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METHODOLOGICAL AND ORGANIZATIONAL ASPECTS OF NEWBORN SCREENING FOR CONGENITAL HYPOTHYROIDISM IN MACEDONIA

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A b s t r a c t: Congenital hypothyroidism (CH) is the most common preventable cause of mental retardation. Early diagnosis and treatment are crucial to the prevention of severe intellectual deficit. Neonatal screening in a blood spot from the heel of the newborn between the 2nd and 5th day after birth and determination of thyroid stimulation hormone (TSH) level by fluoroimmunoassay (DELFIA method) is the commonly used approach for the timely detection and therapy of congenital hypothyroidism. Over the period April 2002 – December 2004 results of 27,782 samples were analysed. They were obtained from 5 hospitals in the Republic of Macedonia (Obstetrics and Gynaecology Clinic, Clinical Centre, Skopje; Cair Obstetrics and Gynaecology Hospital, Mala Bogorodica Hospital and hospitals within the cities of Bitola and Prilep). Over the period January 2005 – December 2007 the analysis of 50,732 samples covered all obstetrics hospitals in Macedonia. For the first period analysed (April 2002 – December 2004) we evaluated the sensitivity and specificity of the biochemical method applied for neonatal screening for CH. In our study TSH was assayed by DELFIA fluorometric kits. The cut-off value in our laboratory was 15 mU/L. We compared coverage, timeliness of programme indicators (age at sampling, recall and treatment initiation, timing of specimen delivery and laboratory results) and specimen quality with international standards. Recall rate, sensitivity, specificity, positive predictive values and relative incidence rate for CH were calculated. The established method was deemed highly sensitive and highly specific. During the period of analysis in our study, 28 cases were detected or an incidence rate of 1 : 2,804 was calculated. Treatment was initiated on the 13^{th} day on average (between the 5th and 35th day).

Key words: congenital hypothyroidism, DELFIA method, thyroid neonatal screening.

Introduction

Thyroid hormone is essential for the growth and maturation of many target tissues, including the brain and skeleton. As a result, abnormalities of thyroid gland function in infancy and childhood result not only in the metabolic consequences of thyroid dysfunction seen in adult patients, but in unique, adverse effects on the growth and maturation of hormone-dependent tissues as well. The history of congenital hypothyroidism includes a variety of nosologic terms including cretinism, endemic cretinism, and sporadic cretinism. Iodine deficiency has been found as a major etiologic factor in endemic goitre, and the term "endemic cretinism" refers to the goitrous cretin in the region of endemic goitre [1, 2].

In the last several decades there have been significant advances in our understanding of foetal and neonatal thyroid physiology, and screening for congenital hypothyroidism has made possible the virtual eradication of the devastating effects of mental retardation due to sporadic congenital hypothyroidism in most of the developed countries of the world.

The term "congenital hypothyroidism" (CH) is used to classify any case of hypothyroidism present at birth. In developed nations without endemic iodine deficiency, these infants represent sporadic CH.

The majority of cases of CH (80–85%) are due to thyroid dysgenesis. Thyroid dysgenesis may result in the complete absence of thyroid tissue (agenesis) or it may be partial (hypoplasia), accompanied by failure in the descended neck level (ectopy). Both genetic and environmental factors are implicated the etiology of thyroid dysgenesis, but in most cases the cause is unknown.

Inborn errors of thyroid hormogenesis (10–15%) are responsible for most of the remaining cases of neonatal hypothyroidism. A number of different defects were characterized, including: 1) defective decreased thyrotropin (TSH) responsiveness, 2) failure to concentrate iodide, 3) defective organification of iodide due to an abnormality in the peroxidase enzyme or in the H_2O_2 generating system, 4) defective thyroglobulin synthesis or transport, and 5) abnormal iodotyrosine deiodinase activity.

Thyroid dyshormogenesis is usually transmitted as an autosomal recessive trait. Thyroid enlargement is present at birth, but in many patients development of the goitre is delayed.

TSH deficiency, due to either a pituitary or hypothalamic abnormality, accounts for < 5% of cases of CH, but usually is not detected in newborn screening programmes using serum TSH levels.

