

RESEARCH PAPER

Arterial blood gases and some blood parameters in Tetralogy of Fallot patients

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ABSTRACT:

The present study was done to assess the effect of the tetralogy of Fallot (TOF) on some arterial blood measurements including pH, the partial pressure of carbon dioxide (PaCO₂), the partial pressure of oxygen (PaO₂), Base excess (BE), Red blood cells (RBC), Packed cell volume (PCV), and Hemoglobin (Hb) concentration in the Erbil City of Iraq. For this purpose 80 (40 males and 40 females) patients with (TOF) and aged between 3-33 years were used in this study. This retrospective cohort study was conducted from March /2018 to October 2020 and carried out in the Surgeries Hospital Specialist - Cardiac Center in Erbil city. The studied parameters were estimated before and two to three weeks after postoperative correction of TOF. A dependent t-test was used for data analysis. The results showed that males and females with (TOF) after surgical correction have significantly $p \leq 0.001$ lower PaCO₂, RBC, PCV, and Hb concentration, while the concentration of PaO₂ and the value of BE were significantly $p \leq 0.001$ higher after surgical correction in comparison with the value before surgery. Moreover, males showed a significantly higher concentration of RBC, PCV, and hemoglobin than females after surgical correction. Conclusions: Surgery repair of (TOF) restore the arterial blood measurements PaCO₂, PaO₂, BE, RBC, PCV, and Hb concentration to the normal value in males and females.

KEY WORDS: Tetralogy of Fallot; PaO₂; PaCO₂; PCV; Surgical correction; Base Excess.

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1. INTRODUCTION:

The prevalence of congenital heart defects is eight in 1,000 births worldwide. TOF is the most common cyanotic congenital heart defect which represents 10% of all heart defects. The severity of cyanosis is determined by the degree of pulmonary blood flow obstruction (Wilson *et al.*, 2019). Tetralogy of Fallot prevalence varies from 0.26 to 0.48% for every 1000 live birth (Agarwalla, 2017). TOF is a congenital cardiac malformation consisting of interventricular contact, often referred to as a ventricular septal defect (VSD), right ventricular hypertrophy, right ventricular outflow tract obstruction, an override of the ventricular septum by the aortic root (Bailliard and Anderson, 2009).

Niels Stensen described it in 1672, Edward Sandiford in 1773, and the French physician Étienne-Louis Arthur Fallot in 1888, after whom it is named. Currently, patients typically present as neonates, with cyanosis of varying severity, depending on the degree of blockage of blood supply to the lungs. The etiology is multifactorial, but the associations identified include untreated maternal diabetes, phenylketonuria, and retinoic acid intake. The probability of familial recurrence is 3%. The chest radiograph, electrocardiogram, and echocardiogram are valuable medical measures for diagnosis. The echocardiogram provides a definitive diagnosis and typically provides appropriate details for the preparation of surgical care (Bailliard and Anderson, 2009).

More than 85% of infants with congenital heart disease are expected to reach adulthood, while the 40-year survival rate for those with TOF is at least 90% (Hickey *et al.*, 2009). When compared to younger patients with TOF surgical correction,

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patients over 35 years of age have a substantially higher mortality rate (Dorobantu *et al.*, 2020). If untreated, ventricular and atrial arrhythmias develop in up to 35% of TOF patients, and the rate of sudden heart death is 6% during a follow-up period of up to 30 years (Murphy *et al.*, 1993). Also, since many patients in early adulthood have no symptoms, they are frequently lost to follow-up, possibly losing the chance of treating problems until they become permanent (Mackie *et al.*, 2009).

The treatment has steadily progressed since the first surgical repair in 1954. Excellent long-term survival outcomes from the clinical methods commonly used in the treatment of TOF (30-year survival ranges from 68.5% to 90.5%). Depending on the level of right ventricular outflow tract stenosis and pulmonary artery anatomy, patients with TOF have different degrees of cyanosis. The anatomical anomalies were seen in TOF range from milder to more extreme phenotypes, such as pulmonary atresia and right ventricle double outlet type TOF. Different management and treatment strategies can involve these more extreme types (Van der Ven *et al.*, 2019).

