Original Article

Assessment of Maternal and Neonatal Risk Factors for Tetralogy of Fallot among Children and Adolescents at Sulaimani Children's Heart Hospital: A Cross-Sectional Study

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Abstract

Background: Tetralogy of Fallot (TOF) is one of the most common congenital heart defects, and understanding the associated risk factors is crucial for developing preventive strategies and improving patient outcomes. **Objectives:** This study investigates the maternal and neonatal risk factors associated with Tetralogy of Fallot (TOF) among children and adolescents in Sulaimani City. The research was conducted at a specialized Children's Heart Hospital. **Materials and Methods:** A descriptive cross-sectional study was carried out, surveying 100 parents using a structured questionnaire. **Results:** The majority of TOF diagnoses (92%) occurred within the first year of life. Age distribution among the children showed that 26% were aged between 6-8 years, while 11% were under 3 years. Significant maternal factors associated with TOF included age during pregnancy, consanguineous marriage, and multiparity, which together accounted for a total variance of 20.842%. Maternal nutrition during pregnancy showed that 63% of mothers reported having a normal diet, 36% had poor nutrition, and 1% reported smoking during pregnancy. Additionally, 62% of the families had no history of heart disease, with the majority being of Kurdish nationality. **Conclusion:** Maternal factors such as mode of delivery, folic acid consumption three months before pregnancy, maternal habits, and diseases during pregnancy (including perinatal infections, anemia, and vitamin D deficiency) were significant contributors to the risk of TOF. The study recommends promoting a healthy diet during pregnancy and implementing educational programs to mitigate the identified risk factors.

Keyword: Tetralogy of Fallot, Risk Factors, Maternal Health, Neonatal, Adolescents, Congenital Heart Disease, Consanguineous Marriage

Introduction

Tetralogy of Fallot (TOF) is a well-recognized congenital heart defect, accounting for approximately 7% to 10% of all congenital heart disease cases [1]. It occurs in an estimated 0.2 to 0.5 cases per 1,000 live births. Thanks to advances in medical interventions and surgical techniques, the postoperative mortality rate has significantly decreased to less than 2%. However, managing TOF in the long term has become increasingly complex [2]. TOF has profound implications for both maternal and neonatal health. Understanding the risk factors of TOF is crucial in pediatric cardiology and maternal-fetal medicine [3]. Characterized by four distinct heart malformations-ventricular septal defects, overriding aorta, pulmonary stenosis, and right ventricular hypertrophy-TOF

requires specialized care and ongoing management. Surgical outcomes for TOF have improved markedly, but the condition's complexity necessitates a comprehensive understanding of its etiology, which involves both congenital factors and maternal and neonatal influences [4]. TOF was one of the earliest congenital heart diseases to be successfully treated [5]. Several risk factors have been associated with TOF, including untreated maternal diabetes, phenylketonuria, and chromosomal anomalies such as trisomy 21, 18, and 13. Despite the complexity of the condition, many TOF patients exhibit mild or no symptoms beyond the neonatal period. Antenatal echocardiography plays a crucial role in the early diagnosis of TOF, identifying the condition in about 50% of cases [6,7]. Maternal health during pregnancy is vital to the development of congenital heart defects, including TOF. Factors such as maternal age, diabetes, and folic acid intake have been identified as potential contributors to TOF incidence. Additionally, neonatal factors like birth weight and gestational age also play a role in the risk profile of this congenital heart disease. Various maternal risk factors are linked to congenital heart disease (CHD) in offspring, further highlighting the importance of addressing these factors. For example, maternal age during pregnancy, maternal diabetes, and folic acid intake are significant contributors. The incidence of TOF in offspring is estimated to be around 34 cases per 1,000 live births (2.7%) [8]. Recent research has suggested potential preventive measures against congenital heart defects. A systematic review and meta-analysis have shown that periconceptional folic acid supplementation significantly reduces the risk of congenital heart defects (risk ratio 0.79; 95% confidence interval 0.71-0.89) [9]. Additionally, large population-based cohort studies have found that mothers with a history of anemia or anemia-related diseases are at a higher risk of giving birth to children with CHD [10, 11]. This research seeks to further investigate the determinants of TOF among pediatric patients, focusing on factors such as age, gender, residency, disease stage, and the prevalence of other cardiac diseases. By enhancing our understanding of TOF's multifactorial nature, this study aims to benefit the health and well-being of children and adolescents affected by this congenital heart defect, with implications for clinical practice and public health interventions.

