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FREQUENCY OF CONGENITAL HEART DISEASES IN INFANTS OF DIABETIC MOTHERS ATTENDING IN A TERTIARY CARE HOSPITAL

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Abstract

Background: *Congenital heart diseases (CHDs) are the most frequent congenital anomalies and a major contributor to infant morbidity and mortality. Infants of diabetic mothers (IDMs) are at increased risk due to hyperglycemia during fetal development. However, prevalence estimates vary widely depending on diagnostic methods, definitions, and population characteristics.*

Objectives: *To determine the prevalence of CHDs among infants of diabetic mothers and to explore associated demographic and clinical factors.*

Methods: *This descriptive cross-sectional study was conducted at Bacha Khan Medical Complex, Gajju Khan Medical College, Swabi, Pakistan, over six months. A total of 360 infants (0–12 months) born to diabetic mothers (gestational or pre-existing) were included through convenience sampling. Maternal demographic and clinical details were collected, and infants underwent clinical examination and echocardiography for CHD detection. Data were analyzed using SPSS version 27. Frequencies and percentages were calculated, and associations between maternal/neonatal factors and CHDs were examined using Chi-square or Fisher's exact tests.*

Results: *CHDs were diagnosed in 8.1% of infants (29/360). The most frequent lesions were atrial septal defect (3.6%) and ventricular septal defect (2.8%), followed by coarctation of the aorta (0.8%), transposition of the great arteries (0.6%), and tetralogy of Fallot (0.3%). No significant associations were found between CHD occurrence and maternal age, type of diabetes, glycemic control, gestational age, pre-eclampsia, gestational hypertension, mode of delivery, or infant sex (all $p > 0.05$).*

Conclusion: *This study highlights a notable prevalence of structural CHDs in infants of diabetic mothers, predominantly septal defects. Routine echocardiographic screening and optimal maternal glycemic control are crucial to reduce undetected cases and improve outcomes. Multicenter studies with larger cohorts are needed to refine risk stratification and guide prevention strategies.*

INTRODUCTION

Congenital heart defects (CHDs) are among the most frequent structural anomalies present at birth and a leading contributor to neonatal morbidity and mortality globally. Infants born to diabetic mothers (IDMs) face elevated risk due to hyperglycemia,

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oxidative stress, metabolic disruption, and teratogenic influences during cardiac morphogenesis. Early recognition of CHDs in such high-risk neonates is crucial for timely intervention and improving outcomes, especially in resource-limited settings.

A nationwide cohort in Finland (620,751 births) showed maternal type 1 diabetes was associated with a 3.77-fold increased adjusted odds for any CHD; the risk was elevated for 6 of 9 CHD subgroups. Overweight/obesity also had associations with some anatomical CHD subtypes(1). A meta-analysis (2018-2023) of 23 observational studies covering ~47 million mother-child pairs found that gestational diabetes mellitus (GDM) increased CHD odds by ~1.32 (95% CI 1.21–1.45), especially for ASD, VSD, and TOF(2). In Egypt, a 2024 hospital-based study found in infants born to diabetic mothers a high incidence of CHDs: Transposition of great arteries, aortic stenosis, and VSD were among top structural defects(3). Another recent meta-analytic work looked at GDM and long-term cardiovascular disease risk and found offspring of GDM mothers have ~20% higher risk of overall CVD outcomes over follow-up, suggesting early cardiovascular impact(4). Another study from Finland highlighted that while type 1 diabetes had the strongest association (OR ~3.77 for any CHD), gestational diabetes and maternal overweight/obesity also contributed risk for specific subtypes(1). In Egypt's Fayoum study (2024), structural defects were found (TGA, VSD, etc.), reinforcing that even in settings with variable healthcare access, CHD incidence remains high among IDMs(3). The meta-analysis of GDM and long-term CVD risk (2024) suggests offspring of GDM mothers have elevated cardiovascular risk beyond infancy, consistent with early structural/functional heart stress(4).

