

Bridging the Gap Beyond Cyanosis: Prevalence and Predictors of Subclinical Hypothyroidism in Acyanotic Congenital Heart Disease.

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Abstract

Background: Thyroid dysfunction may be a hidden risk factor in children with both cyanotic and acyanotic congenital heart disease. Left and right ventricular cardiac functions may be impaired in children diagnosed with subclinical hypothyroidism (SCH). While this association with cyanotic heart disease is well documented, this issue remains underexplored in cases of acyanotic heart disease.

Objective: To estimate the prevalence of SCH and identify relevant clinical risk factors among pediatric patients with acyanotic heart disease.

Methods: In this hospital-based cross-sectional study, investigators evaluated 51 children aged 1 month to 11 years with echocardiographically confirmed acyanotic congenital heart disease. They measured serum TSH and free T4 (FT4) and defined SCH as elevated TSH with normal FT4. Standardized clinical history, medication review, physical examination, anthropometric assessment, and echocardiographic characterization of CHD type and severity were performed. Multiple risk factors were tested to identify those associated with this clinical problem.

Results: SCH affected 19.6% of the cohort. with a mean age of 1.05 ± 1.78 years. Ventricular septal defect was the most common diagnosis (37%). A younger age showed a notable link ($P = 0.016$). During logistic regression analysis, female sex had an odds ratio of 2.89, age <1 year had an odds ratio of 2.83, VSD diagnosis had an odds ratio of 0.67, and hemoglobin <11 g/dL had an odds ratio of 1.16, respectively. Thus, they were possible exploratory clinical predictors for thyroid dysfunction.

Conclusion: Young children with acyanotic congenital heart disease showed significantly high prevalence of SCH, with age being the most important factor according to the study. While ventricular septal defects are indeed the most prevalent congenital anomaly in non-cyanotic heart conditions, we did not observe any other heart defect to independently predict thyroid dysfunction, suggesting that the relationship may be systemic rather than tied to a particular cardiac structure.

Keywords: Acyanotic congenital heart disease; Congenital; Heart Defects; Hypothyroidism; Ventricular septal defect.

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Introduction

Specifically, children with congenital heart disease (CHD) are at an increased risk for thyroid dysfunction, which may compound their existing neurodevelopmental vulnerabilities (1).

In Iraq, cyanotic heart congenital heart disease is prevalent, with ventricular septal defect being the most frequent, so a thorough assessment of their endocrine condition is necessary to reduce the risk of physiological complications and prevent neurocognitive impairment (2). Subclinical hypothyroidism (SH) may influence ventricular function, leading to subtle cardiac dysfunctions even when circulating free thyroid hormone levels appear normal (3,4).

Subclinical hypothyroidism (SCH) is characterized by serum thyroid-stimulating hormone (TSH) levels exceeding the upper boundary of the normal reference range, alongside persistently normal free thyroxine (T4) levels. Mild SCH is defined by TSH levels between 4.5 and 10 mIU/L, while severe SCH is defined by TSH levels above 10 mIU/L (5).

The core pathophysiological mechanism of cyanotic congenital heart defects, such as ventricular septal defects (VSD), atrial septal defects (ASD), and patent ductus arteriosus (PDA), is volume and pressure overload on the heart and lungs, which are recognized as causing left-to-right shunting. This causes the heart to exert much greater effort to circulate additional blood to the lungs, raising the risk of developing pulmonary hypertension and heart failure gradually (6). The body still receives well-oxygenated blood; therefore, cyanosis does not occur. In contrast to cases of cyanotic heart diseases, such as tetralogy of Fallot (TOF), in which there is a structural defect that causes intermixing of blood, leading the deoxygenated blood to bypass the lungs to reach the systemic circulation and causing tissue hypoxia and characteristic cyanosis (7).

