Developmental Outcomes in Early-Treated Congenital Hypothyroidism: Specific Concern in Tc99m Thyroid Scan Role

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Abstract

Background
Congenital hypothyroidism (CH) may cause alterations in the child's global development. The current study aimed to screen the global development of children with and without congenital hypothyroidism, focusing on communication, and cognitive abilities and to investigate the influence of illness severity, clinical history, and treatment factors in the evaluated results.

Materials and Methods
A case control study was conducted on 20 children with early-treated congenital hypothyroidism (CH), and controls without CH (n=100), both groups were matched for age and sex. Patients were subjected to a protocol of assessment applied in Pediatric and Phoniatrics Unit Sohag, Egypt. Assessments included detailed history and medical data, language development testing, intelligence quotient (IQ). According to TSH and T4 levels, case group was divided into controlled group and uncontrolled group. 99m pertechnetate scintigraphy of thyroid (Tc-99m TS) was recommended for all CH children.

Results
Children's ages ranged between 3-7 years with a mean age of (4.6 ±1.9year). There were statistically significant differences between study and control group in presence of middle ear effusion, delayed language development, IQ scores (p<0.001). Interestingly, there was a negative correlation between IQ test and total language age with TSH level (r = -0.06, p= 0.004; r =-0.4, p=0.06), respectively. Tc-99m pertechnetate scintigraphy of thyroid confirmed transient CH diagnosis in three cases.

Conclusion
Despite early treatment in the studied CH children, language and cognitive skills impairments were detected. The magnitude of these impairments related significantly to TSH values and regularity of hormone replacement therapy. TS confirmed transient CH diagnosis in three cases, replacement therapy stopped in those children.

Key Words: Children, Congenital Hypothyroidism, Language development, Thyroid.

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1- INTRODUCTION

Congenital hypothyroidism (CH) is the most common preventable cause of mental retardation worldwide. Corresponding to worldwide data obtained from neonatal thyroid screening programs, CH occurs with an incidence of 1/2000 to 1/4000 (1, 2). However, the incidence changes according to geographic location, ethnicity (3, 4), and environmental factors (5). The most important biologic factor is gender; there is evidence of girls being at higher risk (6, 7). However, the role of gender as a risk factor for congenital hypothyroidism remains unclear. CH is classified into two main categories; permanent and transient. Permanent CH refers to a persistent shortage of thyroid hormone that necessitates life-long treatment. In most cases, permanent hypothyroidism causes are thyroid agenesis (absence of thyroid gland), thyroid hypoplasia (defects in thyroid gland development), ectopic thyroid gland (thyroid gland located in place other than the normal site), or defects in hormone synthesis.

While transient CH means a short-term lack of thyroid hormone that later returns to normal thyroid hormone level. The underlying causes of transient functional impairment are less clear. It can be caused by maternal factors such as iodine deficiency, perinatal exposure to excess iodine or fetal exposure to either maternally derived thyroid blocking antibodies or anti-thyroid drugs taken by pregnant women with autoimmune thyroid disease (8, 9). In fetus and newborn thyroid hormones are essential for normal central nervous system (CNS) maturation, myelination and normal neuronal connections (10, 11). Thyroid hormone deficiency can cause developmental delays of different areas in the brain. It could affect the posterior parietal cortex, responsible for spatial awareness; the inferior temporal lobes, responsible for identification of objects; the caudate

nucleus, associated with attention (11-13). A recent study by Lucia et al., (2018) showed that early postnatal hypothyroidism affects Anterior Commissure (AC) maturation that may affect the transfer of information through the AC (14). Many studies have defined the vulnerability of the different areas of the hippocampus to developmentally induced hypothyroidism. Hippocampus is concerned with diverse memory processes that are essential for learning and memory (15-17). Hearing losses related to CH are related to maturation dysfunction of inner ear structures, VIII cranial nerve myelination, and impaired middle ear ossicles development (18, 19). In fact, thyroid hormone effects on brain cells would certainly be limited to the period of cellular proliferation. This period is different from one area to another in the brain. Because the period when thyroid hormone is required varies for different brain regions, there may be different types of deficits depending on when the hormone levels were insufficient (20).

