The European Research Journal 2024;10(5):465-473 Original Article

DOI: https://doi.org/10.18621/eurj.1488539 *Pediatric Cardiovascular Surgery*

The importance and prognostic effect of thyroid hormones in patients with transposition of the great arteries

Ergin Arslanoğlu[1], Kenan Abdurrahman Kara[1], Shiraslan Bakhshaliyev[2], Fatih Yiğit[1], Doğan Çağrı Tanrıverdi[3], Eylem Tunçer[1], Nihat Çine[1], Hakan Ceyran[1]

[1]Department of Pediatric Cardiovascular Surgery, University of Health Sciences, İstanbul Kartal Koşuyolu Training and Research Hospital, İstanbul, Türkiye; [2]Department of Pediatric Cardiovascular Surgery, Liv Bona Dea Hospital, Bakü, Azarbaijan; [3]Department of Pediatric Cardiology, University of Health Sciences, İstanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital, İstanbul, Türkiye

ABSTRACT

Objectives: Transposition of the great arteries (TGA) is a rare congenital heart disease that occurs in 3 in 10,000 newborns and is rapidly fatal (90%) within one year if left untreated. The prognosis of this pathology changed after introducing an early arterial switch operation (ASO), while the left ventricle could still adapt to systemic high-pressure conditions. Appropriate regulation of thyroid hormones positively impacts metabolism, cardiac function, and postoperative recovery. Therefore, regular thyroid hormone monitoring and thyroid function monitoring of TGA patients may help to improve the health status and prognosis of this group of postoperative patients.

Methods: In our study, 127 patients who underwent ASO at our pediatric cardiac surgery clinic between 01.01.2014 and 18.09.2021 were retrospectively analyzed and included. Among the patients, 43% (n=54) were females, and 57% (n=73) were males.

Results: The coronary arteries were normal in 89.7% (n=114) and abnormal in 10.3% (n=13) of the patients. Twenty-one of the patients exited, and mortality was calculated to be 16.5%. There were no significant differences in mortality or thyroid stimulating hormone (TSH), free thyroxine (T4), or free triiodothyronine (T3) values (P=0.674, P=0.345, P=0.478). In our study, in which we investigated the effect of thyroid hormone levels on prognosis in neonatal patients with TGA with normal free T3, T4, and TSH values, we found that TSH levels were greater in the group with advanced aortic regurgitation and exitus, although the effect of thyroid hormones on postoperative results was not statistically significant.

Conclusions: Congenital hypothyroidism is a common disease with cardiac effects. During the neonatal period, this disease may conceal itself. Careful, expert clinical follow-up and clinical trials are crucial to improve outcomes in the surgical treatment of transposition of the great arteries, a complex congenital heart disease.

Keywords: Transposition of the great arteries, arterial switch operation, thyroid hormones, thyroid stimulating hormone

Corresponding author: Ergin Arslanoğlu, MD.,
Phone: +90 216 500 1 500, E-mail: drerginarslanoglu@gmail.com

How to cite this article: Arslanoğlu E, Kara KA, Bakhshaliyev, et al. The importance and prognostic effect of thyroid hormones in patients with transposition of the great arteries. Eur Res J. 2024;10(5):465-473. doi: 10.18621/eurj.1488539

Received: May 22, 2024
Accepted: August 3, 2024
Published Online: August 6, 2024

Thyroid hormones have many effects on cardiovascular function. Hypothyroidism causes decreased heart rate, stroke volume, and contractility, resulting in decreased cardiac output. Thyroid hormone replacement helps to maintain adequate cardiac output by increasing heart rate, stroke volume, and contractility. Accordingly, there is an important relationship between thyroid hormone levels and cardiac function [1].

Transposition of the great arteries (TGA) is a rare congenital heart disease that occurs in 3 in 10,000 newborns and is rapidly fatal (90%) within one year if left untreated. The prognosis of this pathology has changed since the introduction of the early arterial switch operation (ASO), which was performed while the left ventricle could still adapt to systemic high-pressure conditions [2, 3]. The ASO was first successfully performed in Brazil in the mid-1970s by Dr. Adib Jatene. The ASO, which is usually performed during the neonatal period, initially has a high early mortality rate. However, mortality decreases as the operative experience increases and various technical maneuvers are performed [4].