Current studies examining pediatric cohorts demonstrate that approximately 27.5% of cyanotic CHD patients have subclinical hypothyroidism; patients with cyanotic CHD usually have normal thyroid function. However, if SCH develops (due to genetics, autoimmunity, or non-thyroidal illness), it causes a severe bidirectional negative impact on the acyanotic heart. Thyroid hormones (TH) are crucial for brain development; their deficiency during neurodevelopment impairs neural cell differentiation and causes irreversible neurological alterations (8,9). Determining these subclinical patterns is vital for optimizing long-term cardiac stability and comprehending their potential effects on ventricular function. Monitoring thyroid hormone levels carefully during the perioperative phase is essential, and prompt action should be taken if required. Therapeutic intervention must carefully balance the restoration of age-appropriate thyroid-stimulating hormone levels against the potential for the induction of iatrogenic cardiac arrhythmias. Many cases can present in adulthood (9,10).

Subclinical hypothyroidism has been observed in patients with cyanotic congenital heart disease (11).

Its prevalence and clinical implications in the acyanotic cohort may warrant further investigation. Data specific to the hemodynamic impact of acyanotic defects remain limited. While cyanotic defects are closely tied to hypoxia-induced thyroid alterations, subclinical hypothyroidism is also frequently documented in acyanotic patients, especially in populations with genetic comorbidities such as Down syndrome (12,13).

Recent findings indicate that approximately 12% of pediatric patients undergoing cardiac catheterization develop hypothyroidism within a month of the procedure (14). The total amount of contrast media used may be a notable independent predictor. The evidence suggests that levothyroxine, a synthetic thyroid hormone, may play a significant role in restoring cardiac function and reducing morbidity in patients with hypothyroidism after cardiac surgery (15,16).

While evidence indicates that preoperative thyroid dysfunction may not always correlate with postoperative complications in pediatric cardiac surgery, understanding these subclinical differences is crucial for tailoring perioperative management (17).

This study aimed to determine the frequency of subclinical hypothyroidism in children with non-cyanotic congenital heart defects and to explore whether particular cardiovascular indicators could be linked to ongoing subclinical thyroid dysfunction.

Patients and Methods

This hospital-based cross-sectional study was conducted from October 2023 to March 2026 in the pediatric cardiology unit of the Children's Welfare Teaching Hospital in , The Medical City Complex, Baghdad, Iraq. Children aged approximately 1 month to 11 years with acyanotic congenital heart disease confirmed by echocardiography were included if they had no previous thyroid disease and were not receiving thyroid hormone replacement. Other exclusion criteria included patients with chromosomal abnormalities, such as Down syndrome, and pre-contrast exposure. In contrast, those with cyanotic CHD, major non-cardiac illness, pre-study cardiac intervention, or exposure to thyroid-interfering medications or supplements were excluded. Fifty-one children appear to have been enrolled via a convenience sampling method. After written informed consent was obtained from a parent or legal guardian, a standardized clinical history, medication review, physical examination, anthropometric assessment, and echocardiographic characterization of CHD type and severity were performed. Serum TSH and free T4 and T3 were measured in all participants on two separate visits 2–3 months apart, using an automated chemiluminescent/electrochemiluminescent immunoassay analyzer in the hospital laboratory/electrochemiluminescent immunoassay analyzer according to the manufacturer's instructions. Venous blood was collected in plain

serum tubes, allowed to clot for 20–30 min, centrifuged at 3000 rpm for 10 min, and the serum was separated promptly. Samples were analyzed on the same day, preferably within 2–4 h; when delayed, serum was stored at 2–8°C and analyzed within 24–48 h, and the results were interpreted using age- and assay-specific reference intervals. Subclinical hypothyroidism was operationalized as the presence of TSH concentrations exceeding the age- and assay-specific upper reference limit, concomitant with normal free T4 levels. The age-stratified pediatric reference intervals derived by Kapelari *et al.* (2008) were utilized to interpret childhood thyroid function tests (18). Age, sex, nutritional status, CHD type/severity, and medication exposure were treated as potential confounders and included in adjusted analyses when the sample size permitted; otherwise, residual confounding was acknowledged.

Statistical analysis:

Data were analyzed using SPSS version 26, descriptive statistics, prevalence with 95% confidence intervals, chi-square or Fisher's exact test for categorical variables, and Student's *t*-test or Mann–Whitney U-test for continuous variables as appropriate, with $P < 0.05$ considered statistically significant. Ethical approval was secured from the relevant committee (approval number 42 on 1-10-2024) by the Pediatric Scientific Council Unit.