Rovet and Ehrlich (1995) have proposed that the sensitive periods for THs differ for verbal and nonverbal skills. The thyroid hormones critical period for verbal and memory skills seems to be in the first two months of life, whereas for visuospatial or visuomotor skills it is prenatal (21). There is no doubt that with the advancement of programs of neonatal screening, diagnosis of CH can be established earlier and its treatment initiated during the first few days of life. This could dramatically improve the neuropsychological prognosis in affected children. However, it has been documented that persistent deficits may still occur in early-treated children, such as defective language abilities, impaired neuro-psychomotor development, visuospatial defects, hearing impairment, as well as selective attention and memory deficits (19, 22-25).

Thus, while some effects can be improved by better treatment and management approaches, others caused by prenatal and perinatal thyroid hormone insufficiency may persist. Song et al. showed that neuropsychological function of children with congenital hypothyroidism in the post neonatal screening era was affected by factors associated with etiology and severity of the disease along with the timing of TSH normalization by thyroxin replacement therapy (26). Language development is important for children's success later in life as it provides a central role in learning and social relationships, children with language delays are at increased risk for different types of learning disabilities, emotional, social, and behavior problems (27).

Early identification and intervention of a child's language disorders are internationally well acknowledged, as they markedly decrease and as they prevent the negative impact and offer better quality of life for the children and their parents, which ultimately results in less cost for the government. Bargagna et al. (2000) stated that the language performances are at particular risk in CH children. Accordingly, language development assessment and follow up are mandatory in the congenital hypothyroidism children to achieve better outcomes (28). Therefore, the aim of the current study was to evaluate language and cognitive function in children with treated congenital hypothyroidism, compare them with those without the disease, and to associate language and cognitive findings with illness severity and treatment factors.

2- MATERIALS AND METHODS

2-1. Research design

The current study is a case-control study where confirmed cases of congenital hypothyroidism that were identified through newborn screening and treated from early infancy aged between 3-7 years

compared to age and sex matched controls of children with normal thyroid function as regards presence of language and cognitive delay. Cases and controls included in the study were residents of the same region.

2-2. Setting

The study carried out in the Phoniatric unit, pediatric endocrinology and general pediatric clinics, Sohag University hospital, Sohag, Egypt.

2-2-1. Participants

Case groups were any child less than 7 year-old with previously confirmed diagnosis of congenital hypothyroidism and early treated who referred to the pediatric endocrinology clinic for follow up were included in the current study. Control group were age and sex matched children with normal thyroid function who were randomly chosen from children attending the general pediatric outpatient clinic for diagnosis and treatment of common mild childhood infection such as diarrhea or common cold or any disease that did not interfere with the assessments values. Exclusion criteria in both groups included lack of cooperation during the evaluation; history of impairment in neurological and psychological development; diagnosis or suspicion of genetic syndromes; any other diseases or other endocrine disorders; history of prenatal and perinatal or post-natal complications, positive family history of language disorders, speech problems, or learning problems. Accordingly, 20 cases of congenital hypothyroidism and 100 normal children were included in the study. The number of subjects in the control group is preferred to be double or more of the number of cases to allow proper statistical significance assessment.

2-3. Study instrument

All children underwent thorough routine language evaluation protocol used in

Phoniatrics unit, Sohag University, Sohag, Egypt. The first section included socio-demographic data of the children and their parents (i.e., age, gender, maternal age and job, similar condition, parental consanguinity, etc.). The second section included detailed prenatal, natal, and postnatal history especially the potential risk factors for language disorders, illnesses of early childhood. Moreover, developmental history with a special focus on age of acquisition of the first word, the first sentence, milestone of development. The third section included specific medical information for CH collected about (the age at onset of CH diagnosis and starting treatment; Thyroid function tests [total T4, and TSH levels]), Doses, and Quality of the treatment. Thyroid Scintigraphy and Sonography data about etiology of CH were collected if available.