An increased level of TSH and decreased level of T4 is characteristic of transient CH. Transient CH has been observed in association with iodine or

organic iodinated compound exposure of the mother or infant, maternal antithyroid drugs or other therapeutic agents (amiodarone, anti-asthmatics), and maternal anti-TSH receptor-blocking antibodies. The increased value of TSH is detected by neonatal screening, confirmed through serum. Transient hypothyroidism is of short duration (1–2 weeks) in the case of drug exposure, but will be of longer duration (1–4 months) if related to a maternal TSH receptor-blocking antibody, the half-life of which approximates to 2 weeks.

During the late 1960s and 1970s, development of sensitive TSH and thyroid hormone radioimmunoassays (RIA) facilitated physiologic studies of the foetal and perinatal thyroid function in animal and human species. It showed that the placenta is impermeable to TSH, maternal to foetal thyroid hormone transfer is limited, and the foetal pituitary-thyroid system functions independently of the maternal system. Studies of thyroid function in the newborn infant characterized a state of physiological thyroidal hyperactivity secondary to an early extrauterine TSH surge stimulated by the acute cooling effect of exposure to the extrauterine environment. With this information, several groups focussed on approaches to newborn screening for CH. The most practical approach proved to be utilization of the already extant infrastructure for newborn phenylketonuria (PKU) screening [3].

Using this approach, Dussault and co-workers in Quebec reported the first mass population-screening programme in 1975 [4]. Parallel programmes began in New England and the Northwest United States, with results reported in 1979. A preliminary mass screening report from Europe was published in 1980, adapting the TSH RIA on the filter paper blood spots as the primary screening test. With improvement in the TSH assay sensitivity and automation, most programmes now utilize primary TSH screening.

Newborn screening for CH is now routine in the United States and Canada, and is conducted in most countries of Western Europe and Scandinavia, as well as Japan, Israel, Australia and New Zealand. Newborn CH screening is developed in several areas of Eastern Europe, South America, Asia and Africa, but most infants in these geographic areas have not been being screened.

In 1993, the European Society for Paediatric Endocrinology (ESPE) began recommending neonatal screening for CH. Since then, considerable progress in knowledge of CH and evaluation of the geographic and logistical hardships involved has been achieved. The recommendations were revised in 1999 [5, 6].

According to screening needs, in Europe two screening methods are commonly used. TSH is used as a general screening parameter if the screening need is prevention of severe mental retardation. The TSH screening method, as opposed to the T4 method, is less expensive and easier to perform. The TSH assay is sensitive enough to distinguish between healthy newborns and sick

ones, regardless of the rise in TSH levels in all healthy newborns. The need for repeated screening is lower (recall rate -0.05%) when the borderline value of TSH is 15 mU/L in whole blood, if the immunofluorometric method is used, and 20 mU/L if the radioimmunometric method is used.

The screening results from both methods can be used to monitor iodine supply in the newborn population. This is an important issue in many European countries, which are still iodine deficient. Neonatal serum TSH was included in 1994 by the WHO, the United Nations Children's Fund (UNICEF) and the International Council for Control of Iodine Deficiency Disorders (ICCIDD) as one of the indicators to assess iodine-deficiency disorders and their control.

Centralized screening laboratories should cover large enough regions. The optimal coverage is 100,000 newborn per year. If laboratories handle numbers below 50,000 newborn per year, this may lead to inefficient screening due to a poor cost-benefit ratio and to an insufficient basis for quality control and statistical analysis. Screening laboratories based on less than 50,000 newborn per year may have to be accepted in countries with under-developed postal or alternative communication systems or big countries with a scarce, widespread population. Otherwise, in many European countries, a single centralized screening laboratory is preferable.