In AlAhsa, Saudi Arabia, among 293 neonates of diabetic mothers, 68.3% had CHDs; most common were patent ductus arteriosus (PDA) (71.5%), hypertrophic cardiomyopathy (36.5%), and VSD (11%)(5). In Pakistan (Lahore, Children's Hospital), a cross-sectional study (160 infants of diabetic mothers) reported frequencies: PDA 26.87%, VSD 21.25%, hypertrophic cardiomyopathy 17.50%, PFO 12.50%, ASD 11.25%, TGA 10.63%(6). In Khyber region (provincial referral center), a 2024 study (IDMs 0-28 days) found PDA in 32%, PFO in ~29.3%, HCM 14%, ASD 10%, VSD 6.66%, TGA 4.66%, TOF 3.33%(7). A case-control study in Islamabad, Pakistan (Oct 2024-March 2025) with 390 term neonates showed CHD in IDMs was 22.05% compared with 10.26% in non-diabetic mothers ($p = 0.002$); TGA was the most common in diabetic group (39.53%), whereas VSD dominated in non-diabetics (30%)(8). In Fayoum University Hospital, Egypt (2024), infants of diabetic mothers had high incidence of structural cardiac anomalies; TGA, aortic stenosis, and VSD among the top types(9). A study in India (2025) from Bangalore reported that among IDMs the prevalence of CHD (especially ASD) was high; though exact % not always consistent, emphasised that even well-controlled diabetes still carried risk(9). Another retrospective study in Middle East / South Asia region emphasized that even term neonates with mothers who had good glycaemic control show non-negligible CHD prevalence; the prevalence tends to be higher when echo screening is systematic(5, 6, 9).

In Lahore (Children's Hospital), as above, ~26.87% PDA, 21.25% VSD, etc., showing high structural CHD burden among IDMs(6). At Peshawar / Lady Reading Hospital, a study found among 101 neonates, CHD frequency in IDMs was 52.5%, with PDA 16.8%, VSD 12.9%, ASD 8.9%, PFO 7.9%, TGA 5.9%(10). Another Pakistan study ("Frequency of Congenital Cardiac Conditions") found diabetes mothers' babies vs non-diabetic had ~ 47.3% CHD among diabetics vs 8.5% in non-diabetics(11). In Khyber Teaching Hospital, Peshawar, in an earlier study, among 150 infants of diabetic mothers, CHD was detected in 52.7%; this suggests very high prevalence locally(12).

While there is strong evidence globally, regionally, and nationally that infants of diabetic mothers have substantially elevated risks of structural CHDs—including high rates of PDA, VSD, ASD, TGA, hypertrophic cardiomyopathy—there is marked variation in reported prevalence, likely due to differences in diagnostic protocols, definitions (structural vs functional vs transitional), timing of echocardiography, and maternal glycaemic control assessment. In Pakistan, especially in Khyber Pakhtunkhwa / Peshawar region, data suggest extremely high prevalence (often >50%) when

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rigorous echocardiographic screening is done(10, 12). However, many studies have limited sample sizes, mix structural + functional anomalies, or lack detailed assessment of associations with factors like maternal age, diabetes type, delivery mode, gestational age, etc.

The present study therefore aims to accurately estimate the prevalence of structural CHDs among infants of diabetic mothers in this setting, characterize the types of CHD, and assess associations with maternal and neonatal factors (maternal age, glycaemic control, type of diabetes, gestational age, mode of delivery, infant sex). This will help strengthen regional evidence, inform screening guidelines, and aid clinical management.

Objectives

The primary objectives of this study were:

To determine the prevalence of congenital heart diseases (CHDs) among infants born to mothers with diabetes (both gestational and pre-existing).

To examine the demographic and clinical factors associated with CHDs in this population.

Operational Definitions

Congenital Heart Diseases (CHDs): For this study, CHDs were defined as structural abnormalities of the heart and great vessels present at birth, confirmed by clinical examination and echocardiography. The defects considered included atrial septal defect (ASD), ventricular septal defect (VSD), tetralogy of Fallot (ToF), coarctation of the aorta, and transposition of the great arteries.

Infants: Infants were defined as children aged 0 to 12 months at the time of diagnosis, allowing capture of early congenital conditions within a uniform age group.