In order to determine the etiology of CH, it was recommended that all infants perform 99m pertechnetate scintugraphy of thyroid (Tc-99m TS) before treatment. However, this test is not accepted by parents or even by some of the pediatricians to be used, especially before treatment, in our region. According to our nuclear unit screening strategy, CH children should be evaluated at 3-4 years of age, after interruption of treatment for at least 4 weeks. Based on Tc-99m TS, the thyroid gland is classified as normal scan, ectopic, goiter and athyrosis. Athyrosis was diagnosed in infants whose thyroid scans did not show any radionuclide uptake. Patients' examination includes general examination, neurological examination, vocal tract, and ENT examination to exclude cases with any disorders. The fourth section included: (i) cognitive performance was routinely evaluated by Stanford Binnet Intelligence Scale 4th Arabic version for determination of intelligence quotient (IQ) (scores are given for verbal, performance, and global IQ (29), and Social age: using the Vineland Social Maturity Scale (30), (ii)

Language performance was assessed by the Arabic Language Test for language scale and quantitative measures of communication difficulties, determined by age (31). The child's language performance is considered normally developed if the language ages of the language parameter in the test matches the chronological age of the child. When the obtained language age of a test parameter was less than the child's age by 6 months or more, the child was considered to manifest a language delay in this parameter. Total language age and language age deficits in years were used for statistical analysis. The language age deficit was calculated as the difference between the chronological age at the time of evaluation and the corresponding language age scores obtained at that time, (iii) Audiological evaluations were carried out to ensure normal hearing sensitivity: To evaluate hearing sensitivity through pure tone audiometry, Auditory Brain, Stem Evoked Response (ABR) and tympanometry were performed.

2-4. Ethical considerations

This study complies with regional and institutional ethical guidelines and with the declaration of Helsinki. A written informed consent in the study was obtained from the parents/caregivers of the children to participate in the study. Approval of Faculty of Medicine Ethical Committee of Sohag University was also obtained prior to data collection.

2-5. Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 20.0. Sample characteristics mean and standard deviation (SD) were used in summarizing variables while percentages were used for categorical variables. The effects of TSH and T4 level on the language and neuropsychological test/task scores in the patient group were evaluated with the t-test

for independent samples. P-value less than 0.05 were considered statistically significant. Correlation between the severity of the hypothyroidism at the moment of diagnosis with the language and cognitive skills was done using Pearson correlation coefficient test.

3- RESULTS

Twenty early-treated congenital hypothyroidism children were compared to 100 age and sex matched control group children. The children's ages ranged between 3-7 years with a mean age of (4.6 ±1.9 years). Forty-five percent of the studied CH were males (9 cases). In the comparison between case and control group, history of delayed millstone (sitting and walking) was detected in 15% of CH and 8% of control children; from language examination, cases that have delayed language were 70% CH and 7% for control, and tympanometry results (50% CH have type B tympanometry and 5% only for control, respectively). As regards the intelligence quotients (IQs) mean IQ for the CH group was 66.95 ±22 while for control group it was 94.98 ±10. There were highly statistically significant differences between the study and the control group in the presence of family history of thyroid disease, middle ear effusion, delayed language development, IQ scores, age of the first sentence acquisition (P<0.01). The results are summarized in **Table.1**.

Table-1: Comparison between the congenital hypothyroidism group and the control group regarding tympanometry, milestone of development, detailed language development and family history of thyroid diseases.

Characteristic		Cases (n=20)	Control (n=100)	P-value
Tympanometry (%)	Type A Type B Type C	9 (45%) 10 (50%) 1(5%)	93 (93%) 5 (5%) 2 (2%)	<0.001
Milestone (%)	Delayed	3(15%)	8 (8%)	0.4
	Normal	17(85%)	92 (92%)	
Language (%)	Delayed	14 (70%)	8(8%)	<0.001
	Normal	6 (30%)	92 (92%)	
Family history of thyroid disease (%)	Yes	3(15%)	0 (0%)	<0.001
	No	17 (85%)	100 (100%)	
Mean ± SD	IQ scores	66.95 ±22	94.98 ±10	<0.001
	First word (month)	19.5±7.2	15.8±6.8	0.04
	First sentence (month)	32.2±10.3	22.7±4	<0.001
	Sitting (month)	6±1.7	5.6±1.3	0.2
	Walking (month)	13.6±3.9	12.5±2.7	0.1

IQ: Intelligence Quotient.