Patients undergoing cardiopulmonary bypass (CPB) may have a significant reduction in circulating levels of thyroid hormones. It has been shown that CPB secondary to hemodilution, hypothermia, and ultrafiltration triggers a hypothyroid state [3]. Hypothyroidism affects myocardial energy metabolism and is associated with poor prognosis after cardiac surgery with CPB in patient groups such as at-risk neonates [2, 4].

Congenital hypothyroidism is defined by thyroid hormone deficiency and is the most common endocrine problem in newborn infants. It may be permanent or transient. The clinical findings of more than 90% of congenital hypothyroidism patients do not occur during the neonatal period. This depends on the degree of thyroid gland dysfunction and residual thyroid function, deiodinase adaptation and maternal thyroxine at the end of pregnancy. Early diagnosis and treatment of babies without clinical symptoms are based on newborn screening [5]. In our study, we investigated the effect of thyroid hormone level on the prognosis of ASO in our subclinical patients with thyroid stimulating hormone (TSH) values in the normal range.

METHODS

In our study, 127 patients who underwent ASO at our pediatric cardiac surgery clinic between 01.01.2014 and 18.09.2021 were retrospectively included. The study was conducted retrospectively with the permission of the hospital administration and in accordance with the Declaration of Helsinki and ethical rules (ID: E-22686390-050.99-41961). Patients who had not undergone surgery before were selected. Patients with thyroid hormone levels in the normal range who underwent ASO were included in the study. Patients who required aortic arch repair were not included in the study. Twenty-four patients underwent balloon septostomy preoperatively. TSH, free thyroxine (T4), and free triiodothyronine (T3) are routinely measured in all patients during the preoperative period. We did not routinely administer thyroid hormone replacement during the postoperative period.

The decision for surgical indication was made jointly by the pediatric cardiology and pediatric cardiac surgery team after evaluation of left ventricular geometry, thickness, and function. The coronary anatomy of all patients was evaluated intraoperatively, and appropriate reconstruction was performed. Aorta-bicaval cannulation was performed in all patients.

Preoperative hemodynamic monitoring via the radial artery or femoral artery was performed in all patients. A central venous pressure catheter was placed through the subclavian vein and monitored. A urinary catheter was inserted for urine monitoring.

In patients with ventricular septal defects, the defect was closed with an autologous pericardial patch. All patients underwent sternotomy. Patients were administered heparin (3 mg/kg) before CPB. The activated clotting time (ACT) was maintained above 450 seconds. Under CPB, arterial blood pressure was maintained between 40 and 60 mmHg with a pump flow of 150-175 mL/kg/min. The hematocrit value was maintained between 25 and 35%. Cold blood cardioplegia was used in 21 patients, Custodiol® was used in 14 patients, and del-nido blood cardioplegia was used in the remaining patients. An autologous pericardium was preferred as the pulmonary reconstruction material. Moderate hypothermia (28-32 °C) was induced. All patients underwent the Lecompte maneuver. Routinely, the sternum was exited with an open

sternum. The sternum was closed according to the patient's condition.

The need for extracorporeal membrane oxygenation (ECMO) was decided by the intensive care team after evaluating the patient's urinary diuresis, blood pressure, lactate parameters in blood gas, left ventricular (LV) status and ejection fraction (EF)% on echocardiography. All the ECMOs were placed centrally. In the postoperative intensive care unit (ICU), intensive care was provided by a team of pediatric cardiologists and pediatric cardiac surgeons. Decisions regarding inotropic support and ventilation were made jointly. Peritoneal dialysis was performed 24 h postoperatively when there was inadequate diuresis (1-2 mL/kg/h) and in patients without a diuretic response. The need for diuretics or peritoneal dialysis was determined by intensive care physicians.

Our study was a retrospective, single-center study in which the patient's age, gender, weight, diagnosis, previous operations, performed operations, and biochemistry results were recorded.

Statistical Analysis

The NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. In addition to descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, and maximum), the distribution of the data was evaluated with the Shapiro–Wilk test. The Mann-Whitney U test was used for two-group comparisons of quantitative data that did not show a normal distribution. The Friedman test was used for three or more periodic comparisons, and the Wilcoxon test was used for two-period comparisons. Spearman's correlation analysis was used to determine the relationships between quantitative data. ROC analysis was used to determine the predictive value of the quantitative data. Logistic regression analysis was used to determine the independent variables affecting the dependent variable. Significance was evaluated at the $P<0.01$ and $P<0.05$ levels.