Diabetic Mothers: Mothers were considered diabetic if they had a diagnosis of type 1 or type 2 diabetes before pregnancy, or gestational diabetes mellitus diagnosed during pregnancy. Diagnostic criteria included fasting plasma glucose ≥126 mg/dL, random plasma glucose ≥200 mg/dL with symptoms, or 2-hour plasma glucose ≥200 mg/dL following an oral glucose tolerance test.

Materials and Methods

Study Design and Setting: This descriptive cross-sectional study was conducted at the Pediatrics Department of Bacha Khan Medical Complex, Gajju Khan Medical College, Swabi, Khyber Pakhtunkhwa, Pakistan.

Study Duration: The study was carried out over six months following approval from the institutional ethical review board.

Study Population and Sample Size: The study population comprised infants of diabetic mothers (gestational or pre-existing) presenting to the hospital. The sample size was calculated using OpenEpi (Version 3.01) taking the anticipated prevalence of CHD among infants of diabetic mothers to be 37.6%(13), At a 95% confidence level and with a design effect of 1.0, the minimum sample size required was 360 infants, which was achieved.

Sampling Technique: A non-probability convenience sampling method was used to recruit participants.

Inclusion and Exclusion Criteria: Infants aged 0–12 months born to diabetic mothers (gestational or pre-existing) presenting at the study site were included in our study while infants whose parents or guardians did not provide consent were excluded.

Data Collection: Data were collected after obtaining informed consent from parents/guardians. A structured questionnaire was used to record demographic and clinical details, including maternal age, type of diabetes, and glycaemic control. Clinical examination and echocardiography were performed to confirm CHD diagnoses.

Data Analysis: Data were analyzed using SPSS version 27. Descriptive statistics were calculated for categorical (frequencies, percentages) and continuous variables (means, standard deviationswhere appropriate). Associations between maternal/infant characteristics and CHDs were assessed using Chi-square or Fisher's exact tests, with $p < 0.05$ considered statistically significant.

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Results

Maternal and Neonatal Characteristics

A total of 360 mother–infant pairs were included in the study. The majority of mothers were between 20–29 years of age (46.9%), followed by 30–39 years (37.5%), while 10.0% were over 40 years and 5.6% were under 20 years. With respect to glycemic control, 35.3% of mothers demonstrated good control, 33.6% had fair control, 18.6% poor control, and only 12.5% excellent control. Most deliveries occurred at term (81.4%), whereas 14.7% were preterm and 3.9% post-term. Vaginal delivery was more common

(59.4%) than cesarean section (40.6%). Pre-eclampsia was observed in 10.3% of women, while gestational hypertension was reported in 16.7%. Regarding type of diabetes, more than half had gestational diabetes (56.4%), followed by type 2 diabetes (28.6%) and type 1 diabetes (15.0%). Intrauterine growth restriction (IUGR) was documented in 13.3% of infants. Delivery complications occurred in 65% of cases. Infants were nearly equally distributed by sex (52.5% female, 47.5% male). Birthweight was within the normal range (2.5–4.0 kg) in 67.5% of neonates, with 17.5% being macrosomic (>4.0 kg) and 14.2% of low birthweight (<2.5 kg). Congenital heart disease (CHD) was diagnosed in 8.1% of infants, most commonly atrial septal defect (3.6%) and ventricular septal defect (2.8%). Other congenital anomalies were noted in 7.2% of neonates. (Table 1)

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Table 1 Maternal and Neonatal Characteristics

		Frequency (n=360)	Percentage (%)
Maternal Age	Under 20	20	5.6
	20-29	169	46.9
	30-39	135	37.5
	> 40	36	10.0
Glycemic Control	Poor	67	18.6
	Fair	121	33.6
	Good	127	35.3
	Excellent	45	12.5
	Poor	67	18.6
Gestational Age at Delivery	Pre-term	53	14.7
	Term	293	81.4
	Post-term	14	3.9
	Pre-term	53	14.7
Mode of Delivery	Vaginal	214	59.4
	Ceserean	146	40.6
Pre-eclampsia	No	323	89.7
	Yes	37	10.3
Type of Diabetes	Gestational Diabetes	203	56.4
	Type 1 Diabetes	54	15.0
	Type 2 Diabetes	103	28.6
Gestational Hypertension	No	300	83.3
	Yes	60	16.7
IUGR	no	312	86.7
	Yes	48	13.3
Delivery Complications	No	126	35.0
	yes	234	65.0
Infant Gender	Male	171	47.5
	Female	189	52.5
Infant Birthweight	< 2.5kg	51	14.2
	2.5 - 4 kg	243	67.5
	> 4 kg	63	17.5
CHD Diagnosis	No	331	91.9
	Yes	29	8.1
Type of CHD	None	331	91.9
	ASD	13	3.6
	VSD	10	2.8
	Tetralogy of Fallot	1	.3
	Coarctation of Aorta	3	.8
	TGA	2	.6
Other Congenital anomalies	No	334	92.8
	Yes	26	7.2

