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# Assessment of Maternal and Neonatal Risk Factors for Tetralogy of Fallot among children & adolescents at Sulaimani Children's Heart Hospital: A cross-sectional study.

Chia H. Sadiq [1*], Pary M. Aziz [2], Soran Husen Mohamad [3] Aso Faeq Salih [4]

1Maternity &Obstetric Department. Sulaimani Technical Institute, Sulaimani Polytechnic University.

2Pary M. Aziz, Assistant Professor, RN, MSc, PhD. Nursing department, Sulaimani Technical Institute, Sulaimani Polytechnic University, P.O.Box: 70-236\Sulaymaniyah-Iraq.

3Assistant Lecture; Statistics and Informatics department, College of Administration & Economics Sulaimani University – Sulaimani city.

4Professor, Pediatric Medicine department, College of Medicin, University of Sulaimani.

**Corresponding Author Email: pary.azize@spu.edu.iq**

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## Abstract

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. 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. A descriptive cross-sectional study was carried out, surveying 100 parents using a structured questionnaire, 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. 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.

## 1. 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. 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].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 [5,6,7].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.

## 2. Materials and Methods:

### 2.1. Study Design

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

### 2.2. Participants:

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**.**

### 2.3. 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.

### 2.4. Exclusion criteria

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

### 2.5. Data Collection:

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

### 2.6. Variables of Interest:

#### 2.6.1. Maternal Factors:

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

#### 2.6.2 Neonatal Factors:

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

### 2.7. Data Collection Procedures:

Mothers of children with TOF will be invited to participate in the study during their child's hospitalization at Sulaimani Children's Heart Hospital. After obtaining both verbal and written informed consent, trained interviewers will conduct private, structured interviews to collect information about maternal and neonatal factors.

## 2.8. Ethical Considerations

This study followed all required ethical standards and received approval from the Sulaimani Polytechnic University ethical committee. Informed consent was obtained from all participants, with parental or guardian consent for minors, and everyone was assured of their right to withdraw at any time. Privacy was strictly protected by anonymizing all data and limiting access to authorized personnel. Participants were informed that their data would be used only for research purposes and never shared without permission.

## 2.9. Statistical Methods:

Statistical analysis will be performed using SPSS 24, including reliability testing with Cronbach's alpha, descriptive statistics, and factor analysis using PC. Cronbach's alpha was 0.871, indicating that the questionnaire had high reliability

## 3. Result:

**Table (1): 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 |

Table 1 shows that most mothers were aged 31–35, and most children were between 6–8 years old. Most families lived in non-urban areas (71%). Slightly more children were male (53%) than female (47%).

**Table (2): 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 disease | Yes | 38 | 38.0 |
| | No | 67 | 67.0 | | No | 62 | 62.0 |
| 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 + | 1 | 0.60 | | Down syndrome | 6 | 4.76 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | perinatal infection | | | | 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** |

**Maternal risk factors in Table 2** show that most mothers were 26–35 years old, one-third had consanguineous marriages, and delivery was almost evenly split between vaginal and cesarean. Normal maternal habits were most common, though poor nutrition was reported by over one-third, and smoking was rare. The most frequent maternal health issues were perinatal infections and anemia, while only 11% used folic acid before pregnancy. Most mothers were multipara.**Neonatal findings** show that TOF was diagnosed mostly within the first year of life, and 38% had a family history of heart disease. Most newborns were full-term with normal birth weight; jaundice and respiratory diseases were the most common neonatal conditions. Only a small proportion had Down syndrome or other combined conditions.

**Table (3): Potential maternal risk factors**

**Table (3.1): 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** | 1.627 | 23.237 | 23.237 | 1.627 | 23.237 | 23.237 | 1.459 | 20.842 | 20.842 |
| **2** | 1.331 | 19.013 | 42.251 | 1.331 | 19.013 | 42.251 | 1.415 | 20.217 | 41.060 |
| **3** | 1.060 | 15.141 | 57.392 | 1.060 | 15.141 | 57.392 | 1.143 | 16.332 | 57.392 |
| **4** | .971 | 13.877 | 71.269 | | | | | | |
| **5** | 0.780 | 11.144 | 82.413 | | | | | | |
| **6** | 0.714 | 10.204 | 92.617 | | | | | | |
| **7** | 0.517 | 7.383 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table (3.2): 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.** | | | |

Principal Component Analysis (**PCA**) results (Tables 3.1 and 3.2) identified three key maternal risk factor components explaining 57.39% of the total variance after removing three of the eight items. **The first factor** (20.84%) included maternal age, consanguinity, and multiparity. **The second factor** (20.22%) included mode of delivery and folic acid intake. **The third factor** (16.33%) included maternal habits and maternal pregnancy-related diseases.