RESULTS

The preoperative weight, age, patent ductus arteriosus (PDA) diameter, atrial septal defect (ASD) size, ventricular septal defect (VSD) size, aortic diameter, pulmonary artery diameter, TSH, free T4, free T3 values, total CPB time, aortic cross-clamp (ACC) time, operation time, CPB balance, intensive care unit time, length of stay in hospital and ventilation times are given in Table 1.

Among the patients, 43% (n=54) were females, and 57% (n=73) were males. The coronary arteries were normal in 89.7% (n=114) and abnormal in 10.3% (n=13) of the patients. Twenty-one of the patients exited, and mortality was calculated to be 16.5%.
The degree of postoperative aortic regurgitation was mild in 77.1% (n=98), severe in 2.3% (n=3), moderate in 3.1% (n=4), and absent in 17.5% (n=22) of patients (Table 2).

There was no statistically significant relationship between mortality and sex (P=0.572). There was no statistically significant relationship between mortality and postoperative degree of aortic regurgitation (P=0.072). Preoperative TSH, free T3 and free T4 values were not significantly different from those of postoperative aortic regurgitation. TSH values were calculated as 1.84 mIU/L in patients with moderate AR and 1.84 mIU/L in patients with advanced aortic regurgitation and 7.9 mIU/L in patients with mild and no aortic regurgitation (3.94 mIU/L). There were no significant differences in mortality or TSH, free T4 or free T3 values (P=0.674, P=0.345, P=0.478). However, TSH was greater in the mortality group than in the living group (Fig. 1).

The preoperative heart rate, postoperative heart rate, postoperative hematocrit (HCT) level after CPB, weight, age, PDA size, preoperative heart size, preoperative heart size, and preoperative aortic diameter did not significantly differ among the surviving group and the mortality groups (P>0.05). The difference in the CPB balance between the surviving group and the exitus groups was statistically significant (P=0.001). There was no statistically significant relationship between coronary artery circumference and sex (P>0.05). There was no statistically significant correlation between coronary artery pattern and postoperative degree of aortic regurgitation (P>0.05).

The preoperative heart rate, pump balance, HCT after CPB, weight, age, PDA size, preoperative ASD size, preoperative VSD size, preoperative aortic diameter, pulmonary artery diameter, ventilation time, intensive care unit time, length of stay in the hospital, ACC time, and total CPB time were not significantly

Table 1. Preoperative measurements

	Mean±SD	Min-Max (Median)
Weight (kilogram)	3.39±0.59	2.1-5.8 (3.2)
Age at the time of surgery (days)	15.9±25.66	2-155 (10)
PDA size (mm)	2.66±2.21	0-9 (2.3)
Preoperative ASD size (mm)	5.43±2.76	0-16.5 (5)
Preoperative VSD size (mm)	5.45±5.44	0-21.4 (4)
Preoperative aortic diameter (mm)	8.79±1.77	3.2-14.1 (8.5)
Preoperative pulmonary artery diameter (mm)	10.17±2.19	6.2-16.6 (9.6)
Preoperative aortic diameter (mm)/ Preoperative pulmonary artery diameter (mm) rate	0.87±1.15	0.5-1.35 (0.88)
Preoperative heart rate (min)	141±14.82	110-170 (140)
Preoperative TSH (mIU/L)	3.43±2.63	0.132-9.98 (2.39)
Preoperative free T3 (ng/dL)	2.70 ± 0.6	2.4-3.4 (2.8)
Preoperative free T4 (µg/dL)	12.7 ± 2.9	8.3-14.5 (11.5)
Total CPB time (min)	174.25±54.48	76-410 (173)
ACC (min)	120.78±39.76	31-272 (118)
Operation time (min)	266.37±76.14	150-570 (255)
CPB balance (cc)	-161.49±141.3	-520-495 (-155)
After CPB HCT value (%)	35.98±6.58	13.3-54.4 (36)
ICU time (day)	12±11.58	0.1-48 (9)
Length of hospital stay (days)	3.33±3.71	0-22 (3)
Ventilation (days)	3.93±5.3	0-28.6 (2)

ASD=Atrial Septal Defect, VSD=Ventricular Septal Defect, PDA=Patent Ductus Arteriosus, CPB=Cardiopulmonary Bypass, ACC=Aortic Cross Clamp HCT=Hematocrit, ICU=Intensive Care Unit TSH=Thyroid Stimulating Hormone, SD=standart deviation, min=minimum, max=maximum

different between those with usual and unusual pattern coronary arteries (P>0.05).