Distribution of Continuous Variables

Normality testing using the Shapiro–Wilk test indicated that all continuous variables deviated significantly from a normal distribution ($p < 0.001$). The median maternal age was 29 years (IQR: 13), and the median duration of diabetes was 2.5 years (IQR: 4.87). Neonates had a median age of 5 days (IQR: 6), with a median birthweight of 3.3 kg (IQR: 1.15).(Table 2)

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Table 2 Distribution of Continuous Variables

Variable	Shapiro-Wilk P-value	Median	Interquartile Range
Maternal Age	< 0.001	29.00	13
Duration of Diabetes	< 0.001	2.5	4.87
Infant's Age (Days)	< 0.001	5.00	6.00
Infant Birthweight	< 0.001	3.30	1.15

Association Between Maternal/Neonatal Factors and CHD Diagnosis

Chi-square and Fisher's exact tests showed no statistically significant associations between CHD diagnosis and maternal age, glycemic control, gestational age at delivery, mode of delivery, pre-eclampsia, type of diabetes, gestational hypertension, or infant gender (all $p > 0.05$). Although a slightly higher frequency of CHD was observed among infants of mothers with poor glycemic control and preterm deliveries, the differences were not statistically significant. (Table 3)

Table 3 Association Between Maternal/Neonatal Factors and CHD Diagnosis

		CHD Diagnosis		Ch^2/Fisher Exact Test (P value)
		Yes	No	
Maternal Age	Under 20	20	0	0.207
	20-29	158	11	
	30-39	119	16	
	> 40	34	2	
Glycemic Control	Poor	57	10	0.143
	Fair	114	7	
	Good	118	9	
	Excellent	42	3	
	Poor	57	10	

Association Between Maternal/Neonatal Factors and CHD Type

Further analysis examined potential associations between maternal and neonatal factors and the type of CHD diagnosed. No statistically significant relationships were found between specific CHD subtypes (atrial septal defect, ventricular septal defect, tetralogy of Fallot, coarctation of the aorta, or transposition of the great arteries) and maternal age, glycemic control, gestational age at delivery, pre-eclampsia, gestational hypertension, type of diabetes, or infant gender (all $p > 0.05$). While atrial and ventricular septal defects were more frequently observed in mothers aged 20–39 years and in those with poor or good glycemic control, these findings were not statistically significant. (Table 4)

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Table 4 Association Between Maternal/Neonatal Factors and CHD Type

Gestational Age at Delivery	Pre-term	47	6	0.597
	Term	271	22	
	Post-term	13	1	
Mode of Delivery	No	295	28	0.338
	Yes	36	1	
Pre-eclampsia	No	295	28	0.338
	Yes	36	1	
Type of Diabetes	Gestational Diabetes	189	14	0.344
	Type 1 Diabetes	47	7	
	Type 2 Diabetes	95	8	
Gestational Hypertension	No	275	25	0.665
	Yes	56	4	
Infant Gender	Male	158	13	0.764
	Female	173	16	

Discussion

In this single-center cohort of 360 infants of diabetic mothers (IDMs), the prevalence of structural congenital heart disease (CHD) was 8.1% (29/360), with ASD 3.6% (13/360), VSD 2.8% (10/360), CoA 0.8% (3/360), TGA 0.6% (2/360) and TOF 0.3% (1/360). Most lesions were acyanotic. When set against contemporary population estimates in unselected newborns—typically around 1–2.5 per 1,000 live births, rising when transitional lesions are included—our rate is, as expected, higher for this at-risk group, yet on the lower side compared with some IDM series that used broader case definitions(14, 15). Notably, studies that systematically counted transitional findings (e.g., PDA in preterm infants, PFO) or functional cardiomyopathy report substantially higher "cardiac abnormality" rates in IDMs than we observed after restricting to structural CHD subtypes(15).

