Effectiveness of neonatal hearing screening system: A 12-year single centre study in the Czech Republic

Abstract

Purpose:

The study aims to evaluate the number of examined newborns and the results of screening for twelve years (2008 - 2019) and to assess the effectiveness of the established system of neonatal hearing screening.

Design and Methods:

The study was designed as a retrospective longitudinal data analysis. The data included all the children (19,043) born in the hospital and also children (74) transferred from other healthcare facilities. A total of 19,117 children were included in the research group.

Results:

In the first three years, a higher number of children did not pass the hearing screening, which was followed by a declining trend in the following years. After the first year of screening (2008), there was an improvement in diagnosis linked with a decrease in false-positive screening results (from 9.4% to 6.4%; $p = 0.002$). From 2008 to 2015, the ratio of children with positive screening to those with negative screening had a steady or declining trend.

Conclusions:

The results showed a reduction in false-positive results after the first year of the screening program, probably due to improved care management and a gradual increase in the skills of the nurses performing the screening.

Practice Implications:

The cornerstones of neonatal hearing screening are a sufficient number of trained neonatology nurses, their mutual substitutability and the availability of a hearing screening device in the newborn ward every day. The results imply the importance of periodic evaluation of the obtained data, enabling early detection of possible deficiencies in the hearing screening system.

Key words

Newborn hearing screening, otoacoustic emissions, TEOAE, hearing impairment, permanent hearing loss.

Introduction

The auditory system is a sensory organ that allows you to perceive sound signals from the environment. The World Health Organization considers hearing impairment to be one of the two most serious and most commonly encountered impairment for a human being (WHO, 2021). When suffering from hearing loss they are deprived of up to 60% of the available sensory information. Approximately 5% (466 million) of the world's population suffer from hearing loss, out of which 432 million are adults, and 34 million are children (Skoloudik et al., 2020; WHO, 2020). Hearing impairment in children is particularly serious due to the risk of impaired speech development and the associated acquisition of communication techniques, changes in the thought process and overall development (mental, social). These factors affect the child's socialization, but also educational opportunities and the overall level of attained education (Dršata & Havlík, 2015; Pellant et al., 2019). The basic task of hearing screening of newborns is to identify children with congenital hearing loss, and refer them to determine the severity of hearing loss to start early rehabilitation using hearing aids. In case of an insufficient effect of hearing aids for hearing and speech development, cochlear implants are required, with subsequent phoniatric and speech therapy (van Dyk et al., 2015). This is the only way to ensure the correct development of speech and communication skills. In case of late detection of hearing impairment in a child, the language centre of the cerebral cortex is not stimulated, anatomical and functional changes in neurons and the auditory pathway do not occur, and subsequent speech education is difficult (Patel & Feldman, 2011). If, for any reason, one link in the screening chain that is not centrally monitored and regularly re-evaluated ceases to function, it can be expected that some newborns will either not be examined at all, or their examination will be behind schedule (Vos et al., 2018). This can have a significant impact on the development of children with permanent hearing loss who will not be able to reach their full psychosocial potential.

Newborn hearing screening in the Czech Republic

We can assume that 600-1200 children with moderate and 100 with severe hearing impairment are born annually in the Czech Republic (Kuchynková, 2015). However, the nationwide hearing screening revealed an incidence of hearing loss up to 3 times higher than the previously estimated incidence (Chrobok et al., 2019).

In the Czech Republic, the methodology for newborn hearing screening is standardly implemented at three levels. **At the first level** (in the maternity ward), the recommended screening method for the first hearing examination of newborns is the measurement of transient evoked otoacoustic emissions (TEOAE). In the newly prepared guideline for newborn hearing screening, TEOAE is still recommended for healthy newborns, whereas Automated Auditory Brainstem Responses (AABR) method is recommended for high-risk newborns, as it precisely detects retrocochlear hearing disorders. Only if the screening at the first level was positive (possible detection of hearing loss) the children were referred to the second level of screening.