The detailed data about CH children showed their age range at CH diagnosis was 3 days to 7 months with mean 65.7 (64.2) days. Sixty percent of children stated an irregular use of l-Thyroxine substitution. At the time of the language and cognitive evaluation, seven children showed abnormal total T4 and 12 (60%) had abnormal TSH values: four with values between 6.74 µIU/mL and 10.0 µIU/mL; six between 26.4µIU/mL and 59.72µIU/mL, and two patients ≥100.0µIU/mL[100.0 mU/L]. The mean language age of the CH children was 3.6 ±1.6 years (range: 2–7) (**Table.2**).

Table-2: Distribution of the studied cases of congenital hypothyroidism.

Characteristics	Summary statistics

T4 level
     Range
     Mean (SD)
	0.3-8.4
	 3.5(3)

TSH
     Range
     Mean (SD)
	1.4- 111
	 24.5 (3.2)

Regularity in treatment irregular	12 (60%)

Language age
     Range
     Mean (SD)
	2-7 years
	 3.6 (1.6)

language age deficit (year) No deficit <1 1- 2-3	5 (25%) 5 (25%) 3 (15%) 7 (35%)

SD: Standard Deviation.

Regarding the etiology, of the 20 children with CH, TC-99m TS was performed for nine children (45%) only because the parents of the remaining children did not accept TS being performed. This examination revealed thyroid ectopia in one (5%), thyroid dysgenesis in two (10%), and thyroid hypoplasia in three cases (15%). In addition, three cases (15%) which were confirmed to be transient CH had normal thyroid gland (**Figure.1**). The CH study group was divided according to the level of thyroid stimulating hormone (TSH) and T4 into two groups; group1 subgroup included children with controlled CH (n=8) and subgroup group 2 included children with uncontrolled hypothyroidism (n=12). As shown in **Table.3**, there were statistically significant differences between the controlled and uncontrolled CH groups in the age of acquisition of the first word and first sentence, IQ scores and language age (P<0.05), highly statistically significant differences in language age deficit (P<0.01).
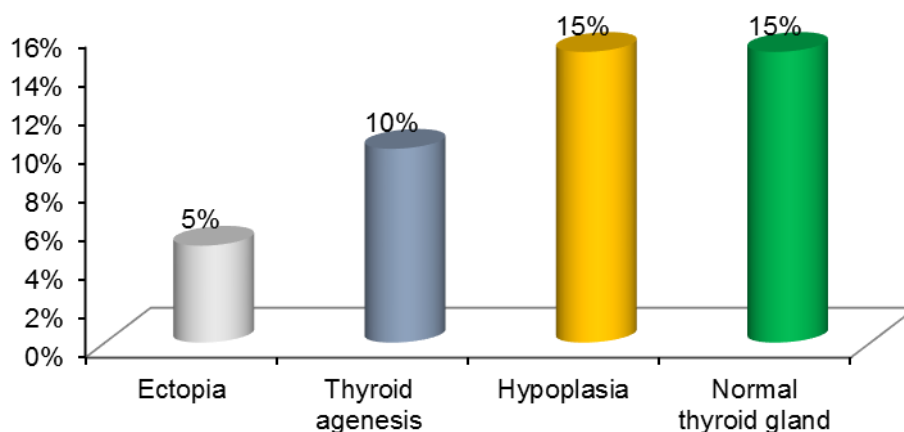
Fig.1: Thyroid Scintigraphy thyroid finding in Children with Congenital Hypothyroidism.

Table-3: Comparison between controlled and uncontrolled CH group as regards IQ score, language age, language age deficit, first word and first sentence.