The Alanine aminotransferase (ALT) value significantly differed according to the period (P=0.001). The preoperative ALT value was significantly lower than that on postoperative day 2 (P=0.001). The postoperative day 1 ALT value was significantly greater than that on postoperative days 2 and 3 (P=0.001). The postoperative day 1 ALT value was significantly greater than that on postoperative day 2 (P=0.001). The aspartate aminotransferase (AST) value significantly differed according to the period (P=0.001). The preoperative AST value was significantly lower than the other measurements (P=0.001). The preoperative

Table 2. The degree of postoperative aortic regurgitation distribution

		n	%
The degree of postoperative aortic regurgitation	**Mild**	98	77.1
	Severe	3	2.3
	Moderate	4	3.1
	Absent	22	17.5

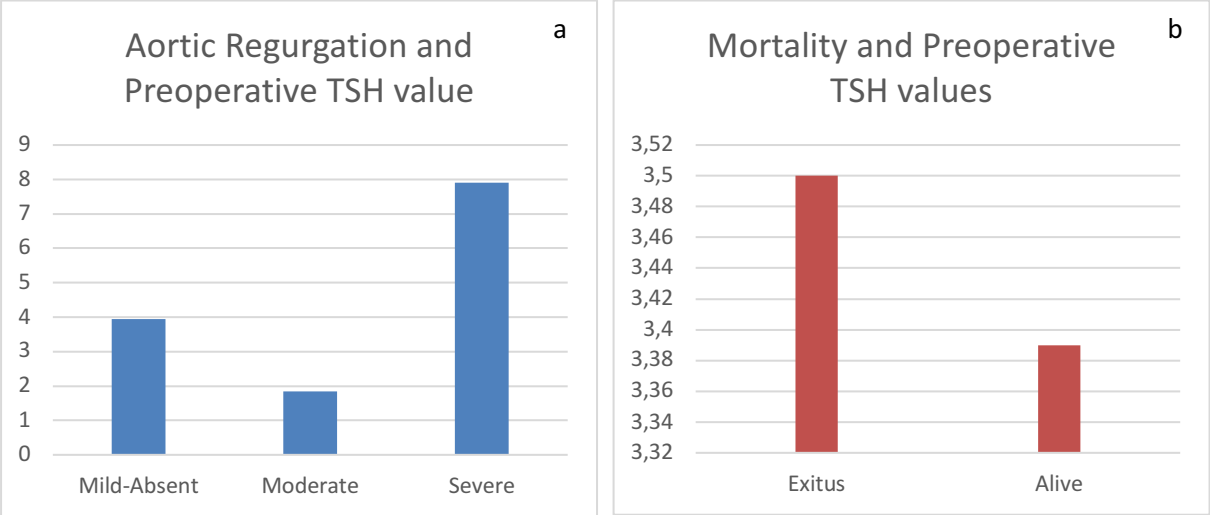

Fig. 1. (a) Aortic regurgitation and preoperative TSH values. (b) Mortality and preoperative TSH values. TSH= thyroid stimulating hormone.

urea value significantly decreased (P=0.001). The preoperative urea value significantly decreased compared with the other measurements (P=0.001). The preoperative creatinine value significantly decreased compared with the other measurements (P=0.001). The hematocrit value did not significantly differ according to the period (P>0.05). The platelet value significantly differed according to the period (P=0.001). The difference between the preoperative platelet value and the other measurements was statistically significant (P=0.001) (Table 3).

In the correlation analysis, there was no statistically significant correlation between preoperative heart rate and pump balance, post-pump heart rate, weight, age at surgery, PDA size, preoperative ASD size, preoperative VSD size, preoperative aorta, pre-