Materials and Methods

Study Design and Participants:

This research was a descriptive cross-sectional study conducted at the Sulaimani Children's Heart Hospital in Sulaimani City.

A sample size of 100 mothers of TOF patients was selected to provide a representative sample for analysis. By conducting direct interviews, this study aims to elucidate maternal and neonatal risk factors associated with TOF among children and adolescents at Sulaimani Children's Heart Hospital, offering valuable insights into the etiology and prevention of this congenital heart defect.

Inclusion Criteria:

- Mothers of children and adolescents aged 1 week to 19 years diagnosed with TOF.
- Mothers with live births diagnosed with TOF, a clear diagnosis of the condition
- Mothers of patients admitted to Sulaimani Children's Heart Hospital.

Exclusion criteria

- Multiple gestations,
- Not willing to participate
- Pre-existing congenital heart disease, or missing data on key variables.

Data Collection:

Questionnaire Development:

- A structured questionnaire will be developed to collect data on maternal and neonatal factors, including maternal health during pregnancy and neonatal information.

Variables of Interest:

Maternal Factors:

- Maternal age at the time of pregnancy.
- Maternal diabetes status during pregnancy.
- Maternal folic acid intake and supplementation.

Neonatal Factors:

- Birth weight.
- Gestational age at birth.
- Neonatal health status and complications.

Data Collection Procedures:

- **Recruitment:** Mothers of TOF patients will be approached and invited to participate in the study during their child's hospitalization at Sulaimani Children's Heart Hospital.
- **Informed Consent:** Informed consent will be obtained verbally and written from each participating mother.
- Trained interviewers will conduct direct interviews with the mothers using the structured questionnaire to collect data on maternal and neonatal factors. Interviews will take place in a private and confidential setting.

Ethical Considerations

This study involved human participants. All procedures performed were in accordance with the ethical standards of the institutional research committee. Ethical review and approval were required and obtained for the study.

Ethical review approval for this study will be obtained from Sulaimani Polytechnic University's ethical committee. This ensures that the research meets the necessary ethical standards and adheres to institutional and regulatory guidelines.

Informed Consent

Informed consent was obtained from all individual participants included in the study. Participants were provided with detailed information about the study's purpose, procedures, potential risks, and benefits. In cases involving minors, consent was obtained from the parents or legal guardians. The participants were informed of their right to withdraw from the study at any time without any consequences.

Privacy and Confidentiality

The privacy and confidentiality of all participants were strictly maintained throughout the study. Personal identifiers were removed, and all data were anonymized before analysis. The data were stored securely, with access restricted to authorized personnel only. Participants were assured that their data would only be used for research purposes and not shared with third parties without explicit permission.

Data Usage and Security

Participants were assured that their data would be used solely for research purposes. Data would not be shared with any third parties without explicit permission from the participants. The study ensured that all data handling procedures met the highest standards of security and confidentiality.

Statistical Methods:

All statistical computations will be conducted using SPSS 24. The data will be coded, tabulated, and presented descriptively. The statistical procedures applied in this study include:

1. **Cronbach's Alpha:** To test the reliability of the questionnaire.
2. **Descriptive Statistics:** Frequency and percentage calculations.
3. **Inferential Data Analysis:** Factor analysis using Principal Component Analysis (PCA).

Results

Reliability Analysis: Table 1 shows that Cronbach's alpha was used to assess the reliability of the questionnaire. The resulting Cronbach's alpha value of 0.871 indicates that the questionnaire is highly reliable.