The lesion spectrum in our cohort—predominantly septal defects—parallels several recent clinical series, where ASD and VSD account for most structural abnormalities detected in IDMs(16-18). Reviews also emphasize that, beyond fixed lesions, IDMs frequently show transient myocardial hypertrophy and diastolic dysfunction, phenomena that may not meet structural CHD criteria but do inflate the overall burden of "cardiac involvement" if counted together with defects(19, 20). This definitional nuance (structural CHD vs structural + functional/transitional anomalies) likely explains much of the between-study variability and helps contextualize why our structural-only estimate (8.1%) sits below reports that include hypertrophic cardiomyopathy (HCM), PDA/PFO, or subclinical strain abnormalities on speckle tracking(15, 18-20).

With respect to maternal diabetes type, we found no statistically significant association between CHD and GDM vs pregestational diabetes (overall χ^2 p=0.344). That absence of signal contrasts with large registry and meta-analytic data. In a nationwide Finnish cohort of >620,000 births, type 1 diabetes was associated with ~3.8-fold higher odds of any CHD and increased risk across multiple CHD subgroups; risks were smaller for type 2 diabetes and GDM [8]. Two recent meta-analyses broadly corroborate this gradient (strongest for pregestational diabetes, modest for GDM) and also show subtype-specific excesses (e.g., septal defects, outflow tract anomalies) in offspring of mothers with diabetes(2, 21, 22). The discrepancy likely reflects limited power in our study, potential grouping of heterogeneous glycemic phenotypes, and our strict structural-only outcome definition.

Glycemic control at the time of pregnancy, categorized clinically in our dataset, did not correlate with structural CHD (p=0.143). While several contemporary studies argue that poor glycemic control is linked more strongly to functional myocardial changes (e.g., septal hypertrophy, impaired longitudinal strain) than to major fixed malformations, it remains biologically plausible that suboptimal control during the critical window of cardiogenesis contributes to some defects(18-20). The dominant signal in recent syntheses is that pregestational diabetes (a proxy for hyperglycemia

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during organogenesis) carries the greatest structural CHD risk, whereas GDM—often diagnosed later—shows smaller, but still measurable, associations with septal and conotruncal lesions(2, 21-23). Our null result may therefore reflect classification limits (coarse control categories), residual confounding, and sample size.

We also observed no significant associations between structural CHD and maternal age (p=0.207), gestational age at delivery (p=0.597), pre-eclampsia (p=0.338), gestational hypertension (p=0.665), mode of delivery (p=0.338), or infant sex (p=0.764). Some of these factors—especially pre-eclampsia and maternal obesity—emerge as modest prenatal CHD risk factors in recent large meta-analyses, whereas delivery mode generally does not influence prenatal malformation risk (it is a perinatal management decision rather than a teratogenic exposure)(21, 22). Given our precision limits, we cannot exclude small effects consistent with pooled estimates.

Finally, our study's strengths include a clearly defined structural CHD endpoint and complete case ascertainment across a sizeable IDM cohort. Limitations include single-center design, limited power for subgroup analyses (especially by diabetes type), and the lack of systematic advanced echocardiographic strain analysis that might have detected subclinical dysfunction reported elsewhere. Future work could integrate longitudinal speckle-tracking or MRI to clarify the clinical course of functional changes in IDMs and their relationship to early glycemic exposure(20, 24).

Conclusion

In this study, congenital heart disease was identified in 8.1% of infants of diabetic mothers, with atrial and ventricular septal defects being the most common anomalies. Although no significant associations were observed between CHD and maternal or neonatal factors such as diabetes type, glycemic control, or gestational age, the findings reinforce the importance of systematic screening in this high-risk group. Early detection through echocardiography, coupled with optimal preconception and antenatal glycemic management, may reduce the burden of CHDs. Larger multicenter studies are recommended to clarify risk patterns and strengthen preventive strategies.

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