Table 3. ALT, AST, urea, creatinine, hematocrit, platelet measurements

	Preoperative	Postoperative (1st day)	Postoperative (2nd day)	Postoperative (3rd day)	P value
ALT (IU/L)	15.95±17.69 0.1-118.3 (12.1)	40.49±148.55 4.01-1205 (11.8)	37.49±118.62 0.01-734 (6.51)	34.63±130.15 0.01-725 (3.7)	**0.001****
AST (IU/L)	57.23±106.23 15-904.4 (37.2)	183.13±346.75 15-2798 (101.6)	224.47±571.28 10.2-3930 (72.65)	207.38±705.91 11.9-3995.3 (43.7)	**0.001****
Urea (mg/dL)	28.32±13.44 6.78-66.61 (29.26)	36.39±20.11 16-160 (32)	49.2±31.31 10.59-236 (43)	49.85±34.44 8.33-253 (43.2)	**0.001****
Creatinine (mg/dL)	0..6±0.25 0.17-1.49 (0.61)	0.73±0.28 0-1.31 (0.69)	0.8±0.38 0.22-1.84 (0.72)	0.76±0.41 0.18-1.96 (0.66)	**0.001****
Hematocrit (%)	42.12±15.84 26.5-156 (39.7)	37.63±7.02 20.2-60.5 (36.9)	38.84±6.3 26.3-54.1 (38.8)	37.88±5.42 28-49.2 (37.8)	**0.574**
Platelets ($\times10^3$/µL)	302.79±125.5 46.7-689 (288)	156.45±93.14 31-470 (132)	152.83±82.83 31.8-427 (131)	143.13±59.21 13.3-290 (142)	**0.001****

Data are shown as mean±standard deviation and median (minimum-maximum). ALT= alanine aminotransferase, AST=aspartate transferase

Friedman test: **P<0.01

operative pulmonary artery diameter, ratio to pulmonary/aorta size, total CPB, ACC, operation time, intensive care unit time, length of stay in hospital or ventilation days (P>0.05).

There was a positive and weakly significant relationship between hematocrit after CBP and length of service (r=.264, P<0.05). There was a positive and weakly significant relationship between the hematocrit after CBP and the number of days of ventilation (r=,250, P<0.05). There was no statistically significant correlation between hematocrit after CPB and weight, age at surgery, PDA size, preoperative ASD size, and preoperative VSD. size, preoperative aorta diameter, preoperative pulmonary artery diameter, pulmonary aorta, preoperative TSH, total CBP, ACC, operation time, or intensive care unit duration (P>0.05).

There was no statistically significant relationship between preoperative TSH or free T4 free T3 values and operation time, intensive care unit time, hospital stay time, or ventilation days (P>0.05). There was a positive and highly significant correlation between the length of service and the number of ventilation days (r=.687, P<0.01).

DISCUSSION

Congenital hypothyroidism is defined by thyroid hormone deficiency and is the most common endocrine problem in newborn infants. It may develop due to genetic factors such as mutations in the thyroid peroxidase (TPO) or TSH receptor (TSH-R) gene or immunological factors such as elevated anti-TPO levels or morphologic thyroid gland defects. Disorders that may occur in newborns with subclinical hypothyroidism may be difficult to detect due to the absence of sensitive markers. Lipid metabolism, myocardial function, linear growth, and cognitive abilities may be affected [6]. As a result of increasing surgical experience, the results of the ASO are encouraging. Although known factors affecting the success of the surgical operation include the patient's age and weight at the time of intervention, repair of a concomitant ventricular septal defect, coronary artery anomaly, CPB time, and time, there is no specific study on the patient's thyroid hormone levels. [10] In our study, in which we investigated the effect of thyroid hormone levels on the prognosis of neonatal patients with TGA with normal free T3 and T4 and TSH values, we found that the effect of thyroid hormones on postoperative results was not statistically significant, but we found that the TSH level was greater in the group with postoperative advanced aortic regurgitation and exitus.

Children undergoing cardiopulmonary bypass are known to develop low serum T3 levels during bypass and in the postoperative period [7]. The decrease in T3 levels is more profound and long-lasting than that observed in adults.

Portman *et al*. [8] compared patients treated with free T3 and placebo immediately after CPB among patients who underwent pediatric cardiac surgery in a pediatric population younger than 1 year. They found an increase in the peak systolic pressure ratio in patients treated with T3 and suggested that this improved cardiac performance and myocardial oxygen consumption. They suggested that cardiac output increased and pulmonary vascular resistance decreased after systemic T3 administration [8]. In our clinic, we do not routinely perform thyroid hormone replacement but rather only in patients with a diagnosis.

A study on the pharmacokinetic evaluation of T3 administration in the pediatric population revealed that the T3 hormone was cleared faster than it was in adults [9]. Therefore, we believe that the neonatal group is more sensitive to events that may occur in T3 metabolism.