Table 1: Reliability in this study

Methods	Result
Alpha Cronbach	0.871
Sample	100

Socio-Demographic Characteristics: Table 2 provides the socio-demographic characteristics of both mothers and children. Regarding maternal age, the largest proportion falls within the 31-35 age range, representing 23% of the total, closely followed by the 36-40 age group at 20%. Mothers aged 41-45 and 26-30 constitute 19% and 15%, respectively, while those over 50 make up the smallest proportion at 9%. For children's age, the distribution is more evenly spread, with the highest percentage in the 6-8 age group (26%), followed by the 9-13 age range (25%) and the 14-17 age range (21%). Younger children under 3 years old account for 11%, and those aged 3-5 represent 17%. In terms of residency, the majority of respondents (71%) live outside urban areas, while 29% reside in urban areas. Among the children surveyed, males constitute the majority at 53%, with females representing 47%.

Table 2: socio-demographic characteristics of the mother and child

Mother demographic		Fr.	%	Child demographic		Fr.	%
Age (years)	20 – 25	3	3.0	Age (years)	<3	11	11.0
	26- 30	15	15.0		3-5	17	17.0
	31 -35	23	23.0		6-8	26	26.0
	36-40	20	20.0		9-13	25	25.0
	41- 45	19	19.0		14- 17	21	21.0
	46-50	11	11.0	Sex	Male	53	53.0
	> 50	9	9.0				
Residency	Inside	29	29.0		Female	47	47.0
	Outside	71	71.0				
Total		100	100.0	Total		100	100.0

Maternal Risk Factors: Table 3 presents various potential maternal risk factors related to pregnancy, along with their frequencies and percentages. Maternal age during pregnancy is distributed across three categories: ≤ 25 years (35%), 26-35 years (37%), and ≥36 years (28%). Consanguineous marriage, associated with genetic risks, is reported in 33% of cases, while the remaining 67% involve non-consanguineous marriages. Regarding the mode of delivery, there is a near-equal split between vaginal delivery (49%) and cesarean section (51%). Maternal habits are categorized as normal (63%), poor nutrition (36%), and smoking (1%).

In terms of maternal diseases during pregnancy, the majority of cases (28.74%) involve perinatal infections, followed by anemia (26.95%), pre-eclampsia (13.77%), and vitamin D deficiency (12.57%). Gestational diabetes is reported in 5.39% of cases, with a very small percentage (0.60%) involving both gestational diabetes and perinatal infection. Additionally, only 11% of mothers took folic acid three months before pregnancy, highlighting a potential area for improvement in prenatal care. The majority of mothers (89%) are multipara, indicating they have given birth to two or more children. Overall, the data underscores a range of maternal

risk factors that may impact pregnancy outcomes, including maternal age, consanguinity, mode of delivery, maternal habits, and various maternal health conditions.

Neonatal Risk Factors: The data also highlights potential neonatal risk factors and their respective frequencies and percentages. The age at diagnosis of Tetralogy of Fallot (TOF) is primarily within the first day to one year, accounting for 92% of cases, with smaller percentages diagnosed at ages 2-3 years (5%) and 4-5 years (3%). A family history of heart disease is reported in 38% of cases, while 62% have no such history. Additionally, 12% of neonates have a sibling with TOF, while 88% do not. Regarding gestational age at birth, the majority are born full-term (81%), with 15% born preterm and 4% post-term. Common neonatal diseases include jaundice (38.89%) and respiratory disease (21.43%). Other reported conditions include infections (5.56%), down syndrome (4.76%), and various combinations of jaundice, respiratory disease, and infection, albeit at lower frequencies. In terms of neonatal weight, the majorities of neonates are of normal weight (77%), with 21% classified as underweight and only 2% as overweight, while none are classified as obese.

Overall, the data highlights various potential neonatal risk factors, including the timing of TOF diagnosis, family history of heart disease, gestational age at birth, and neonatal health conditions.

Table 3: Potential maternal risk factors & potential neonatal risk factors characteristics