The TOF contributes to low blood oxygenation. This is due to the mixing of oxygenated and deoxygenated blood through the ventricular septal defect in the left ventricle and the preferential flow of mixed blood through the aorta from both ventricles due to the restriction of flow through the pulmonary valve (Abdulla, 2011). Depending on the severity of the anatomical defects, blood oxygenation varies significantly from one patient to another. Symptoms range from no cyanosis or mild cyanosis to profound cyanosis at birth, depending on the degree of obstruction. It is often referred to as a 'pink tet' if the baby is not cyanotic. Other signs include a heart murmur that can range from almost imperceptible to very loud, trouble eating, weight loss, slow growth and physical development, exertional labored breathing (dyspnea), finger and toe clubbing, and polycythemia (Hay *et al.*, 2009).

The present study was done to evaluate the effect of TOF on some arterial blood measurements including pH, PaCO₂, PaO₂, BE, RBC, PCV, and Hb. Moreover the evaluation of the degree the repaired of these parameters to the normal level after surgery and successfully of the Fallot correction.

2.MATERIALS AND METHODS

2.1Subjects

The study included 80 persons and divided into two groups:

- 1- Males with TOF (40 patients).
- 2- Females with TOF (40 patients).

The study was carried out in the Cardiac Center in Erbil city from March /2018 to October/2020. The ages of the patients ranged from 3-33 years. The diagnosis of heart defect TOF) was based on clinical signs, echocardiography, and sometimes angiography for each patient.

2.2 Blood sample collection and analysis

Five ml of fresh blood obtained from each patient and put in a heparinized tube and the blood is added to the arterial blood gas analysis system (Medica, USA) for measurements of the pH, PaCO₂, PaO₂, and BE. Also, the RBC, PCV, and Hb concentration were measured by using a Coulter Counter instrument (Medonic, USA).

2.3 Statistical analysis

Analysis of data was performed by using Statistical Package for Social Science (SPSS), version 17. Results are expressed as mean \pm S.E. Dependent t-test was used for comparison of different arterial blood parameters, RBC, PCV, and Hb concentration before and after surgery. A P-value of less than 0.05 was considered to be statistically significant.

3.RESULTS

Table 1 showed the effect of the TOF on arterial blood pH, PaCO₂, PaO₂, BE, RBC, PCV, and Hb concentration in male patients. The results showed that there is a significant $p \leq 0.001$ increase in the PaO₂ 95.05 ± 5.76 mmHg, Base excess -2.11 ± 0.34 , mmol/L and a significant decrease $p \leq 0.001$ in the PaCO₂ 37.45 ± 1.74 mmHg, RBC $4.78 \pm 0.10 \times 10^6/\mu\text{L}$, PCV 40.26 ± 2.42 %, and Hb concentration 15.25 ± 0.34 g/dL in arterial blood after surgical correction when compared with the value before surgery PaO₂ 62.62 ± 5.97 mmHg, Base excess -4.28 ± 0.41 , mmol/L, PaCO₂ 47.40 ± 2.22 mmHg, RBC $5.55 \pm 0.12 \times 10^6/\mu\text{L}$, PCV 50.66 ± 3.03 %, and Hb 18.33 ± 0.41 g/dL .

The results presented in Table 2 showed the comparison of the arterial blood pH, PaCO₂, PaO₂, BE, RBC, PCV, and Hb concentration in female patients pre and postoperative correction. The results revealed that there is a significant $p \leq 0.001$ increase in the PaO₂ 93.99 ± 5.88 mmHg,

Base excess -2.01 ± 0.29 , mmol/L and a significant decrease $p \leq 0.001$ in the PaCO₂ 38.95 ± 1.89 mmHg, RBC $4.02 \pm 0.14 \times 10^6/\mu\text{L}$, PCV $36.33 \pm 1.60\%$, and Hb concentration 13.43 ± 1.29 g/dL in arterial blood after surgical correction when compared with the value before surgery PaO₂ 56.80 ± 5.17 mmHg, Base excess -4.27 ± 0.51 mmol/L, pCO 48.22 ± 2.79 mmHg, RBC $4.86 \pm 2.56 \times 10^6/\mu\text{L}$, PCV $47.26 \pm 2.56\%$, and Hb 17.23 ± 1.51 g/dL.

The comparison of pH, PaCO₂, PaO₂, Base excess, RBC, PCV, and Hb after postoperative

correction between male and female TOF patients are observed in Table 3. The male patients showed a significantly $p \leq 0.05$ higher concentration of the RBC $4.78 \pm 0.10 \times 10^6/\mu\text{L}$, PCV $40.26 \pm 2.42\%$, and Hb 15.25 ± 0.34 g/dL than that of the females RBC $4.02 \pm 0.14 \times 10^6/\mu\text{L}$, PCV $36.33 \pm 1.60\%$, and Hb 13.43 ± 1.29 g/dL after surgery. No significant differences were observed in the pH, PaCO₂, PaO₂, and BE between male and female patients after surgical correction.