Materials and Method

The material was the results of neonatal screening for CH from a dry drop of blood from the heel of newborn children over the periods April 2002 – December 2004 and January 2005 – December 2007. For the first period analysed (April 2002 – December 2004) we evaluated the sensitivity and specificity of the applied biochemical method for neonatal screening for CH. For this analysis we used samples obtained from the following hospitals: Obstetrics and Gynaecology Clinic – Clinical Centre, Skopje, Cair Obstetrics and Gynaecology Hospital, Mala Bogorodica Hospital and hospitals within the cities of Bitola and Prilep. Since December 2005 neonatal screening for CH has been a routine procedure for the newborn in all obstetrics hospitals in Macedonia. The drop of blood from the heel of the newborn is taken between the second and fifth day from birth, but not earlier than 48 hours after birth. Standardized filter paper is used for this purpose (Schleicher & Schull 903) [7] together with a specially-created computer printed form for the newborn children of the Macedonian population. Data on these forms play an integral role in recalling the children with higher levels of TSH. The back of the form contains detailed instructions on the proper method of obtaining the sample of blood from the heel of newborn.

As previously explained, blood samples obtained on the filter papers of all the newborn were screened at the laboratory for neonatal screening at the Paediatric Clinic in Skopje.

TSH was assayed using DELFIA fluorometric kits (Wallac Oy, Turku, Finland). The DELFIA® Neonatal hTSH (human TSH) assay is a solid phase, two-site fluoroimmunometric assay based on the direct sandwich technique in which two monoclonal antibodies (derived from mice) are directed against two separate antigenic determinants on the hTSH molecule. Standards, controls and the specimen containing hTSH are reacted simultaneously with immobilized monoclonal antibodies directed against a specific antigenic site on the α hTSH sub-unit and europium-labelled monoclonal antibodies (directed against a different antigenic site located partly on the α sub-unit and partly on the β subunit) in an assay buffer. The assay buffer elutes hTSH from the dried blood spots on the filter paper discs. The complete assay requires only one incubation step. Enhancement Solution dissociates europium ions from the labelled antibody into solution where they are highly fluorescent with components of the Enhancement Solution. The fluorescence in each well is then measured. The fluorescence of each sample is proportional to the concentration of hTSH.

Control samples were used to assure the day-to-day validity of results. Controls were made simultaneously with samples. Controls at two different levels are included in the kit. Each laboratory should establish its own mean and acceptable range. The established mean should be within ± 20% of the values stated on the quality control certificate. Sample results were reported only if control results for the assay met the laboratory's established criteria for acceptability [8].

The results were available after 48 hours. The cut-off value in our laboratory was 15 mU/L. This borderline value was based on representative samples. The analysis was normally repeated using the same drop of blood when the value of TSH was higher than 15 mU/L.

The organisational approach was designed in the following manner:

1. Training medical personnel in the proper way to obtain a blood sample from the heels of the newborn.

2. Implementing an early recall system of all newborn with high levels of TSH (telephone contact), clinical evaluation, and starting therapy during the first 15 days after birth.

3. Blood samples from hospitals within Skopje were transported daily to the laboratory, while the surrounding cities transported them within 2 to 3 days.

4. The samples from Skopje and the surrounding cities were evaluated and compared.

5. Results of all samples analysed were reported only if the results of the controlled samples were within the standard laboratory guidelines.

6. All hospitals were informed once a month of the results, or immediately if high TSH levels were detected.

Results

In the period April 2002 – December 2004, the results of 27,782 samples were analysed. They were obtained from 5 hospitals in the Republic of Macedonia (Obstetrics and Gynaecology Clinic, Clinical Centre, Skopje, Cair Obstetrics and Gynaecology Hospital, Mala Bogorodica Hospital and hospitals within the cities of Bitola and Prilep). In the period January 2005 – December 2007, analysis of 50,732 samples covered all obstetrics hospitals in Macedonia. The number of children screened throughout the hospitals has increased yearly. Coverage during 2002 was 52.43–70.15%, during 2003 it was 83.16–95.25%, during 2004 it was 89.43–98.39%, and during 2005–2007 it was between 90.00 and 97.89%.

This data is very important and proves that the Republic of Macedonia has the possibility of including neonatal screening of the newborn with CH within preventive programmes with complete coverage of the newborn of all hospitals.

Analysis of screening samples of the newborn (between the 2nd and 5th day of life) showed that 95.6% of samples had values between 0–5 mU/L. Within this range, most of the samples had values between 1–2 mU/L (Table 1).