Potential maternal risk factors		Fr.	%	potential neonatal risk factors		Fr.	%
Potential maternal age during pregnancy	≤ 25	35	35.0	Age at diagnosis of ToF (years)	First day -1	92	92.0
	26-35	37	37.0		2- 3	5	5.0
	≥36	28	28.0		4- 5	3	3.0
Consanguineous marriage	Yes	33	33.0	Family history of heart	Yes	38	38.0
	No	67	67.0		No	62	62.0
				disease			
Mode of delivery	Vaginal delivery	49	49.0	Sibling with TOF	Yes	12	12.0
	Cesarean section	51	51.0		No	88	88.0
Maternal habits	Normal	63	63.0	Gestational age at birth	Preterm	15	15.0
	Poor nutrition	36	36.0		Full term	81	81.0
	Smoking	1	1.0		Post-term	4	4.0
Maternal disease during pregnancy	No disease	20	11.98	Neonatal disease	No disease	31	24.60
	Pre-eclampsia	23	13.77		Respiratory disease	27	21.43
	Gestational diabetes	9	5.39		Jaundice	49	38.89
	Perinatal infection	48	28.74		Infection	7	5.56
	Gestational diabetes + perinatal infection	1	0.60		Down syndrome	6	4.76
					Jaundice + infection	3	2.38
	Vitamin D deficiency	21	12.57		Respiratory disease + infection	2	1.59
	Anemia	45	26.95		Respiratory disease + jaundice disease + infection	1	0.79
Total		167	100.0	Total		126	100
mother takes folic acid 3 months before pregnancy	Yes	11	11.0	Neonatal weight	Normal weight	77	77.0
	No	89	89.0		Underweight	21	21.0
The mother multipara	Yes	89	89.0		Overweight	2	2.0
	No	11	11.0		Obesity	0	0.0
Total		100	100.0	Total		100	100.0

Principal Component Analysis (PCA): According to Tables 4.1 and 4.2, three potential maternal risk factors affecting TOF were identified using the correlation matrix and principal component analysis (PCA). The analysis indicated that three out of eight items were eliminated. The PCA identified factors that clarify 57.392% of the variance, with the results identifying three main factors:

1st Factor: This factor includes maternal age during pregnancy, consanguineous marriage, and multiparity, with a total variance of 20.842%.

2nd Factor: This factor includes the mode of delivery and folic acid intake three months before pregnancy, with a total variance of 20.217%.

3rd Factor: This factor includes maternal habits and maternal diseases during pregnancy, with a total variance of 16.332%.

Table 4: Potential maternal risk factors

Table (4.1): Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.62	23.23	23.23	1.62	23.23	23.23	1.45	20.84	20.84
2	1.33	19.01	42.25	1.33	19.01	42.25	1.41	20.21	41.06
3	1.06	15.14	57.39	1.06	15.14	57.39	1.14	16.33	57.39
4	0.97	13.87	71.26						
5	0.70	11.14	82.41						
6	0.74	10.20	92.61						
7	0.51	7.383	100.00						
Extraction Method: Principal Component Analysis.									

Table(4.2): Rotated Component Matrix			
Rotated Component Matrix			
	1	2	3
Potential maternal age during pregnancy	0.702	0.290	0.089
Consanguineous marriage	0.720	0.080	-0.166
Mode of delivery	0.149	0.812	-0.026
Maternal habits	-0.161	-0.311	0.649
Maternal disease during pregnancy	0.106	0.161	0.817
mother takes folic acid 3 months before pregnancy	-0.034	-0.552	0.020
The mother multipara	-0.622	0.487	-0.131
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 6 iterations.			

Tables 5.1 and 5.2 present three potential neonatal risk factors affecting TOF, also analyzed using the correlation matrix and PCA. The analysis eliminated three out of eight items. The PCA identified factors that clarify 62.260% of the variance, with the results identifying three main factors:

1st Factor: This factor includes a family history of heart disease, gestational age at birth, and neonatal weight, with a total variance of 24.813%.

2nd Factor: This factor includes having a sibling with TOF and neonatal disease, with a total variance of 20.239%.

3rd Factor: This factor includes the age at diagnosis of TOF, with a total variance of 17.208%.

Table 5: potential neonatal risk factors

Table (4.1): Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.56	26.05	26.05	1.56	26.05	26.05	1.48	24.81	24.81
2	1.16	19.38	45.43	1.16	19.38	45.43	1.21	20.23	45.05
3	1.01	16.82	62.26	1.01	16.82	62.26	1.03	17.20	62.26
4	0.99	16.63	78.89						
5	0.66	11.13	90.02						
6	0.59	9.97	100.00						
Extraction Method: Principal Component Analysis.									