Table 1. Arterial blood gases and blood parameters in pre and postoperative correction in male patients with TOF (Mean \pm SEM)

Arterial blood gases and some blood parameters	Preoperative	Postoperative	p-value
pH	7.32 ± 0.01	7.39 ± 0.01	0.378
PaCO ₂ mmHg	47.40 ± 2.22	37.45 ± 1.74	0.001
PaO ₂ mmHg	62.62 ± 5.97	95.05 ± 5.76	0.001
Base excess mmol/L	-4.28 ± 0.41	-2.11 ± 0.34	0.001
Red blood cells $\times 10^6/\mu\text{L}$	5.55 ± 0.12	4.78 ± 0.10	0.001
Packed cell volume %	50.66 ± 3.03	40.26 ± 2.42	0.001
Hemoglobin g/dL	18.33 ± 0.41	15.25 ± 0.34	0.001

N= 40

P-value ≤ 0.05 considered significant
SEM = standard error of the mean

N= number of samples

Table 2. Arterial blood gases and blood parameters in pre and postoperative correction in female patients with TOF (Mean \pm SEM)

Arterial blood gases and some blood parameters	Preoperative	Postoperative	p-value
pH	7.34 \pm 0.01	7.38 \pm 0.01	0.378
PaCO₂ mmHg	48.22 \pm 2.79	38.95 \pm 1.89	0.001
PaO₂ mmHg	56.80 \pm 5.17	93.99 \pm 5.88	0.001
Base excess mmol/L	-4.27 \pm 0.51	-2.01 \pm 0.29	0.001
Red blood cells $\times 10^6/\mu\text{L}$	4.86 \pm 2.56	4.02 \pm 0.14	0.001
Packed cell volume %	47.26 \pm 2.56	36.33 \pm 1.60	0.001
Hemoglobin g/dL	17.23 \pm 1.51	13.43 \pm 1.29	0.001

N= 40

P-value \leq 0.05 considered significant

N= number of samples

SEM = standard error of the mean

Table 3. Arterial blood gases and blood parameters comparison of postoperative correction between male and female patients with TOF (Mean \pm SEM)

Arterial blood gases and some blood parameters	Males	Females	p-value
pH	7.39 \pm 0.01	7.38 \pm 0.01	0.378
PaCO₂ mmHg	37.45 \pm 1.74	38.95 \pm 1.89	0.547
PaO₂ mmHg	95.05 \pm 5.76	93.99 \pm 5.88	0.238
Base excess mmol/L	-2.11 \pm 0.34	-2.01 \pm 0.29	0.654
Red blood cells $\times 10^6/\mu\text{L}$	4.78 \pm 0.10	4.02 \pm 0.14	0.05
Packed cell volume %	40.26 \pm 2.42	36.33 \pm 1.60	0.05
Hemoglobin g/dL	15.25 \pm 0.34	13.43 \pm 1.29	0.05

N= 40

P-

value ≤ 0.05 considered significant

N= number of samples

SEM = standard error of the mean

4.DISCUSSION

The majority of children born with TOF undergo corrective surgery and live to adulthood (Long and Duffy, 1990). In recent eras, overall survival after TOF repair has improved significantly (Van der Ven *et al.*, 2019). The optimum age for full TOF surgical correction has fallen and is now considered to be between the ages of 3 and 12 months (Shinebourne *et al.*, 2006). The repair includes using ventricular septal defect patch closure and separating the aorta back to the left ventricle, resection of muscle bundles of the right ventricular outflow tract (RVOT), and decreasing the degree of valvular stenosis of RVOT (Sommer *et al.*, 2008).

In this study, the decrease in PaO₂ and increase in PaCO₂ in arterial blood in patients with TOF in both sexes is results in low blood oxygenation and due to the mixture of oxygenated and deoxygenated blood in the left ventricle via ventricular septal defect and preferential mixed

blood flow. It appears that low preoperative oxygenation is one of the important factors influencing early mortality in TOF patients (Bhardwaj *et al.*, 2017). Owing to the obstruction of flow through the pulmonary valve, the mixed-blood flow from both ventricles through the aorta is preferential. This is known as a right-to-left shunt. The primary sign is low saturation of blood oxygen with or without cyanosis from birth or growth in the first year of life (Josos and Judas, 2020). The surgical correction returned PaO₂ and PaCO₂ to the normal level. In the present study, the Base excess decrease in the patients with TOF beyond the normal range in both sexes, and after postoperative correction, the values of Base excess returned to the normal value. The obtained results in the current study are in agreement with the findings of (Bhardwaj *et al.*, 2017), who found an increase in the PaO₂ and a decrease in the Base excess after postoperative of patients with tetralogy of TOF in India.