Table 1 – Табела 1

Distribution of TSH values
Дистрибуција на вредностите на ТСХ

Year	0–1 mU/L	1–2 mU/L	2–3 mU/L	3–4 mU/L	4–5 mU/L	*Total*
2002	27.37 %	39.44 %	18.47 %	7.85 %	3.35 %	96.48 %
2003	25.72 %	35.08 %	18.82 %	9.07 %	4.90 %	93.59 %
2004	28.24 %	38.27 %	18.96 %	7.75 %	3.50 %	96.72 %

Table 2 shows the indicators for screening efficacy: recall rate, sensitivity, specificity and positive predictive value (PPV) for CH. An apparent sensitivity of 100% and specificity more than 99% were reported for CH.

Table 2 – Табела 2

Indicators for screening efficacy for CH
Индикатори за квантитативна оценка на применетата метода за КХ

Indicator	Year		
	2002	2003	2004
Recall rate	0.17%	0.30%	0.09%
Sensitivity	100%	100%	100%
Specificity	99.88%	98.79%	99.95%
PPV	30.76%	16.66%	20.00%

Table 3 shows the timeliness of screening programme indicators compared with international standards. The mean age at sampling was 5.3 days (range: 3–17 days), with 96.5% (2002), 97% (2003), and 100% of subjects aged less than 10 days. The percentage of specimens received at the laboratory by the fifth working day after samples were taken increased from 69.0% in 2002 to 79.0% in 2003 and 89.0% in 2004. The percentages of results available within 2 working days of receipt at the laboratory were 79.5% (2002), 87.3% (2003) and 90.0% (2004). The mean age of infants at recall was 19.5 days (range: 5–35 days) with 89.0% (2002), 90.3% (2003) and 94.0% (2004) of results of first specimens available at or less than 20 days after birth. The mean age of treatment initiation was 13 days (range: 5–35 days) with 100% for all three years.

Table 3 – Табела 3

Timeliness indicators of Newborn Screening Programme for CH
Временски индикатори на неонаталниот скрининг за КХ

Indicator	National Programme percentage achieved			International standard
	2002	*2003*	*2004*	
• Age of sampling (% sampling at age <10 days)	96.5%	97.0%	100%	100%
• Timing of specimen delivery (% specimens received at lab. on or before 5 working days after sample taken)	69.0%	79.0%	89.0%	95.0%
• Timing of results (% results available on or before 2 working days after receipt at laboratory)	79.5%	87.3%	90.0%	90.0%
• Age of newborn at time of recall (% results of first specimens available on or before 20 days postpartum)	89.0%	90.3%	94.0%	95.0%
• Age of initiation of treatment (% positive cases started ontreatment on or before 21 days postpartum)	100%	100%	100%	95.0%

The international standard for unsatisfactory specimen quality is less than 3% of specimens. In our study, unsatisfactory specimen quality was 1.56% during 2002, 0.29% during 2003, and 0.78% during 2004.

In a three-year period studied (April 2002 – December 2004) ten children with CH were detected, or an incidence of 1 : 2.778. Cases with transient CH were not detected. Seven children (70% of the total observed) had normal thyroid gland, and only three (30%) had hypoplastic (n = 1) or aplastic (n = 2) thyroid glands. The majority of these patients were suspected of suffering from thyroid dyshormogenesis and a precise assessment of thyroid function abnormality was not carried out in this group of patients.

Table 4 represents the number of screened newborn and newborn with CH during the period April 2002 – December 2007.

Table 4 – Табела 4

Number of newborn screened and newborn with CH during the period April 2002 – December 2007
Број на скринирани новородени деца и новородени деца со КХ во периодот април 2002 – декември 2007

Year	Number of newborn screened	Number of newborn with CH
2002	7.552	4
2003	10.027	4
2004	10.203	2
2005	9.826	3
2006	19.813	5
2007	21.093	10
Total	78.514	28

The incidence of permanent CH over a six-year period (April 2002 – December 2007) was 1 : 2.804.

Discussion

The thyroid hormones play an integral part in the development of the brain in perinatal and postnatal life, and in normal intellectual development.

There are a large number of studies that indicate the primary goal of neonatal CH screening is to initiate therapy early, and to achieve an optimal coefficient of intelligence.