Table(4.2): Rotated Component Matrix			
Rotated Component Matrix			
	1	2	3
age at diagnosis of TOF	0.089	0.051	0.959
Family history of heart disease	0.660	-0.062	0.013
Sibling with TOF	-0.265	0.781	0.193
Gestational age at birth	-0.631	0.058	-0.210
Neonatal disease	0.272	0.692	-0.101
Neonatal weight	0.709	0.339	-0.142
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 3 iterations.			

Table 6 summarizes the PCA results for potential maternal and neonatal risk factors. For potential maternal risk factors, the first principal

component accounts for 20.842% of the variance, the second for 20.217%, and the third for 16.332%. Together, these three components explain 57.392% of the total variance. For potential neonatal risk factors, the first principal component accounts for 24.813% of the variance, the second for 20.239%, and the third for 17.208%, cumulatively explaining 62.260% of the total variance. These findings suggest that both maternal and neonatal risk factors exhibit multidimensional structures, with several components contributing to their variability.

Table 6: Summary of the risk factor between Potential maternal risk factors & potential neonatal

Risk factors	Component	% of Variance	Cumulative %
Potential maternal risk factors	1	20.842	20.842
	2	20.217	41.060
	3	16.332	57.392
potential neonatal risk factors	1	24.813	24.813
	2	20.239	45.052
	3	17.208	62.260

Discussion

Congenital heart diseases (CHD) are significant contributors to cardiovascular morbidity and mortality in young children and adolescents, representing the most prevalent type of structural congenital anomalies. Despite their prevalence, there is limited information on the incidence and types of these conditions in Sulaimani [12]. This study was conducted to highlight the significance of TOF as a major cause of congenital heart disease, accounting for a substantial proportion of cases. Although the etiology of TOF is multifactorial, involving both genetic and environmental factors, the impact of maternal health on the occurrence and development of TOF in children has garnered increasing research interest [5].

In this discussion, we explore the existing body of literature that investigates the effect of various aspects of maternal health on the development of TOF in children. By examining studies and research findings, we aim to shed light on the potential risk factors, mechanisms, and preventive measures associated with maternal health and TOF. This exploration will contribute to a more comprehensive understanding of the complex etiology of TOF and inform healthcare practices aimed at promoting maternal and child health [13]. Maternal health plays a critical role in fetal development, and disturbances during pregnancy can contribute to congenital heart defects, including TOF. Understanding the intricate interplay between maternal health and the incidence of TOF is essential for improving preventive strategies, enabling early diagnosis, and ultimately enhancing the overall well-being of affected children [6]. Understanding socio-demographic characteristics is vital for maternal and child health outcomes. In this study, most mothers fell within the typical childbearing age (26-35 years), with a notable presence of older and younger mothers. Older mothers may face age-related risks, while younger mothers may need additional support. Maternal age impacts pregnancy outcomes like preterm birth, low birth weight, and congenital anomalies, underscoring the importance of tailored interventions for different age groups [14-16]. In terms of residency, the higher percentage of mothers residing outside urban areas underscores the need for improved healthcare access and resources in rural and semi-rural regions. Bridging the urban-rural healthcare gap could enhance maternal and child health outcomes. The environment in which a child grows up significantly impacts their health, as access to healthcare services, exposure to environmental factors, and socio-economic conditions can vary