Results

We enrolled 51 children with clinically acyanotic congenital heart disease. The cohort was very young overall, with a mean age of 1.05 ± 1.78 years, and showed a modest male predominance, as 31 patients (60.8%) were males and 20 (39.2%) were females. The mean hemoglobin and hematocrit were 11.22 ± 1.77 g/dL and $34.18 \pm 5.99\%$, respectively, while the mean TSH was 3.43 ± 3.03 mIU/L (**Table 1**).

Of the 51 children, 41 were euthyroid, and 10 had subclinical hypothyroidism, corresponding to an SCH prevalence of 19.6%. Therefore, the figure highlights that approximately one in five children in

this acyanotic-CHD cohort met the biochemical criteria for SCH (**Figure 1**).

Table 1: Baseline demographic and clinical characteristics of the study population (n = 51)

Variable	Value
Age (years), mean $\pm$ SD	1.05 ± 1.78
Male, n (%)	31 (60.8%)
Female, n (%)	20 (39.2%)
Hemoglobin (g/dL), mean $\pm$ SD	11.22 ± 1.77
Hematocrit (%), mean $\pm$ SD	34.18 ± 5.99
TSH (mIU/L), mean $\pm$ SD	3.43 ± 3.03
Clinically acyanotic CHD, n (%)	51 (100%)

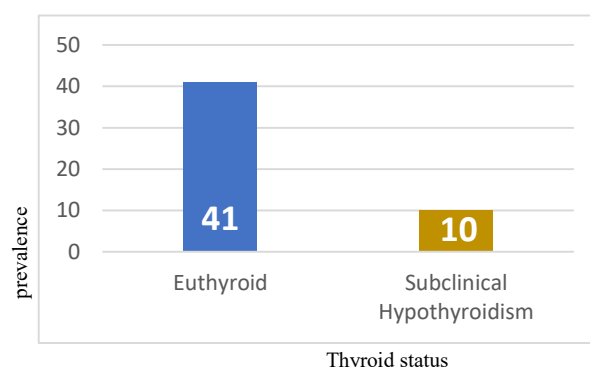


Figure 1: Prevalence of Subclinical Hypothyroidism.

The thyroid profile of the cohort showed a mean TSH of 3.43 ± 3.03 mIU/L, with values ranging from 0.11 to 12.20 mIU/L. Reported FT3 values showed marked dispersion, with a mean of 5.42 ± 22.53 ng/dL and a range from 0.57 to 16.3 ng/dL. FT4 had a mean of 111.58 ± 51.58 µg/dL, with a range from 4.36 to 238.50 µg/dL. Taken together, these data suggest broad heterogeneity in thyroid indices across the cohort and justify cautious interpretation of mean hormone values in isolation as revealed in **Table 2**.

Table 2. Thyroid Function Profile of the Study Population (n = 51)

Thyroid Parameter	Mean $\pm$ SD	Minimum	Maximum
TSH (mIU/L)	3.43 ± 3.03	0.11	12.20
FT3 (ng/dL)	8.44 ± 3.45	0.57	16.3
FT4 (µg/dL)	111.58 ± 51.58	4.36	238.50

Ventricular septal defect was the commonest diagnosis (19 cases), followed by atrial septal defect 10, patent ductus arteriosus 9, atrioventricular canal defect 6, and a smaller “other lesions” category that included aortic stenosis, pulmonary stenosis,

coarctation of the aorta, dilated cardiomyopathy, and hypertrophic cardiomyopathy. This figure shows that septal lesions constituted the dominant case mix in the present series (**Figure 2**).