Variables	Controlled (Mean ± SD)	Uncontrolled (Mean ± SD)	P-value
IQ scores	83±18	56.6±18.7	0.01
Language age	4.6±1.5	3±0.6	0.01
Language age deficit	0.4±0.8	1.5±0.6	0.005
First word (month)	16±8.6	21.7±5.4	0.01
First sentence (month)	27.6±9	35.6±10.7	0.03

SD: Standard Deviation.

Correlation between language parameters and intelligence quotient scores with the levels of TSH level in the CH group was observed. A highly positive significant correlation was found between the language deficit, age of first word and age of first sentence with the level of TSH (r = 0.7, P <0.001; r = 0.5, P = 0.007; r = 0.8, P <0.001), respectively. There is a very strong positive correlation with age of first sentence, strong positive correlation with language deficit, and moderate positive correlation with age of first word. While there was a negative correlation between IQ test and total language age with the TSH level (r = -0.06, P = 0.004; r = -0.4, P = 0.06), respectively, increases in TSH level led to lower IQ, and total language age as shown in **Table.4**. This indicates Moderate negative correlation with language age and weak negative correlation with IQ are indicated.

Table-4: Correlation between language parameters and intelligence quotient score and the levels of TSH in the CH group

Parameters	P-value	Pearson correlation coefficient
IQ	0.004	-0.06
Language age	0.06	-0.4
Language deficit age	<0.001	0.7
Language percentage	<0.001	-0.7
Age of first word	0.007	0.5
Age of first sentence	<0.001	0.8

4- DISCUSSION

The current study aimed to assess the language development in early treated CH children and to identify the related risk factors that could hinder the better outcomes of those children. The result revealed a highly statistically significant difference between children with hypothyroid function and children with normal thyroid in the presence of middle ear effusion, delayed language, IQ values even with early starting of replacement therapy. This is similar to previous studies that reported subtle but statistically significant neurological and language deficits in children with early treated CH when compared to unaffected individuals (23, 25, 28, 32-34). Hrytsiuk et al. (2002) reported behavioral disorders in 23%, language disorders in 20%, learning disorders in 26% in CH children starting replacement therapy before the age of 2 years (35). Moreover, Bargagna et al.'s study (2009) indicated 20% of early treated CH children showed a generalized learning disorder. They stated that, low IQ scores and poor language performances were associated with learning problems. Thus, prompt initiation of language and speech assessment and early rehabilitation is recommended in order to prevent consequent learning disorders (36).

A long-term follow up study of CH children by Rovet and Ehrlich (1995) indicted that early identification and treatment of CH is associated with almost complete prevention of mental retardation and significantly improved intellectual functioning. While considerable and persistent impairments may occur in language, non-verbal and visuospatial skills are markedly lower than that of their siblings, and the differences increase with age (21). In spite of earlier therapy for CH there are still residual deficits seen in some children that could be related to intrauterine thyroid deficiency.

Thus, applying alternative diagnostic actions for earlier identification of CH even in utero would diminish the risk of any consequent impairment and markedly improve development of affected fetuses (37). Furthermore, in the present study there was a significant difference between the controlled and uncontrolled CH even with the early diagnosis and early starting of replacement therapy. 60% of children stated an irregular use of L-thyroxine substitution that can explain the considerable gap/the large gap between the case and the control group results as well as between controlled and non-controlled case groups. Besides, there were highly positive significant correlations between language deficits, age of first word, age of first sentence with TSH concentration, and there were negative correlations between

IQ test, total language and TSH values. These results indicate the significance of regular treatment as well as early starting of the therapy for these children. Similar to our finding, previous studies noted that there is another variable thought to be an important prognostic factor for intellectual outcome that is compliance to L-thyroxine treatment (38-40). Thus, children of poor compliance families are at higher risk for manifesting long-term sequelae, especially if they are not effectively treated during the first three years of life until brain development is complete. Children's IQs are generally normal if the postnatal treatment is sufficient to restore the serum thyroid-stimulating hormone (TSH) to normal levels (41). The New England Congenital Hypothyroidism Collaborative reported normal IQ scores up to the age of 14 years in CH children except in certain circumstances (42). These are consistent with previous studies that stated that greater frequency of increased serum TSH is associated with normal serum T4 concentrations in patients with lower IQ. Those findings indicated that poor compliance to treatment might be another

