Table 4: Characteristics of Persistent Left Superior Vena Cava (PLSVC) Drainage Patterns in Study Population

PLSVC Characteristics	Number of Patients	Percentage (%)
Drainage into Coronary Sinus	13	17.11%
Drainage into the Right Atrium	15	19.74%
Other Drainage Pattern	15	19.74%
No Detailed Drainage Information Available	6	7.89%

Discussion

The study conducted by Zahid. et al., and our research share the geographical context of the same city. In their study, out of 123 patients, 65 (52.8%) had cyanotic heart defects, and 58 (47.1%) presented with cyanotic heart defects. The most common cyanotic lesions were Ventricular Septal Defect (VSD) at 33.8%, followed by Patent Ductus Arteriosus (PDA) at 23.0%, and Atrial Septal Defect (ASD) at 16.9%. Tetralogy of Fallot (TOF) was identified as the most common cyanotic lesion. In our study, which specifically investigated Persistent Left Superior Vena Cava (PLSVC) in pediatric patients with congenital heart disease (CHD), Tetralogy of Fallot (TOF) emerged as the most prevalent CHD, accounting for 26.7% of the cases. The overall prevalence of TOF in our study aligns with the findings from the Rehman Medical Institute study, suggesting consistency in the prevalence of this specific cardiac anomaly in the pediatric population of Peshawar (Zahid et al., 2013).

Notably, our study provides a focused investigation into the prevalence and characteristics of PLSVC within the broader spectrum of CHD, offering a specific anatomical perspective. The prevalence rates of specific cardiac anomalies, particularly TOF, demonstrate similarities between the two studies, reinforcing the significance of these conditions in the local pediatric population.

In comparing the results of a study done by k.Shahnawaz et al., with a cohort of 72 pediatric patients, some notable similarities and differences emerge. The gender distribution in our study revealed 43 males (60.52%) and 29 females (39.47%), which aligns with the general understanding that congenital heart diseases (CHD) may exhibit varying prevalence among different genders. Regarding specific CHD types, both studies identified Tetralogy of Fallot (TOF) as a prevalent condition, with a prevalence rate of 26.7% in our study and 15.2% in the referenced study. The differences in prevalence rates may be attributed to variations in the study populations, geographical locations, or other demographic factors. Atrial Septal Defect (ASD) was identified in 16.0% of cases in our study, aligning with the findings of the referenced study, where ASD was observed in 19.2% of cases. Single Ventricular Atrial Septal Defect (SVASD) was noted in 12.0% of our study and 13.4% of the referenced study. Coarctation of the Aorta (COA) had a prevalence of 10.7% in my research, which was not specified in the referenced study. Left atrial isomerism (LAI) was observed in 8.0% of my study and 3.0% of the referenced study. Ventricular Septal Defect (VSD) occurred in 4.0% of my research, aligning with the referenced study's prevalence of 4.5%. Transposition of the Great Arteries (TGA) and Right Atrial Isomerism (RAI) both had a prevalence of 4.0% in my study, while they were not specified in the referenced study. While there are similarities in the prevalence of certain CHD types, variations in the rates suggest potential differences in the demographics or methodologies between the two studies. These disparities emphasize the importance of considering regional and population-specific factors in understanding the distribution and prevalence of congenital heart diseases. Further collaborative research and a broader dataset may help elucidate these differences and contribute to a more comprehensive understanding of the global landscape of pediatric genetic heart diseases (Shahnawaz et al., 2021).

Similar to our study, the investigation conducted at the National Institute of Cardiovascular Diseases (NICVD) reveals a gender distribution, with 56.3% males and 43.6% females in their cohort. This consistency in gender distribution suggests that the prevalence of CHD may exhibit comparable patterns across different populations. The prevalence of Tetralogy of Fallot (TOF) in the NICVD study (24.4%) aligns with our findings, where TOF was identified as the most prevalent CHD at 26.7%. This similarity in the predominance of TOF emphasizes its significance and highlights its common occurrence in pediatric patients with congenital heart diseases. Notably, both studies acknowledge the need for early detection of CHD, with the NICVD study indicating an increasing trend in early detection. This parallels our emphasis on the importance of preoperative detection in optimizing surgical planning and outcomes, particularly in complex congenital heart disease cases. Despite these similarities, there are variations in the prevalence rates of specific CHD types between the two studies. For instance, the NICVD study reports Atrial Septal Defect (ASD) at 9.3%, whereas our research identified ASD in 16.0% of cases. These differences may be attributed to variations in study populations, geographical locations, or other demographic factors (Khokhar et al., 2019).