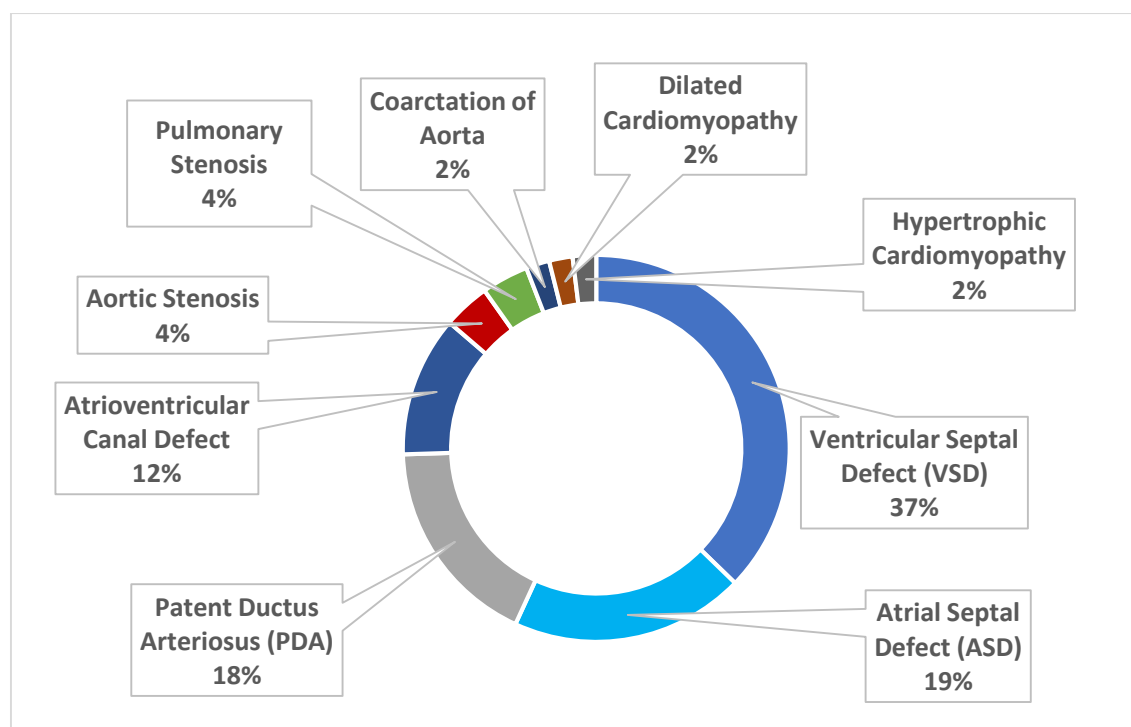


Figure 2: Distribution of Acyanotic Congenital Heart Disease Types.

When we compared children with and without subclinical hypothyroidism, age emerged as the only variable showing a statistically significant difference. Children with SCH were younger (0.42 ± 0.28 years) than those without SCH (1.21 ± 1.96 years), with a p-value of 0.016. By contrast, sex

distribution, hemoglobin, and hematocrit did not differ significantly between groups. These findings suggest that younger age may be the principal demographic characteristic associated with SCH in this cohort, as shown in **Table 3**.

Table 3. Association between subclinical hypothyroidism and demographic/clinical variables

Variable	SCH Present (n = 10)	SCH Absent (n = 41)	P-value
Age (years), mean $\pm$ SD	0.42 ± 0.28	1.21 ± 1.96	0.016
Male gender, n (%)	4 (40.0%)	27 (65.9%)	0.163
Female gender, n (%)	6 (60.0%)	14 (34.1%)	0.163
Hemoglobin (g/dL), mean $\pm$ SD	10.87 ± 1.39	11.30 ± 1.85	0.440
Hematocrit (%), mean $\pm$ SD	34.40 ± 5.99	34.12 ± 6.06	0.897

SCH was identified in 5 VSD cases, 2 ASD cases, 1 PDA case, 1 AV canal defect case, and 1 case within the “other lesions” group. Although VSD contributed the largest absolute number of SCH

cases, it still had a clinically insignificant P value (0.731), largely reflecting that VSD was the most common lesion in the cohort overall (**Figure 3**).