**Table (4) 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 | 1.563 | 26.052 | 26.052 | 1.563 | 26.052 | 26.052 | 1.489 | 24.813 | 24.813 |
| 2 | 1.163 | 19.382 | 45.434 | 1.163 | 19.382 | 45.434 | 1.214 | 20.239 | 45.052 |
| 3 | 1.010 | 16.825 | 62.260 | 1.010 | 16.825 | 62.260 | 1.032 | 17.208 | 62.260 |
| 4 | 0.998 | 16.636 | 78.895 | | | | | | |
| 5 | 0.668 | 11.131 | 90.026 | | | | | | |
| 6 | 0.598 | 9.974 | 100.000 | | | | | | |

**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.**

PCA results (Tables 4.1 and 4.2) identified three key neonatal risk factor components explaining 62.26% of the variance after removing three of the eight items. The first factor (24.81%) included family history of heart disease, gestational age, and neonatal weight. The second factor (20.24%) included having a sibling with TOF and neonatal disease. The third factor (17.21%) consisted of the age at TOF diagnosis.

**Table (5): Summary of the risk factor between Potential maternal risk factors & potential neonatal**

| | Component | % of Variance | Cumulative % |
|---|---|---|---|
| **Potential maternal** | **1** | **20.842** | **20.842** |
| | **2** | **20.217** | **41.060** |
| | **3** | **16.332** | **57.392** |

| | | | |
|---|---|---|---|
| **risk factors** | | | |
| **potential neonatal risk factors** | **1** | **24.813** | **24.813** |
| | **2** | **20.239** | **45.052** |
| | **3** | **17.208** | **62.260** |

Table 5 shows that maternal risk factors are explained by three PCA components covering 57.39% of the variance, while neonatal risk factors are explained by three components covering 62.26%. This indicates that both maternal and neonatal risks are multidimensional, with several factors contributing to overall variability.

## 4. Discussion

Congenital heart diseases (CHDs) are major contributors to cardiovascular morbidity and mortality in children, with Tetralogy of Fallot (TOF) accounting for a significant proportion of cases [12]. TOF arises from a combination of genetic and environmental factors, and growing evidence highlights the critical role of maternal health in its development [5]. Understanding these maternal influences is essential for improving preventive strategies, early diagnosis, and child outcomes [13]. In this study, most mothers were aged 26–35, although both younger and older mothers were represented. Maternal age influences pregnancy outcomes such as preterm birth, low birth weight, and congenital anomalies, emphasizing the importance of age-specific care and monitoring [14,15,16]. Additionally, the higher proportion of mothers residing outside urban areas underscores the need to improve healthcare access in rural and semi-rural regions, where environmental exposures, socio-economic factors, and limited medical resources may affect maternal and child health [17]. Consanguinity was present in 33% of mothers, which is a noteworthy factor given its association with increased genetic and congenital risks in offspring [18,19]. Regarding delivery mode, cesarean sections slightly outnumbered vaginal deliveries (51% vs. 49%), consistent with general trends. While cesarean delivery may not directly cause TOF, it can be more common in pregnancies complicated by fetal intolerance or other maternal conditions [20]. Several maternal risk factors for TOF were identified. Poor nutrition was reported by 36% of mothers, and only 11% took folic acid before conception. Folic acid supplementation is well-known to reduce the risk of congenital heart defects, and its low uptake highlights the need for increased awareness and prenatal education [23]. Perinatal infections were observed in 28.7% of mothers, which is concerning given their established link to CHDs, including TOF [22,23]. Maternal conditions such as preeclampsia, anemia, vitamin D deficiency, and gestational diabetes were also noted, each contributing to adverse fetal outcomes through mechanisms such as impaired placental perfusion or disrupted fetal growth [24,25,26]. Most mothers were multiparous (89%), indicating prior childbirth experience that may influence maternal care and risk assessment [24]. Neonatal factors also play a role. Preterm birth occurred in 15% of cases, which increases vulnerability to health challenges, including congenital anomalies. Genetic factors, neonatal weight, and family history remain critical in understanding TOF development and tailoring early interventions [27]. Early detection and diagnosis are essential for optimal outcomes. Prenatal imaging, fetal echocardiography, and postnatal assessments, including detection of cyanosis and heart murmurs, enable timely interventions, such as surgical correction, which are vital for survival and long-term quality of life [27]. In summary, TOF results from a complex interplay of maternal, neonatal, and genetic factors. Effective maternal care—through nutrition, folic acid supplementation, infection prevention, and management of chronic conditions—combined with early neonatal screening, is key to reducing TOF incidence and improving outcomes. This study underscores the need for multifaceted preventive strategies and highlights areas for further research to support maternal and child health in the region.

### Three Main Factors Highlighted

1. Genetic & Early Development: Family history, gestational age, and neonatal weight influence TOF.
2. Familial Clustering & Neonatal Health: Genetic counseling and careful neonatal care reduce complications.
3. Early Screening & Diagnosis: Prenatal imaging and postnatal assessments enable timely interventions, improving survival and quality of life.

## Conclusion & Recommendations

TOF is the most common cyanotic congenital heart defect, usually diagnosed in infancy. Maternal risk factors identified include gestational diabetes, preeclampsia, perinatal infections, anemia, and insufficient folic acid intake. Reducing CHDs requires improved antenatal care, maternal health education, and management of high-risk pregnancies. Premarital counseling to limit consanguinity is also recommended.

## Strengths and Limitations

This study Highlights maternal risk factors for TOF, supporting targeted interventions. While , Small sample size and limited neonatal data reduce generalizability

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## Conflict of Interest

The authors declare no conflicts of interest. All procedures followed ethical standards.

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