Another important concern after ASO in patients undergoing ASO is the risk of NeoAVR. Neo-aortic valve insufficiency can develop due to the anastomosis site of the neo-aorta or the size difference of the large arteries [11]. In our series, 2.7% (n=2) of patients had advanced postoperative aortic regurgitation, and 2.7% (n=2) had intermediate postoperative aortic regurgitation. The higher mean TSH values in the advanced aortic regurgitation group, although not statistically significant, suggest that this group is more at risk for subclinical hypothyroidism.

Most of the time, compensated hypothyroidism is asymptomatic in newborns due to maternal thyroid hormones and is detected in the laboratory. The causes of compensated hypothyroidism are unclear. Autoimmunity has been hypothesized by several authors in the literature. The natural history of congenital hypothyroidism is not consistent, which is why many authors do not favor replacement unless a definitive

diagnosis is made. In TGA patients, having appropriate levels of thyroid hormones affects energy regulation in the body. Insufficient thyroid hormones can lead to slowed metabolism and reduced energy production. This may have negative effects on the growth, development and general health status of TGA patients [9, 10].

The effects of T3 on the heart are due to transcriptional regulation of several contractile and calcium-processing genes. These effects follow their role in postnatal heart development, and cardiomyocytes exit the cell cycle and differentiate terminally soon after birth, suggesting a role for thyroid hormones in postnatal heart development. Furthermore, recent evidence that cardiomyocytes retain their proliferative competence beyond that of newborns has shown that cardiomyocytes can revert to the proliferative phase [12]. In patients with cardiomyocyte, the levels and function of cardiac thyroid hormones may be affected. This is because TGA causes severe abnormalities in the cardiovascular system and affects systemic and pulmonary blood circulation. In addition, the blood supply to the thyroid gland may also be altered in TGA patients. Therefore, we believe that proper regulation and monitoring of thyroid hormones will be highly important in TGA patients. In the subclinical patient group in which we performed ASO, we did not find a statistically significant correlation between TSH values and intensive care unit stay or service time. We believe that this may be due to the lack of severe hypothyroidism in the selected patient group and compensatory mechanisms of the newborn.

Patients with TGA often have saturation largely dependent on the shunt between the right and left systems, despite being affected by adequate respiratory function, anemia, and low cardiac output. There is no definitive study on how hypoxia-induced inflammation and oxidative stress affect thyroid hormone sensitivity [13, 14]. Additionally, the lack of a statistically significant correlation in our results may be attributed to the possibility that inflammation in patients could vary in response.

The primary reason for perinatal iodine overload is the local application of iodine antiseptics to both the mother and the baby. Topical iodine applied to the mother during childbirth or to the baby, especially for umbilical cord care after birth, can lead to iodine overload in babies. Topically applied iodine can be easily absorbed through the skin and mucous membranes. Furthermore, the intake of iodine-containing compounds such as amiodarone and contrast agents can also lead to iodine overload. Topical iodine applied to newborns can inhibit thyroid hormone synthesis and secretion through the Wolff–Chaikoff effect. Newborns are the most sensitive group to iodine overload. Maternal iodine overload during pregnancy can result in increased TSH levels in babies [15-18]. We believe that the use of topical iodine during childbirth should be considered to prevent iodine overload in such a sensitive population. We also believe that examining individual sensitivities and genetic factors in interpreting babies' responses to iodine overload will be instructive.

Dopamine, a commonly used drug in pediatric cardiac intensive care units, acts through TSH, while amiodarone affects thyroid hormone metabolism by inhibiting the monodeiodinase enzyme that converts T4 to T3 [19]. In our practice with newborn patients, we avoid these drugs unless absolutely necessary and regularly monitor thyroid function. We believe that clinicians should be particularly mindful of thyroid problems in patients treated with dopamine and amiodarone, especially those with Down syndrome.

The ASO is considered the best surgical option for patients with transposition of the great arteries. Although newborn patients are sensitive, the success of surgery can be enhanced with increased experience and precautionary measures [2, 20]. We believe that larger studies are needed to assess the preoperative and postoperative changes in thyroid hormone levels, which may influence patient prognosis, especially considering the known cardiac effects of thyroid hormones.