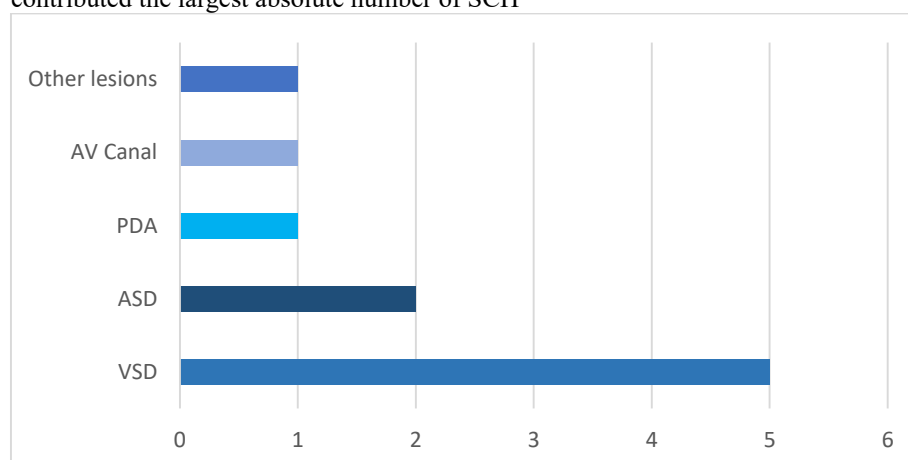


Figure 3: Prevalence of SCH According to CHD Type.

Thyroid hormone values did not differ significantly across acyanotic CHD types. Mean TSH ranged from 2.64 to 4.71 mIU/L across the lesion groups, mean T3 from 1.50 to 10.51 ng/mL, and mean FT4 from 91.69 to 141.27 µg/dL. None of these

comparisons reached statistical significance, although the FT4 comparison approached the conventional threshold more closely than the other parameters ($p = 0.086$), (Table 4).

Table 4. Comparison of thyroid hormone levels according to type of acyanotic congenital heart disease.

CHD Type	Mean TSH (mIU/L)	Mean T3 (ng/mL)	Mean FT4 (µg/dL)
VSD (n = 19)	2.96	10.51	91.69
ASD (n = 10)	4.71	3.20	130.53
PDA (n = 9)	3.86	1.50	97.32
AV Canal Defect (n = 6)	2.64	2.06	135.25
Other lesions* (n = 7)	3.03	2.70	141.27
p-value	0.581	0.826	0.086

*Other lesions included aortic stenosis, pulmonary stenosis, coarctation of the aorta, dilated cardiomyopathy, and hypertrophic cardiomyopathy.

In Table 5; there is a **weak negative correlation** between age and TSH level ($r = -0.168$), but this association is **not statistically significant** because the p-value is 0.240 and the 95% CI includes zero.

Table 5: Pearson correlation between age and TSH level

Statistic	Result
Sample size	51
Pearson correlation (r)	-0.168
95%CI for r	-0.240 to 0.113
P value	0.240
Direction	Negative
Statistical significance	Not significant

In multivariable logistic regression, Female sex had an odds ratio of 2.89 (95% CI 0.70–11.97), age <1 year had an odds ratio of 2.83 (95% CI 0.53–15.04), VSD diagnosis had an odds ratio of 0.67 (95% CI 0.15–2.97), and hemoglobin <11 g/dL had an odds ratio of 1.16 (95% CI 0.29–4.62), (Table 6).

Table 6: Logistic Regression Analysis for Predictors of Subclinical Hypothyroidism.

Variable	Odds Ratio (OR)	95% Confidence Interval	P-value
Female gender	2.89	0.70–11.97	0.163
Age < 1 year	2.83	0.53–15.04	0.287
VSD diagnosis	0.67	0.15–2.97	0.425
Hemoglobin <11 g/dL	1.16	0.29–4.62	0.83

Finally, the forest plot in **Figure 4** shows odds ratios (ORs) and 95% confidence intervals (CIs) for factors associated with subclinical hypothyroidism. The vertical dashed line represents the null value (OR = 1.0). The evaluated predictors were clinically relevant because all confidence intervals included the null value.

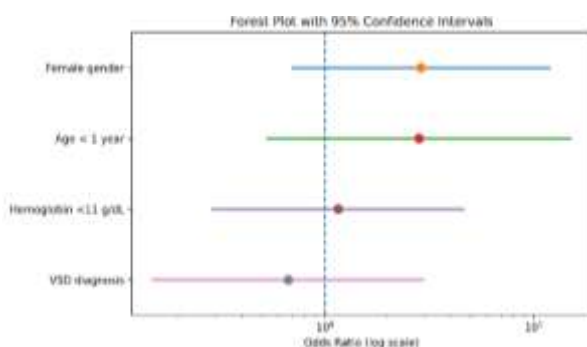


Figure 4. Predictors of SCH.