At the second level (in the Ear, Nose, and Throat, ENT department), re-screening of hearing is performed using the same method used in the first screening of the particular child in the maternity ward (TEOAE or AABR). The children with positive rescreening were referred again to the third level of hearing screening.
At the third level (at the ENT centre), the Brainstem Evoked Responses Audiometry (BERA) method or the Steady State Evoked Potentials (SSEP) methods are used for more precise examination (Chrobok et al., 2019; Czech Republic, 2012; Havlíková et al., 2015). The same recommended screening methods for hearing in newborns are also used in 24 countries of the European Union (Vos et al., 2016).

In most developed countries, screening programs are often organized at the national level, which enables an early diagnosis of hearing impairment in children and an early start of rehabilitation, ideally via a hearing aid within 6 months, and a cochlear implant within 1-2 years (Vos et al., 2018; Wood et al., 2015; Wroblewska-Seniuk et al., 2017). At present, a nationwide screening network has been built in the Czech Republic, but a fully functional database of screening results are only available in the Moravian-Silesian region, Hradec Králové region, and Pardubice region (Chrobok et al., 2019; Komínek et al., 2017). A similar database works in Poland or Germany (Matulat & Parfitt, 2018; Szyfter et al., 2013).
Vos et al. (Vos et al., 2018) mention in their study that data collection from hearing screening is logically its inseparable part. It enables us to accurately assess the success of the programme, and to design and manage organizational changes.

Objectives of the study

1. Evaluate the number of examined newborns and the results for the twelve-year period of neonatal hearing screening (2008 - 2019).
2. Evaluate the effectiveness of the neonatal screening system (e.g. the development of the ratio of positive screening and re-screening, or the number and reasons for false-positive results in individual years).

Materials and Methods

Design and Setting

A quantitative retrospective observational study with subsequent partial qualitative component was used. Its advantage is the possibility to retrospectively compare the data in particular years. This enables us to identify periods in which newborn hearing screening did not function flawlessly, and, subsequently, to determine the objective causes of such periods. The data were obtained from the database of the Department of Otorhinolaryngology and Head and Neck Surgery (ENT Clinic) of the regional hospital.

The children were examined at the level of screening (neonatology department and perinatology centre of intermediate care), re-screening (ENT Clinic), and at the level of the regional centre (ENT Clinic).

Sample

Data from newborn hearing screening were obtained from all children born in the period 2008-2019 in the hospital where the study was conducted (n = 19,043) or from children transferred to this hospital from other health care facilities (n = 74). The research group includes a total of 19,117 children. The statistical testing does not cover children from outpatient deliveries (the period of hospitalization shorter than 72 hours at mother's request), children who died, or children who were transferred to another healthcare facility as hearing screening could not be performed on days 2-3 after the delivery (n = 289).

Instruments and data collection

Data collection was performed by a retrospective method from the ENT clinic database. Since 2008, all children born in the hospital where the study was conducted (or transferred there after the delivery) have undergone hearing screening on a regular basis. The newborns are examined at 3 levels in accordance with the guidelines (Czech Republic, 2012). TEOAEs were used for **hearing screening** (level 1). The OAE screening device marked the otoacoustic emission for each child as TEOAE pass or TEOAE refer. Children who did not undergo the test before being discharged were marked as “TEOAE not tested.” A trained neonatal nurse performed the examinations in healthy newborns on day 2-3 after delivery. Newborns requiring additional healthcare in the first days after birth were examined later. If the hearing screening was positive at the first examination (TEOAE refer) or the child could not be examined (child restless, crying, etc.); the examination was repeated the following day of hospitalization. If the screening was positive again (TEOAE refer or TEOAE not tested) the child's parents were, when being discharged, informed of the outcome of the hearing screening, including an explanation of what could have been the cause of their child's "positive screening" (possible positive detection of hearing loss). The parents were also informed about the need for re-screening and other procedures for a hearing examination. Parents with a child who was invited to an ENT clinic for hearing re-screening before the child was 6 weeks of age and at the same time received a card with necessary information (Pellant et al., 2019; Škvrňáková et al., 2016).