The findings of this study provide significant contributions to our understanding of the frequency and attributes of congenital heart abnormalities (CHD) in children. A substantial proportion of the participants included in the research exhibited a greater prevalence of males. This finding aligns with other research that has also shown a more

significant occurrence of congenital heart disease (CHD) in younger children, as well as a slightly elevated frequency in males (Khokhar et al., 2019). The predominant congenital heart defect (CHD) identified in this study was Tetralogy of Fallot (TOF), followed by Partial Anomalous Pulmonary Venous Drainage (PAPVD), Coarctation of the Aorta (COA), and Atrial Septal Defect (ASD). The results of this study align with other research that has also identified tetralogy of Fallot (TOF) as the predominant form of congenital heart disease (CHD), followed by partial anomalous pulmonary venous drainage (PAPVD) and coarctation of the aorta (COA) (Galdini et al., 2021; Krause et al., 2020). However, the incidence of atrial septal defect (ASD) seen in this particular investigation was found to be lower in comparison to earlier studies, where it has been identified as the second most prevalent form of Congenital Heart Disease (CHD) (Bean Jaworski et al., 2017; Zhao et al., 2013). The observed discrepancy may be attributed to the limited sample size used in this investigation or potential geographical disparities in congenital heart disease (CHD) incidence.

This study evaluated the presence of Persistent Left Superior Vena Cava (PLSVC), identified (26.32%). This is equivalent to previous studies that have found PLSVC in 30-60% of CHD patients (Miyazaki et al., 2020; Özsürmeli et al., 2019). The study also discovered a wide range of drainage patterns associated with PLSVC, with draining into the coronary sinus and left atrium being the most prevalent. This is consistent with prior findings of comparable drainage patterns (Kurtoglu et al., 2011). However, the percentage of patients with PLVC in this study was more significant than in prior investigations, which indicated a range of 10-20% (Hof et al., 2009; Marom et al., 2004). This could be owing to the study's limited sample size or geographical differences in the prevalence of distinct drainage patterns. Previous studies with comparable results include CA Smith (2019), who discovered TOF to be the most frequent CHD in the pediatric population (Smith et al., 2019). Another study by Katre et al. (Katre et al., 2012) (2012) found PLSVC in 40% of CHD patients, with a similar distribution of drainage patterns. These papers support the study's findings and show the need for further research.

Overall, the findings of this study are consistent with previous studies on the prevalence and features of CHD in children. However, some discrepancies in the reported percentages and values could be attributable to variances in the study population, sample size, and techniques used.The small sample size of this study, which may not be representative of the overall pediatric population with CHD, is one of its significant weaknesses. Furthermore, the study was done in a specific location, which may restrict the findings' generalizability to other populations. More study with larger sample sizes and more diverse populations is required to corroborate these findings.

Conclusion

Our study investigating Persistent Left Superior Vena Cava (PLSVC) within the pediatric population with congenital heart disease (CHD) in Peshawar revealed Tetralogy of Fallot (TOF) as the predominant anomaly, constituting 26.7% of cases. The prevalence rates align with similar studies conducted in the region, emphasizing the consistent occurrence of TOF in the pediatric cardiac population. This focused anatomical exploration contributes valuable insights into the specific prevalence and characteristics of PLSVC, shedding light on its significance within the broader spectrum of CHD. The findings underscore the importance of understanding such anatomical variations for informed clinical management and emphasize the need for continued research to enhance our comprehension of congenital heart anomalies in the local context.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate
Approved by the department Concerned.

Consent for publication
Approved

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Not applicable

Conflict of interest

The authors declared absence of conflict of interest.

Author Contribution

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Conception of Study, Development of Research Methodology Design, Study Design,, Review of manuscript, final approval of manuscript.
Coordination of collaborative efforts.
IJAZ HUSSAIN (Professor and HOD)
Manuscript revisions, critical input.
Coordination of collaborative efforts.
HASEEN DIL WAZIR (Assistant Professor)
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SOHAIB (Fellow)
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Conception of Study, Development of Research Methodology Design, Study Design,, Review of manuscript, final approval of manuscript
MUHAMMAD SOHAIL KHAN (Fellow)
Data entry and Data analysis, drafting article

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