Discussion

In this hospital-based cross-sectional study of young children with clinically acyanotic congenital heart disease, we found a 19.6% prevalence of subclinical hypothyroidism, meaning nearly one in five patients demonstrated elevated TSH levels despite having normal circulating thyroid hormone concentrations. While thyroid dysfunction is well-documented in children with cyanotic CHD, especially those dealing with chronic hypoxemia or the effects of cardiopulmonary bypass, acyanotic lesions have received far less attention (19).

Fakhari *et al.* study in 2023 they found that 27.5% of cyanotic patients had subclinical hypothyroidism and 10% had overt hypothyroidism, which was correlated with the severity of cyanosis and oxygen saturation, while none of the acyanotic heart disease patients had subclinical hypothyroidism (7). Another study by Mohammed *et al.* in 2022 showed that the overall prevalence of thyroid hypofunction in both cyanotic and acyanotic heart disease was approximately 14%, and specifically 42.8 % of cases occurred in cases of Tetralogy of Fallot (the most common cyanotic congenital heart disease (20).

Consistent with the global trend in acyanotic CHD (2), the current cohort showed a higher incidence of septal defects, with ventricular septal defects accounting for a substantial portion. Although VSD accounted for the highest number of SCH cases, this occurrence was as expected due to the prevalence of the defect in our study and did not attain statistical significance. This implies that the higher rate of SCH is not specific to lesions but might be linked to shared physiological or developmental factors that are common in congenital heart disease during early life (21).

Different physiological mechanisms may be responsible for the higher prevalence of SCH in this population. Infants with acyanotic congenital heart disease that is hemodynamically significant frequently encounter multiple challenges, including persistent cardiac volume overload, changes in systemic blood flow, repeated infections, inadequate

nutrition, and slow growth, all of which can interfere with the hypothalamic–pituitary–thyroid axis (22).

Age was highlighted as the sole factor significantly correlated with SCH (0.42 ± 0.28 vs. 1.21 ± 1.96 years; $P = 0.016$), and inspecting the age–TSH correlation visually indicated an inverse pattern, with higher TSH levels in infancy. This aligns with other studies (23).

According to these findings, the observed subclinical hypothyroidism might be age-related and temporary to some degree (5). It is essential to observe biochemical patterns; longitudinal research helps determine whether these patterns resolve, persist, or worsen over time (24).

The mean TSH, FT3, and FT4 values were generally comparable across all lesion types, and no intergroup comparisons achieved statistical significance although the T4 values came close to the threshold ($p = 0.086$). The absence of a lesion-specific effect is consistent with the hypothesis that the relationship between SCH and acyanotic CHD is systemic rather than structural (8).

Even though 40% of patients with SCH showed mild anemia, this was not found to independently indicate thyroid dysfunction. (25). Anemia in the context of CHD is multifactorial and potentially reflects nutritional deficiencies, chronic diseases, or hemodilution (26, 27).

In a multivariable logistic regression analysis containing multiple predictors, the results regarding female sex, infants under one year old, VSD diagnosis, or hemoglobin levels below 11 g/dL could be exploratory because of the small sample size. A thorough analysis of these findings is required. The relatively small sample size ($n = 51$) and the limited number of SCH factors, including cases ($n = 10$), constrain the statistical power.

Furthermore, the broad spectrum of FT3 and FT4 levels reflects the physiological diversity among children. Clinical context should be considered alongside thyroid function tests, which should not be interpreted in isolation because of heterogeneity. (28).

The management of subclinical hypothyroidism in infants remains a topic of debate among healthcare professionals. According to current pediatric endocrine guidelines, decisions should be made on an individual basis, taking into account TSH levels, age, clinical presentation, and the presence of risk factors (29). In cases of congenital heart disease (CHD), increased surveillance is advisable, especially for infants under one year of age. The potential advantages of initiating levothyroxine therapy early in this group for outcomes such as growth, cardiac function, and neurodevelopment have not been conclusively demonstrated and require further prospective assessment (30).

Limitations:

This study has limitations due to its single-center focus and modest participant number. The study missed data on thyroid autoantibodies, iodine status, nutritional profiles, inflammatory markers, and

cardiac function, each of which could have offered deeper mechanistic insights. For validating current prevalence estimates and enhancing our understanding of associated risk factors, future multicenter, prospective research with a larger sample size is crucial.