Hearing re-screening (level 2) was conducted at the ENT clinic again using TEOAE. In the case of a positive re-screening (TEOAE refer or TEOAE not tested), an appointment was made for the child to be examined using Brainstem Evoked Response Audiometry (BERA, BAEP) at 3 or 4 months of age.

The BERA examination in the regional centre (level 3) verified the hearing disorder and determined its severity. If the examination was conducted at another healthcare facility, its results were requested. All results from the mentioned examinations and data on subsequent hearing compensation method (e.g. hearing aids, cochlear implants) were searched for data analysis.

The quantitative research was complemented with a partial qualitative component, a critical assessment of the results with healthcare professionals who performed examinations in the healthcare facility. The results for the entire 12-year period were presented to two nurses who organized and performed screening and re-screening of children's hearing. At the same time, the nurses were asked to provide detailed information on the course of the screening programme and to comment on statistically significant results related to changes and fluctuations in the number of children with positive screening or re-screening in individual years (e.g. a decrease in positive screening in 2009, and an increase in 2016 - 2017).

Statistical analysis

Data completeness was checked in all years and double-entry of data for transferring data into the electronic form was used. The characteristics of the research sample and data for individual years of neonatal hearing screening were evaluated using descriptive statistics with absolute and relative frequency for categorical data. Using the Shapiro-Wilk test, a nonparametric distribution of the data was found. The χ^2 test and the calculation of the Spearman correlation coefficient were used for statistical analysis.

Ethical considerations

Ethical approval was obtained from the responsible local ethics committee. The research was conducted in compliance with the Declaration of Helsinki.

Results

Between 2008 and 2019, 19,117 children were born who were to be screened for hearing using TEOAE. Of these, 96.8% (18,510) of the children were examined at the screening level.

Positive screening (children with possible hearing loss or those who did not undergo screening) was found in 1029 (5.4%) children (Table 1). Out of this number, 711 (69.1%) did not have TEOAE present (TEOAE refer) and 318 (30.9%) did not undergo examination (TEOAE not tested). The most common reasons for not performing the examination were organizational and personnel (discharge of the child on a weekend or outside standard working hours), and also unavailability or failure of the hearing screening device.

Table 1: Summary statistics (2008 - 2019).

	relative frequency %	absolute frequency n
Screening (n=19117)		
Negative screening	93.1	17,799
Positive screening	5.4	1,029
TEOAE refer	3.7	711
TEOAE not tested	1.7	318
Transfer, death, outpatient delivery	1.5	289
Re-screening (n=1029)		
Negative re-screening	75.7	779
Positive re-screening	23.2	239
Unilateral TEOAE refer	12.9	133
Bilateral TEOAE refer	6.9	71
Failed to attend the examination	3.4	35
Examined in another facility	1.1	11
Regional centre, BERA (n=215)		
Normal BERA	8.8	19
Unilateral hearing loss	61.9	133
Mild hearing loss	7.0	15
Moderate and severe hearing loss		
Hearing aids	13.5	29
Cochlear implant (CI)	3.3	7
Diagnosis and treatment in another facility	5.6	12

Children who did not pass were supposed to undergo re-screening. Only 983 (95.5%) attended re-screening, 35 (3.4%) failed to appear for the examination, and 11 (1.1%) were examined at another facility. A total of 204 children had unilateral or bilateral TEOAE refer, out of which 133 (12.9%) were unilateral and 71 (6.9%) were bilateral. BERA examination was performed on 215 children. Of these, the results were normal in 19 (8.8%) children. The relative frequency of all hearing loss in relation to the total number of children undergoing the examination (n = 19.117) for the period 2008 - 2019 was 0.96% (184). Unilateral hearing loss was found in 133 (0.70%) children. Mild hearing loss was found in 15 (0.08%) children, who continued to be monitored for hearing and speech development. Hearing loss was addressed in 29 (0.15%) children by hearing aids and in 7 (0.04%) children by cochlear implants from the entire study sample.