The possibilities of diagnosing CH based on clinical signs and symptoms during the first days following birth are limited. Only 5% of the newborn

are diagnosed by clinical symptoms and signs, 30% of them during the first month of life, when the diagnosis and treatment are too late.

According to the definition by C-Hennekes [9], neonatal screening represents a population programme for public health. Drops of blood obtained from a heel prick are used to detect and diagnose illness before there are any visible symptoms or signs. The screening process alone is not sufficient to diagnose the illness. Newborn with positive test results are put through additional diagnostic tests to determine if they actually do have CH.

According to Delange [10], CH characteristics that justify the screening process are:

1. It occurs often. The incidence worldwide is 1 : 2200 to 1 : 4000 live births.

2. The diagnosis must be established early in order to prevent mental retardation.

3. Successful treatment exists. Treatment must begin before the age at which clinical symptoms manifest themselves.

4. Early clinical detection is difficult and nearly impossible. The test to detect CH is simple, precise, sensitive, specific, and adapted to mass screening.

5. There is a favourable connection between the screening of the newborn and early treatment as opposed to the costs necessary to treat the side-effects of the illness when it is detected at a later stage.

The screening method should not be considered as diagnostic. Diagnosis by additional methods is recommended after high TSH levels are detected.

Countries that have implemented neonatal screening programmes have an ethical and financial obligation to establish a treatment programme for the newborn with the detected illness.

According to Toublanc *et al*., in the period 1985–1990 the average incidence in Europe was 1 : 3801, and in the U.S. in the period 1988–1990 the average incidence of CH was 1 : 4199 [11]. CH is one of the most common treatable causes of mental retardation.

During the period of analysis in our study, ten cases were detected or an incidence rate of 1 : 2778 was calculated. Incidence in our country is similar compared with other countries. Treatment was initiated on the 13th day on average (between the 5th and 35th day). Earliest CH treatment was of children born in Skopje.

Table 5 – Табела 5

Incidence of CH in different countries
Инциденца на КХ во различни земји

Country	Incidence	Therapy (in days)	Year of screening implementation
France	1 : 4131	/	/
Germany	1 : 3827	8–9	1975
Greece	1 : 3314	22–50	1979
Hungary	1 : 5632	13	1982
Italy	1 : 2043	15–40	1977
Switzerland	1 : 3913	9	1977
Scotland	1 : 3655	11	1979
England	1 : 3937	17	1978
Turkey	1 : 4131	7–35	1992
Slovenia	1 : 4143	12.3	1981
Croatia	1 : 3563	/	1985
Poland	1 : 4000	/	1985
Bulgaria	1 : 2600	28	1995
USA (Midwest)	1 : 4461	15	1978
Canada	1 : 3884	28	/
China	1 : 2068	28	1981

Two screening strategies for the detection of CH have evolved: a primary thyroid-stimulating hormone (TSH)/backup thyroxin (T4) method and a primary T4/backup TSH method. Most programmes in Europe, Japan, Canada, Mexico, and the United States screen by using primary TSH measurements, supplemented by T4 determination for infants with elevated TSH values. With this approach, delayed TSH elevation in infants with thyroid-binding globulin (TBG) deficiency, central hypothyroidism and hypothyroxinemia will be missed. Delayed TSH elevation is particularly common in infants with low birth weight (LBW [< 2500g]) and very low birth weight (VLBW [< 1500g]).

Current TSH assay techniques (enzyme-linked immunoassays, chemiluminescent assays, and fluoroimmunoassays) use nonradioactive labels and have improved sensitivity with a potential for better separation of normal and abnormal TSH concentrations. Thus many screening programmes are considering switching to a primary TSH approach.

Laboratories for neonatal screening need to satisfy the international indicators established by the American Academy of Paediatrics Newborn Screening Task Force and the principles of TQM (total quality management approach) [12, 13].

In our study, TSH was assayed by DELFIA fluorometric kits. The established method was deemed highly sensitive and highly specific.

The international standard of coverage with neonatal screening is 99%. During the analysed period there was a marked increase in coverage throughout the hospitals of Skopje, Prilep, and Bitola (from 66% to 95%).