When evaluating serum hormone levels, it is important to remember that TSH, sT3, and sT4 levels may vary according to the norm used in the kit [21]. We used the same kit used in our laboratory and did not change the results.

Thyroid hormone changes occurring in postoperative intensive care patients without primary thyroid disease are termed "nonthyroidal illness syndrome." Although characterized by a decrease in free T3 and an increase in reverse T3 without an increase in thyroid-stimulating hormone levels, these values can remain within the normal range in newborns. Although low free T3 levels have been associated with poor progno-

sis in studies involving these patient groups, the effect of replacement therapy has not been proven [22]. We believe that clinicians need to be aware of postsurgical hypothalamic-pituitary-thyroid axis changes and the effects of commonly used drugs on thyroid hormone metabolism and take necessary precautions.

Hemodilution and hypothermia associated with CPB can suppress enzyme activity involved in thyroid hormone synthesis and disrupt thyroid metabolism. The suppression of TSH release may also be associated with hypothalamic dysfunction (low levels of thyroid-releasing hormone) or a reduced response to TSH [23]. We used moderate hypothermia (28-32°C) during CPB and tried to keep the CPB lines as short as possible to avoid hemodilution.

CONCLUSION

Proper regulation of thyroid hormones has a positive impact on metabolism, cardiac function, and postoperative recovery. Therefore, regular monitoring of thyroid hormone levels and follow-up of thyroid function in patients with TGA can improve the health status and prognosis of this patient group. Congenital hypothyroidism is a commonly encountered disease with cardiac implications that can persist during the neonatal period. Careful expert clinical follow-up and further clinical research are crucial for improving outcomes in the surgical treatment of complex congenital heart diseases such as TGA.

Authors' Contribution

Study Conception: EA KAK; Study Design: EA KAK; Supervision: HC ET; Funding: EA; Materials: EA; Data Collection and/or Processing: EA, SH, FY; Statistical Analysis and/or Data Interpretation: DCT, EA, FY; Literature Review: EA, SH, KAK; Manuscript Preparation: EA, KAK and Critical Review: HC, NC.

Ethical declaration

Ethical permission was obtained from the Atlas University, Medical Faculty Clinical/Human Research Ethics Committee for this study with date 22.04.2024 and number 04/18 and Helsinki Declaration rules were followed to conduct this study.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

Financing

The authors disclosed that they did not receive any grant during conduction or writing of this study.

Acknowledgement

Thanks to all Kartal Kosuyolu Research Hospital Healthcare co-workers for their efforts.

REFERENCES

1. Mainwaring RD, Lamberti JJ, Billman GF, Nelson JC. Suppression of the pituitary thyroid axis after cardiopulmonary bypass in the neonate. Ann Thorac Surg. 1994;58(4):1078-1082. doi: 10.1016/0003-4975(94)90459-6.
2. Daoud Z, Nuri HA, Miette A, Pomè G. Transposition of the great vessels and intact ventricular septum: is there an age limit for the arterial switch? Personal experience and review of the literature. Cardiol Young. 2020;30(7):1012-1017. doi: 10.1017/S1047951120001456.
3. Yu D, Zou L, Cun Y, et al. Preoperative thyroid hormone levels predict ICU mortality after cardiopulmonary bypass in congenital heart disease patients younger than 3 months old. BMC Pediatr. 2021;21(1):50. doi: 10.1186/s12887-021-02513-6.
4. Jonas RA. The Arterial Switch Operation in 2019: How to Do It and How to Teach It. World J Pediatr Congenit Heart Surg. 2019;10(1):90-97. doi: 10.1177/2150135118811115.
5. Léger J, Olivieri A, Donaldson M, et al; ESPE-PES-SLEP-JSPE-APEG-APPES-ISPAE; Congenital Hypothyroidism Consensus Conference Group. European Society for Paediatric Endocrinology consensus guidelines on screening, diagnosis, and management of congenital hypothyroidism. J Clin Endocrinol Metab. 2014;99(2):363-384. doi: 10.1210/jc.2013-1891.
6. Yordam N, Calikoğlu AS, Hatun S, et al. Screening for congenital hypothyroidism in Turkey. Eur J Pediatr. 1995;154(8):614-616. doi: 10.1007/BF02079061.
7. Klemperer JD. Thyroid hormone and cardiac surgery. Thyroid. 2002;12(6):517-521. doi: 10.1089/105072502760143917.
8. Portman MA, Fearneyhough C, Ning XH, Duncan BW, Rosenthal GL, Lupinetti FM. Triiodothyronine repletion in infants during cardiopulmonary bypass for congenital heart disease. J Thorac Cardiovasc Surg. 2000;120(3):604-608. doi: 10.1067/mtc.2000.108900.
9. Bettendorf M, Schmidt KG, Grulich-Henn J, Ulmer HE, Heinrich UE. Tri-iodothyronine treatment in children after cardiac surgery: a double-blind, randomised, placebo-controlled study. Lancet. 2000;356(9229):529-534. doi: 10.1016/S0140-6736(00)02576-9.
10. García Hernández JA, Montero Valladares C, Martínez López