The absolute frequency of children to be examined is closely related to the number of children born in each year. The highest number of children to be examined was 1738 (the year 2008) and the smallest number was 1486 (years 2013 and 2014). The average number of children to be examined in a year was 1593.1. In the first three years of the screening, there was a higher number of children who did not undergo the screening, followed by a declining trend in the following years (Table 2). According to the comments of the nurses who participated in the hearing screening in the medical facility, the main reason was the low number of trained nurses in the neonatal ward (2008-2010 only 1-2 nurses). In the first year, screening was practically performed by one neonatal nurse only, who worked solely on the eight-hour morning shift.

An interesting result demonstrating the necessity of proper training of nurses and their sufficient number for effective screening and re-screening is the number of children with false-positive re-screening, which was found most often in years 2008-2011 when the hearing screening was being started in the given healthcare facility. In this period, only 1-2 nurses (out of the total number of 15) performed the screening in the neonatology department. A part of the children who were referred to the third level of screening (16.6% - 33.3%) had a normal BERA (Table 2).

Table 2: Development of the number of examined children at the levels of screening, re-screening, and BERA.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Children to be examined	1,738	1,667	1,713	1,561	1,547	1,486	1,486	1,577	1,578	1,600	1,592	1,572
Screening, % (n)												
TEOAE pass	89.7 (1,559)	92.6 (1,543)	91.3 (1,564)	93.7 (1,462)	93.1 (1,441)	95.1 (1,413)	96.5 (1,434)	97.0 (1,529)	94.0 (1,484)	91.0 (1,456)	89.9 (1,432)	94.3 (1,482)
TEOAE refer	5.6 (98)	2.8 (46)	2.2 (38)	3.1 (49)	3.2 (50)	3.4 (50)	2.4 (35)	2.3 (37)	4.8 (76)	6.9 (111)	3.7 (59)	3.9 (62)
TEOAE not tested	3.6 (63)	3.6 (60)	4.6 (78)	2.0 (31)	2.4 (37)	0.9 (13)	0.2 (3)	0.0 (0)	0.0 (0)	1.2 (19)	0.6 (9)	0.3 (5)
Transfer, death, outpatient delivery	1.0 (18)	1.1 (18)	1.9 (33)	1.2 (19)	1.2 (19)	0.7 (10)	0.9 (14)	0.7 (11)	1.1 (18)	0.9 (14)	5.8 (92)	1.5 (23)
Re-screening, % (n)	n=161	n=106	n=116	n=80	n=87	n=63	n=38	n=37	n=76	n=130	n=68	n=67
TEOAE pass	80.7 (130)	77.4 (82)	80.2 (93)	70.0 (56)	78.2 (68)	66.7 (42)	63.2 (24)	54.1 (20)	73.7 (56)	78.5 (102)	88.2 (60)	68.7 (46)
TEOAE refer unilaterally	9.9 (16)	6.6 (7)	4.3 (5)	17.5 (14)	14.9 (13)	17.5 (11)	10.5 (4)	29.7 (11)	15.8 (12)	19.2 (25)	1.5 (1)	20.9 (14)
TEOAE refer bilaterally	5.6 (9)	12.3 (13)	6.9 (8)	7.5 (6)	3.4 (3)	12.7 (8)	15.8 (6)	16.2 (6)	5.3 (4)	2.3 (3)	1.5 (1)	6.0 (4)