between urban and rural areas. Recognizing the distribution of residency is crucial for tailoring interventions that address specific challenges faced by each group [17]. Regarding consanguinity and its relation to TOF in children, the prevalence of consanguineous marriages (33%) is noteworthy and may be a critical factor in assessing the child's health. Consanguineous marriages have been linked to an increased risk of genetic disorders and congenital anomalies in offspring. Studies consistently report a higher prevalence of certain health conditions among children born to consanguineous couples. Acknowledging the prevalence of consanguinity is essential for assessing potential health risks within the child population [18]. This is further supported by retrospective data from the Sulaimani Maternity Hospital database, which indicated that congenital anomalies were predominantly observed in children born to consanguineous couples compared to those born to non-consanguineous couples [19]. Regarding the mode of delivery in your study, the near-equal split between vaginal delivery (49%) and cesarean section (51%) is consistent with general findings, though it is important to recognize that the reasons behind cesarean sections (C/S) could vary. C/S may not always be directly associated with congenital heart defects like Tetralogy of Fallot (TOF), but certain conditions may make cesarean delivery more common in pregnancies with heart defects. For example, some studies suggest that cesarean delivery is more likely in pregnancies complicated by fetal intolerance of labor, which could be seen in certain congenital heart defects (CHD) [20]. Regarding child characteristics, the age distribution of children and their gender balance provide a foundation for understanding the demographic composition of the study sample. Different age groups may exhibit varying susceptibilities to health conditions, and gender differences can play a role in the prevalence and manifestation of certain diseases [20]. In this study, potential maternal risk factors for TOF in children were identified, including poor nutrition, perinatal infections, low folic acid intake, and a notable proportion of preterm births. While the majority of mothers (63%) exhibited normal nutritional habits, the 36% who reported poor nutrition warrant attention, as this could contribute to adverse pregnancy outcomes and may influence the development of congenital conditions such as TOF. A review of maternal lifestyle factors highlights the significant influence of elements like nutrition, smoking, substance use, and chronic conditions on the risk of congenital heart defects such as TOF. Poor lifestyle habits, including inadequate diet, lack of prenatal care, and insufficient folic acid intake, have been linked to adverse pregnancy outcomes and fetal developmental issues. Managing these factors through proper healthcare and preventive measures is crucial to reducing the risk of congenital anomalies like TOF [21]. The prevalence of perinatal infections (28.74%) observed in this study is concerning, as these infections have been linked to significant maternal and neonatal health outcomes. Studies have shown that maternal infections, such as rubella, chlamydia, and other viral infections, are associated with an increased risk of congenital heart defects, including Tetralogy of Fallot (TOF) [22]. Infections during pregnancy may disrupt fetal development, influencing the formation of critical structures, including the heart. This highlights the need for preventive strategies, including vaccination and early treatment of infections, to mitigate the risk of congenital anomalies [23]. Preeclampsia is well-documented as a maternal risk factor for congenital heart defects, including TOF. It is

believed that the condition disrupts placental blood flow, which can lead to fetal growth restriction and developmental abnormalities in the fetus, including congenital heart defects. The underlying pathophysiology involves endothelial dysfunction and poor placental perfusion, contributing to these adverse outcomes. Given the significant association between preeclampsia and congenital heart defects, it is crucial to manage preeclampsia effectively during pregnancy to mitigate the risk of these complications [24]. Anemia and maternal vitamin D deficiency during pregnancy are well-established risk factors for congenital heart defects, including TOF. Studies have shown that anemia, particularly iron deficiency anemia, can result in poor fetal growth, low birth weight, and an increased risk of congenital anomalies. Additionally, maternal vitamin D deficiency has been linked to higher risks of congenital heart defects. These findings highlight the importance of adequate prenatal care, including iron supplementation and vitamin D monitoring, to mitigate these risks and improve pregnancy outcomes [25]. Finally, **gestational diabetes**, which was reported in a small proportion of cases in this study, is another well-established risk factor for congenital heart defects, including TOF. Hyperglycemia during pregnancy can adversely affect fetal heart development, leading to structural abnormalities such as TOF. Managing blood glucose levels during pregnancy through dietary control, insulin therapy, and regular monitoring is crucial to minimize the risk of congenital heart defects and other related complications [26]. In summary, the maternal factors identified in this study perinatal infections, preeclampsia, anemia, vitamin D deficiency, and gestational diabetes—underscore the complexity of risk factors associated with TOF. The interplay of these conditions suggests that a multifaceted approach to maternal healthcare, including regular prenatal care, monitoring, and targeted interventions, is essential for reducing the risk of TOF and other congenital anomalies. Further research is needed to clarify these associations and inform preventive strategies aimed at improving maternal and neonatal health outcomes.

Regarding folic acid intake, the low percentage of mothers taking folic acid (11%) three months before pregnancy is concerning. This finding is supported by a hospital-based case-control study initiated in China in 2010, which examined 358 cases and 422 controls. The study found that folic acid (FA) supplementation is associated with a reduced risk of congenital heart defects (CHDs) The timing and duration of FA supplementation play a crucial role, with earlier initiation before pregnancy and longer supplementation correlating with a lower risk of CHDs. Therefore, adequate folic acid intake is crucial for preventing neural tube defects in newborns. Efforts should be made to increase awareness and encourage prenatal supplementation to improve child health outcomes [23]. The fact that the majority of mothers were multiparous (89%) suggests a population with prior childbirth experience, which can impact health outcomes. The healthcare system should consider this when providing care to this demographic group [24].