factor affecting intellectual outcome (43). Accordingly, the actual outcome of children with congenital hypothyroidism is generally good. However, several factors such as the severity of congenital hypothyroidism at diagnosis, poor compliance to replacement therapy might affect the developmental outcome (26, 32, 39). Therefore, early identification and strict surveillance of the therapy will probably assure a normal or near normal outcome in all patients with congenital hypothyroidism. In agreement with previous studies showing that middle ear effusion (OME) incidence was higher in CH than in the control group, even if they receive adequate replacement therapy (44, 45). In the current study, it was noticed that there are highly statistically significant differences between the study and the control group in the presence of OME while there are no detected differences between the controlled and uncontrolled hypothyroidism group. However, the possible explanation of CH susceptibility to ME dysfunction or otitis media is not yet clarified. Previous researches noted that middle ear maturation is dependent on thyroid hormone (46). Two major misconceptions were noted among CH children's parents in the current study.

First, many of them do not fully understand the seriousness of the disease, and show poor compliance in treatment and follow-up. Second, others believe that the thyroid scan is carcinogenic for a young child and refuse to have the test conducted. Even clinicians believe that presence, absence, or abnormal location of a thyroid does not alter the situation. Even though they know the underlying etiology of CH is important in determining disease severity, outcome and treatment schedules. Patients with athyrosis have the greatest hormonal alteration and need for higher treatment doses and closer monitoring, particularly early in life (47-49). Additionally, diagnosis of transient hypothyroidism is important to avoid lifelong unnecessary therapy with its possible side effects; the governmental financial burden for this unnecessary therapy could be spent on other purposive health services. Moreover, the psychological benefit to the children and families who are relieved of the concern about the disorder is crucial and invaluable (50-52). Usage of both thyroid scintigraphy and ultrasound results in a more complete depiction of neonatal congenital hypothyroidism than either test alone (53). Thyroid scintigraphy is fast, easy, inexpensive, well tolerated, safe and clinically relevant in babies.

It helps confirm normal glands in patients with false-positive screening and it is especially important in differentiating the three subgroups of patients with CH (hypoplasia-ectopia, non-visualization, and dyshormonogenesis). It identifies those patients who should be given lifelong replacement therapy (hypoplastic ectopic thyroid), and indicates those patients who need re-evaluation (non-visualization or dyshormonogenesis). Ultrasound is less sensitive in detecting ectopic thyroid as it is absent thyroid gland. However, thyroid scintigraphy revealed ectopic foci of thyroid tissue (54). Bekhit and Yousef (2013), studied cases detected by Fayoum neonatal screening program (NSP) between January 2003 and December 2011 and showed that 44 patients (17.7%) did not need treatment to maintain normal hormone concentrations, and thus have transient hypothyroidism (52). In the current study, three cases out of 9- cases who accepted TS examination were confirmed to be a transient CH.

5- CONCLUSION

The findings of this study showed that despite early detection and treatment in the studied CH children, there was a highly statistically significant difference between children with hypothyroid function and

children with normal thyroid in the presence of middle ear effusion, delayed language, IQ values. Moreover, there were significant differences between the controlled and uncontrolled CH children results in the overall language profile, IQ scores. The magnitude of the deficits depends on TSH current levels and regularity of hormone replacement therapy. Thus, irregular use of hormonal replacement has a great impact on CH children's language and cognitive development outcomes. This emphasizes the importance of increasing the parents' awareness of treatment adequacy and regularity in preventing such complications. There is greater importance in incorporating TS in the assessment protocol of CH to detect and confirm the underlying etiology. This could determine the disease severity, affect the treatment doses, and follow up schedules. The role of Phoniatrics specialty team in congenital hypothyroidism children is still poorly discussed and deserves attention. Therefore, the inclusion of this professional in inter-disciplinary teams that follow CH children should be considered.

6- CONFLICT OF INTEREST: None.

7- ACKNOWLEDGEMENT

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