Failed to attend the examination	2.5 (4)	2.8 (3)	8.6 (10)	2.5 (2)	2.3 (2)	3.2 (2)	7.9 (3)	0.0 (0)	5.3 (4)	0.0 (0)	2.9 (2)	4.5 (3)
Examined in another facility	1.2 (2)	0.9 (1)	0.0 (0)	2.5 (2)	1.1 (1)	0.0 (0)	2.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	5.9 (4)	0.0 (0)
Regional centre (BERA), % (n)	n=27	n=21	n=13	n=22	n=17	n=19	n=11	n=17	n=16	n=28	n=6	n=18
Normal BERA	14.8 (4)	33.3 (7)	15.4 (2)	13.6 (3)	0.0 (0)	10.5 (2)	0.0 (0)	0.0 (0)	0.0 (0)	3.6 (1)	0.0 (0)	0.0 (0)
Unilateral hearing loss	59.3 (16)	33.3 (7)	38.5 (5)	63.6 (14)	76.5 (13)	57.9 (11)	36.4 (4)	64.7 (11)	75.0 (12)	89.3 (25)	16.7 (1)	77.8 (14)
Mild hearing loss (up to 40 dB)	3.7 (1)	0.0 (0)	23.1 (3)	9.1 (2)	17.6 (3)	21.1 (4)	0.0 (0)	5.9 (1)	0.0 (0)	0.0 (0)	0.0 (0)	5.6 (1)
Moderate or severe hearing loss												
Hearing aid	11.1 (3)	28.6 (6)	23.1 (3)	4.5 (1)	0.0 (0)	5.3 (1)	27.3 (3)	23.5 (4)	25.0 (4)	0.0 (0)	16.7 (1)	16.7 (3)
Cochlear implant	3.7 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	5.3 (1)	27.3 (3)	5.9 (1)	0.0 (0)	3.6 (1)	0.0 (0)	0.0 (0)
Diagnosis and treatment in another facility	7.4 (2)	4.8 (1)	0.0 (0)	9.1 (2)	5.9 (1)	0.0 (0)	9.1 (1)	0.0 (0)	0.0 (0)	3.6 (1)	66.7 (4)	0.0 (0)

In individual years, the variability between positive and negative screening is evident. Yearly changes and the number of children with positive screening are shown in Table 3. From 2008 to 2015, the ratio of children with positive screening to those with negative screening had a steady or declining trend. The most significant decrease was between the years 2008 and 2009 (from 9.4% to 6.4%; $p = 0.002$) and between 2013 and 2014 (from 4.3% to 2.6%; $p = 0.012$). At the level of re-screening, in the first years (2008 - 2010) there was a high proportion of children with negative re-screening. High numbers of children with positive screening can, therefore, be explained as false-positive results.

Another statistically significant increase in the number of children with positive screening occurred in 2016 and 2017. In 2015, there was a positive screening in 2.4% of children and 2016, 4.9% ($p < 0.001$), in 2017 the number rose to 8.2% ($p < 0.001$) of children.

Table 3: Yearly comparison of negative and positive screenings.

Year (number of children)	Negative screening		Positive screening		χ^2 test (p-value)
	n	%	N	%	
2008 (n=1720)	1559	90.6	161	9.4	-
2009 (n=1649)	1543	93.6	106	6.4	0.002
2010 (n=1680)	1564	93.1	116	6.9	0.581
2011 (n=1542)	1462	94.8	80	5.2	0.041
2012 (n=1528)	1441	94.3	87	5.7	0.537
2013 (n=1476)	1413	95.7	63	4.3	0.073
2014 (n=1472)	1434	97.4	38	2.6	0.012
2015 (n=1566)	1529	97.6	37	2.4	0.698
2016 (n=1560)	1484	95.1	76	4.9	<0.001
2017 (n=1586)	1456	91.8	130	8.2	<0.001
2018 (n=1500)	1432	95.5	68	4.5	<0.001
2019 (n=1549)	1482	95.7	67	4.3	0.780

Notes:
χ^2 test – Pearson's chi-squared test

The relationship between the results of positive screening and both positive and negative re-screening is evident from Figure 1. Negative re-screening copies the curve of positive screening. Their mutual correlation is very strong (r = 0.977, p <0.001). In a large percentage of children, re-screening showed TEOAE present (TEOAE pass). There is also a statistically significant correlation between positive screening and positive re-screening (r = 0.768, p = 0.004), which is moderately strong. There is a noticeable increase in positive screening in the years 2016 - 2017, with a peak in 2017 (8.2%, 130 children). This year, a higher number of false-positive screening results was found, as well as a higher number of unilateral hearing loss in children. After processing the results of the screening for the 12-year period, we asked the nurses who performed the screening to comment on the abnormal values. The higher number of false-positive results in 2017 was caused by technical problems when there was only one screening device available in the department. First, a device failure occurred (thus increasing the number of children with TEOAE refer), and then it was repeatedly sent away for repair and calibration.