Conclusion

The current study indicates that young children with acyanotic congenital heart disease often have subclinical hypothyroidism, with age being the most critical factor. Apart from VSD, it did not identify any specific heart defect that consistently predicted thyroid problems, implying that the connection might be systemic rather than linked to a particular cardiac structure. These results indicated the possible advantages of early thyroid tests for these newborns and the necessity for further studies to gain a better understanding of the clinical impact on their future health.

Authors' declaration:

We confirm that all Figures and Tables in the manuscript belong to the current study.

Approval-Ethical Clearance: The project was approved by the local ethics committee in the Children's Welfare Teaching Hospital, Medical City Complex, Baghdad, Iraq, according to the code number 42 (01/ 10/ 2024).

Conflict of Interest: The authors declare no conflict of interest

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Data availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request

Authors' contributions:

Study conception & design: Muneera F. Ridha & Bayar A. Ahmed². Literature search: Muneera F. Ridha Data acquisition: Munaf J. Yaseen. Data analysis & interpretation: Muneera F. Ridha. Manuscript preparation: Muneera F. Ridha & Bayar A. Ahmed. Manuscript editing & review: Muneera F. Ridha & Bayar A. Ahmed.

AI declaration:

No artificial intelligence tools were used in the design, analysis, or writing of this manuscript.

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سد الفجوة التي تتجاوز الزرقة: انتشار وتوقع قصور الغدة الدرقية دون السريري في أمراض القلب الخلقية غير المزرقة

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الخلاصة

الخلفية: قد يضيف خلل وظائف الغدة الدرقية عامل خطر خفي لدى الأطفال المصابين بأمراض القلب الخلقية المزرقة وغير المزرقة. قد تتأثر وظائف القلب البطيني الأيسر والأيمن عند الأطفال الذين تم تشخيص إصابتهم بقصور الغدة الدرقية دون السريري. في حين أن هذا الارتباط بمرض القلب المزرق موثق جيداً، إلا أن هذه المشكلة لا تزال غير مستكشفة بشكل كافٍ في حالات مرض القلب غير المزرق.

الهدف: تقدير مدى انتشار قصور الغدة الدرقية دون السريري وتحديد عوامل الخطر السريرية ذات الصلة بين المرضى الأطفال المصابين بأمراض القلب غير المزرق

الطريقة: في هذه الدراسة المقطعية التي أجريت في المستشفى، قام الباحثون بتقييم 51 طفلاً تتراوح أعمارهم بين شهر واحد إلى 11 عاماً والذين تم تأكيد إصابتهم بأمراض القلب الخلقية غير المزرقة عن طريق فحص الايكو للقلب، تمت قياس هرمونات الغدة الدرقية في زيارتين منفصلتين تم إجراء التاريخ السريري الموحد، ومراجعة الأدوية، وفحص البدني، والتقييم الأنثروبومتري، وتوصيف تخطيط صدى القلب لنوع وشدة أمراض القلب التاجية. لقد قمنا باختبار عوامل الخطر المتعددة لتحديد تلك المرتبطة بهذه المشكلة السريرية.

النتائج: أثر قصور الغدة الدرقية دون السريري على 19.6% من المجموعة، بمتوسط عمر 1.78 ± 1.05 سنة. وكان عيب الحاجز البطيني هو التشخيص الأكثر شيوعاً (37%). وأظهر العمر الأصغر ارتباطاً وثيقاً $p \text{ value} : 0.016$ أثناء تحليل الانحدار اللوجستي، كان لدى الجنس الأنثوي نسبة احتمالات 2.89، وكان لدى العمر > 1 سنة نسبة احتمال 2.83 وكان لدى الهيموجلوبين > 11 جم/ديسيلتر نسبة احتمالات 1.16، على التوالي. مما يشير إليهم كمتنبئات سريرية استكشافية محتملة لخلل الغدة الدرقية في هذه الدراسة

الكلمات المفتاحية: عيوب القلب، قصور الغدة الدرقية، خلقي، مرض القلب الخلقية المزرق، عيب الحاجز البطيني.