In the Republic of Macedonia there are favourable circumstances for the development and maintenance of a screening programme:

1. A relatively low number of newborn during one year (25,000 – 30,000). The majority of them are born in hospitals (> 90%).

2. Short geographical distances.

3. Good communication and networking between neonatal departments of hospitals and the Paediatric Clinic in Skopje.

4. The existence of an accredited laboratory and specialized personnel at the Paediatric Clinic in Skopje.

5. Extensive experience of treating patients with CH at the endocrinology and genetics department.

6. Low costs in relation to the preparedness of pre-laboratory, laboratory, and post-laboratory phases.

The accuracy and interpretation of results (normal, hypothyroid, suspected hypothyroid) obtained in our laboratory are constantly verified by the International Accredited Laboratory in Bonn every six months with unknown concentrations of TSH. The samples are tested at the laboratory for neonatal screening at the Paediatric Clinic in Skopje, and the results are sent to the laboratory in Bonn.

In conclusion, significant progress in all phases of neonatal screening during the period between 2002 and 2007 at the laboratory for neonatal screening at the Paediatric Clinic in Skopje was achieved. Since 2005, neonatal screening for CH is a preventive programme covering the newborn from all obstetric hospitals in Macedonia. Based on the statistical data of the incidence of CH in the R. Macedonia and success achieved in early detection, treatment and follow-up, we stress the importance of programme continuity and the necessity of strengthening programme capacity. The organization model functions well and provides coverage of 90% of the newborn. However, further improvements are warranted.

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Резиме

МЕТОДОЛОШКИ И ОРГАНИЗАЦИСКИ АСПЕКТИ НА НЕОНАТАЛНИОТ СКРИНИНГ ЗА ВРОДЕН ХИПОТИРОИДИЗАМ ВО МАКЕДОНИЈА

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Конгениталниот хипотироидизам (КХ) е една од најчестите причини за ментална ретардација, која може да биде превенирана, ако навреме се открие.

Раното откривање на конгениталниот хипотироидизам и започнување со лекување во текот на првите две недели од животот е асоцирано со важна елиминација на менталната ретардација и со сигнификантно подобрување на интелектуалната функција.

Методот на неонатален скрининг, со земање на капка крв од петицата на новороденчето во периодот од 2-от до 5-от ден по раѓањето и испитување на вредноста на тиреостимулативниот хормон (ТСХ) во неа со помош на флуороимуноесеј (ДЕЛФИА метод), е општоприфатен начин за навремено откривање на конгениталниот хипотироидизам.

Во период од април 2002 до декември 2004 година евалуирана е синзитивноста и специфичноста на применетата биохемиска метода и анализирани се резултатите од 27.782 примероци од новородени деца од 5 породилишта во Р. Македонија (Гинеколошко-акушерската клиника при Клиничкиот центар во Скопје, Гинеколошко-акушерската болница „Чаир“, болницата „Мала Богородица“ и породилиштата во Битола и Прилеп). Во периодот од јануари 2005 до декември 2007 година анализирани се резултатите од 50.732 примероци од новородени деца од породилиштата во сите градови на Република Македонија.

Во нашата студија ТСХ беше одередуван со флуороимунометриски метод (ДЕЛФИА метод). Примероците од крв од петицата на новородените деца беа земени меѓу 2-от и 5-от ден од животот. Гранична вредност во нашата лабораторија беше 15 mU/L. Извршена е компарација на опфатеноста на новородените деца со неонатален скрининг во породилиштата, бројот на примероците со незадоволителен квалитет и временските индикатори за неонатален скрининг (време на земање на примерокот, време на примање на примерокот во лабораторијата, време на издавање на резултатот, време на повторно земање на примерок за тестирање, по добивање на вредност над граничната и возраст на започнување со терапија) со интернационалните

стандарди. Применетата метода беше оценета како високосензитивна и специфична.

Во текот на шестгодишен период на анализа откриени се 28 деца со конгенитален хипотироидизам, или проценета беше инциденца од 1 : 2.804.

Терапијата е започната меѓу 5-от и 35-от ден од животот (средно 13-ти ден).

Клучни зборови: конгенитален хипотироидизам, ДЕЛФИА, неонатален тироиден скрининг.

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