Regarding potential neonatal risk factors affecting TOF, the mode of delivery shows a high percentage of cesarean sections (51%) compared to vaginal deliveries (49%), raising questions about the reasons for this prevalence. It is important to explore whether these interventions are medically necessary or if other factors influence the mode of delivery. A retrospective cohort study involving 672 women with a history of one prior cesarean delivery

found that neonates born after elective repeat cesarean delivery exhibit significantly higher rates of respiratory morbidity, NICU admission, and prolonged hospital stays compared to those born via vaginal birth after cesarean [25]. These findings suggest that an abnormal amount of amniotic fluid serves as an independent predictive factor for TOF with genotype alterations. This discovery may have implications for prenatal and neonatal counseling and management [26] The percentage of preterm births (15%) is noteworthy and requires attention, as preterm deliveries can lead to various health challenges, including an increased risk of cardiovascular anomalies such as TOF. Preterm labor was more common among patients with associated genotype anomalies, underscoring the multifactorial nature of CHDs like TOF, where both genetic and environmental factors play significant roles [27].

Three main factors are highlighted:

1. **Genetic and Early Developmental Factors:** Family history, gestational age, and neonatal weight are crucial in understanding the interplay between genetics and early development in the context of TOF.
2. **Familial Clustering of TOF and Neonatal Health:** Genetic counseling and screening for families with a history of TOF could be beneficial. Effective management of neonatal diseases is also essential to reduce the risk of complications associated with CHDs.
3. **Importance of Early Screening and Diagnosis:** Early detection and diagnosis are crucial for improving management and outcomes for neonates with TOF. Early screening allows for timely surgical interventions, which are vital for the survival and quality of life of affected infants. Early screening for Tetralogy of Fallot (TOF) primarily involves prenatal imaging and neonatal assessments. Fetal echocardiography is often used to detect cardiac anomalies during pregnancy, especially for high-risk cases. Postnatally, physical examination, including detection of cyanosis and heart murmurs, is critical. Confirmatory diagnostic methods include echocardiography, which provides detailed heart structure images. Early detection enables timely interventions, such as surgery, to manage the condition and improve long-term outcomes, especially survival and quality of life for affected neonates.

Conclusion

Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart defect, primarily diagnosed in infancy but occasionally later. This study identifies significant maternal risk factors such as gestational diabetes, pre-eclampsia, prenatal infections, anemia, and insufficient folic acid intake before pregnancy as contributors to TOF. To reduce congenital heart anomalies, policies should focus on improving antenatal care, promoting maternal health education, and addressing high-risk pregnancies. Additionally, discouraging consanguineous marriages through premarital counseling, especially in families with consanguinity, is essential to mitigate genetic risks associated with congenital anomalies.

The strengths and Limitations

The focus on identifying maternal risk factors linked to Tetralogy of Fallot (TOF) is one of the study's strengths; it adds important knowledge about congenital heart defects. In order to provide a foundation for focused interventions, the study also highlights particular maternal conditions, such as anemia, preeclampsia, and gestational diabetes. Furthering the

examination of risk factors is the examination of consanguinity and folic acid supplementation. By emphasizing the value of prenatal care and public health initiatives to lower the incidence of TOF, these findings can help guide healthcare policies and preventative measures. A significant limitation of this study is its relatively small sample size, which restricts the generalizability of the findings and limits the ability to robustly measure the associations between specific maternal risk factors and Tetralogy of Fallot (TOF). Additionally, the lack of information on neonatal weight across different gestational ages hinders a comprehensive understanding of neonatal health outcomes. Moreover, further investigation is needed to explore maternal and neonatal health practices, such as the high prevalence of cesarean sections. Addressing these limitations in future research will enhance the validity and applicability of the findings.

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Conflict of Interest:

The authors declare that they have no conflict of interest related to this study. All procedures followed comply with the ethical standards of the responsible institutional and national committees.

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