Base excess and base deficiency in human physiology apply to an excess or deficit in the amount of base present in the blood respectively (Fischbach and Dunning, 2009). The additional base that must be applied to a liter of blood to normalize the pH is the base deficit. The substantial base deficit is a predictor of morbidity and mortality in patients who are seriously ill and trauma (Paladino *et al.*, 2008, Ouellet *et al.*, 2012). The value is generally stated as a concentration in mmol/L units, with positive numbers suggesting a base surplus and a deficit being negative. A standard BE comparison range is between -2 and $+2$ mmol/L. Comparing the base excess with the reference range helps decide whether a cardiac, metabolic, or mixed metabolic/respiratory problem triggers an acid/base disturbance. While the respiratory portion of the acid-base balance is characterized by carbon dioxide, the metabolic component is defined by BE. The measurement of BE is then specified under a standardized carbon dioxide pressure by titration back to a standardized blood pH of 7.40. Bicarbonate is the primary base that leads to base excess. A divergence of serum bicarbonate from the reference range is therefore typically expressed by a deviation in the BE (Fischbach and Dunning, 2009).

In our results, there is an increase in RBC, PCV, and Hb concentration. In most patients, the numbers of RBC increased above $6 \times 10^6/\mu\text{l}$ and causing secondary polycythemia. Congenital heart defects with right-to-left shunting are one of the causes of acquired polycythemia associated with hypoxia. Despite an increased Hb level, erythropoietin-mediated and hypoxia-dependent polycythemia is characterized by an elevated erythropoietin level (Sirhan *et al.*, 2005). In the study of (Gunduz *et al.*, 2014), the results found an increase in the RBC $7 \times 10^6/\mu\text{L}$, PCV 64.4%, Hg 21.5 g/dL in adult females with uncorrected TOF. A physiological reaction to tissue hypoxia is secondary erythrocytosis associated with cyanotic congenital heart disease, resulting in a rise in serum erythropoietin level, stimulating bone marrow erythropoiesis, resulting in increased red cell mass, PCV, and viscosity of the whole blood (Territo and Rosove, 1991, Warrell *et al.*, 2003). Increased oxygen-carrying capacity is provided by the rise in circulating red cells. This effect, however, is offset by the increase in the viscosity of serum that with consequent symptoms of

hyperviscosity such as headache, visual disturbance, loss of concentration, paresthesia, muscle weakness, and fatigue, it decreases blood flow and tissue perfusion and impairs the delivery of tissue oxygen (Replogle *et al.*, 1967, Thorne, 1998).

Limitations

Included criteria

There are several limitations in this study. This is a retrospective cohort study with a small population, representing only one center. While the multiple centers may reflect a more diverse population, the type of surgery and timing were not standardized either within or across the institutions and may affect the ability to extrapolate results to other institutions. Additionally, Patients with intrauterine growth restriction have been noted to have alterations in fetal Doppler indices. This population was not excluded from this current study. The sample size of this retrospective cohort study was not thought to be large enough to adequately detect differences between groups with and without intrauterine growth restriction (IUGR).

Excluded criteria

Owing to the limitations of fetal imaging, I have removed patients who do not have a ductus arteriosus. Without the opportunity to run off, these people may have a very different physiology.. Other noncardiac factors that could have pushed an intervention forward or backward were not considered. Any births that were not carried to term or had their first cardiac operation after birth were excluded from the study. Patients who were removed from the sample due to chromosomal or neurologic anomalies would not benefit from these findings (which includes 22q11.2 deletion syndrome).

CONCLUSIONS

The current study concluded that TOF in both sexes caused a decrease in the arterial PaO₂ and an increase in the PaCO₂. Also, polycythemia with an increase in the number of RBC, Hematocrit, and Hb concentrations was observed in TOF patients. Operative correction restored the arterial blood gases, RBC, and Hb to the normal value.

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Conflict of Interest

The author declares no conflict of interest

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