AI, et al. [Risk factors associated with arterial switch operation for transposition of the great arteries]. Rev Esp Cardiol. 2005;58(7):815-821. [Article in Spanish]
11. Santens B, Van De Bruaene A, De Meester P, et al. Outcome of arterial switch operation for transposition of the great arteries. A 35-year follow-up study. Int J Cardiol. 2020;316:94-100. doi: 10.1016/j.ijcard.2020.04.072.
12. Li M, Iismaa SE, Naqvi N, Nicks A, Husain A, Graham RM. Thyroid hormone action in postnatal heart development. Stem Cell Res. 2014;13(3 Pt B):582-591. doi: 10.1016/j.scr.2014.07.001.
13. Akpınar EE. An underestimated comorbidity of COPD: Thyroid dysfunction. Tuberk Toraks. 2019;67(2):131-135. doi: 10.5578/tt.68257.
14. Latham GJ, Joffe DC, Eisses MJ, Richards MJ, Geiduschek JM. Anesthetic Considerations and Management of Transposition of the Great Arteries. Semin Cardiothorac Vasc Anesth. 2015;19(3):233-242. doi: 10.1177/1089253215581852.
15. Nishiyama S, Mikeda T, Okada T, Nakamura K, Kotani T, Hishinuma A. Transient hypothyroidism or persistent hyperthyrotropinemia in neonates born to mothers with excessive iodine intake. Thyroid. 2004;14(12):1077-1083. doi: 10.1089/thy.2004.14.1077.
16. l'Allemand D, Grüters A, Heidemann P, Schürnbrand P. Iodine-induced alterations of thyroid function in newborn infants after prenatal and perinatal exposure to povidone iodine. J Pediatr. 1983;102(6):935-938. doi: 10.1016/s0022-3476(83)80028-6.
17. Lin CP, Chen W, Wu KW. Povidone-iodine in umbilical cord care interferes with neonatal screening for hypothyroidism. Eur J Pediatr. 1994;153(10):756-758. doi: 10.1007/BF01954494.
18. Zupan J, Garner P. Topical umbilical cord care at birth. Cochrane Database Syst Rev. 2000;(2):CD001057. doi: 10.1002/14651858.CD001057.
19. Plumpton KR, Anderson BJ, Beca J. Thyroid hormone and cortisol concentrations after congenital heart surgery in infants younger than 3 months of age. Intensive Care Med. 2010;36(2):321-328. doi: 10.1007/s00134-009-1648-4.
20. Arslanoğlu E, Işık ME, Kara KA, Çine N, Tunçer E, Ceyran H. Surgical Approach and Management Strategies in a Pediatric Cardiovascular Surgery Clinic During the COVID-19 Outbreak. Braz J Cardiovasc Surg. 2022;37(4):466-471. doi: 10.21470/1678-9741-2020-0614.
21. Talwar S, Khadgawat R, Sandeep JA, et al. Cardiopulmonary bypass and serum thyroid hormone profile in pediatric patients with congenital heart disease. Congenit Heart Dis. 2012;7(5):433-440. doi: 10.1111/j.1747-0803.2012.00667.x.
22. Danzi S, Klein I. Thyroid Abnormalities in Heart Failure. Heart Fail Clin. 2020;16(1):1-9. doi: 10.1016/j.hfc.2019.08.002.
23. Flores S, Loomba RS, Checchia PA, Graham EM, Bronicki RA. Thyroid Hormone (Triiodothyronine) Therapy in Children After Congenital Heart Surgery: A Meta-Analysis. Semin Thorac Cardiovasc Surg. 2020;32(1):87-95. doi: 10.1053/j.semtcvs.2019.05.020.