Another factor that significantly affects the number of screenings and re-screenings performed and their outcome is the number of nurses trained in hearing screening. While in 2008-2011 only 1-2 (7.7 – 13.3%) nurses out of the total number of 15 performed the screening, in 2012 -2019 it was on average 5 (28.2%) neonatal nurses out of the total average of 15.5 nurses.

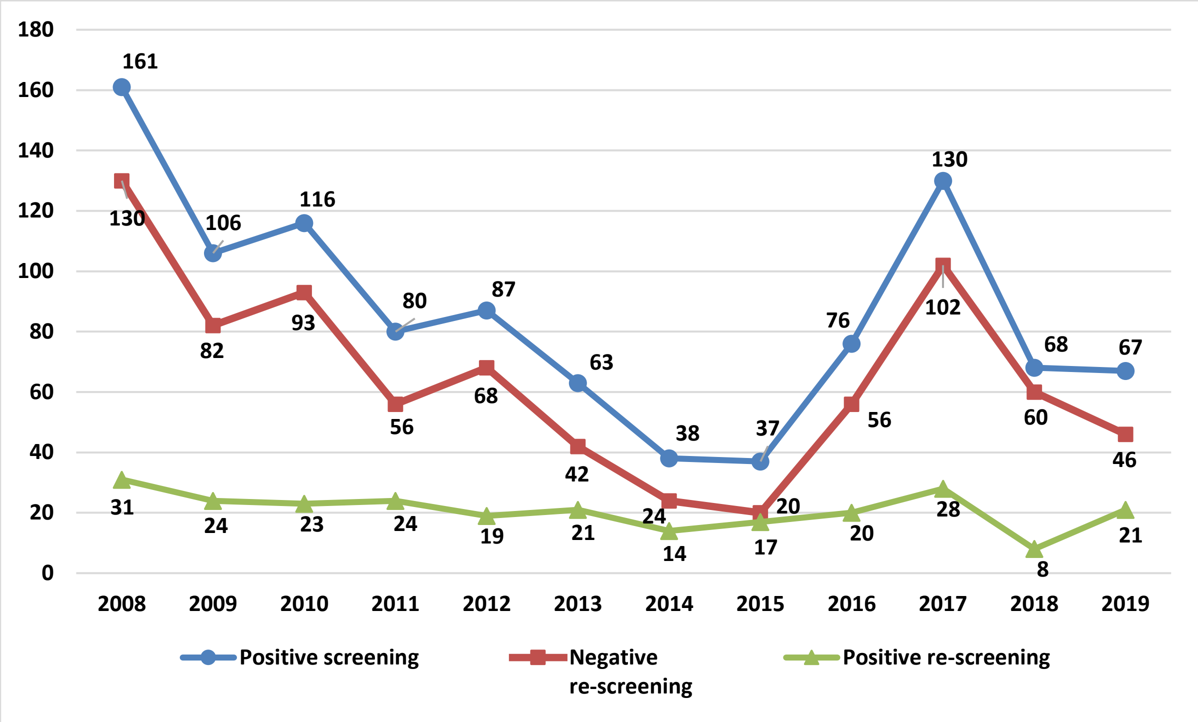

Figure 1: Relationship between positive screening and re-screening presented by the number of newborns in different years (n = 1029).

Discussion

From the total number of 19,117 newborns 96.8% (18,510) were screened, which is less than in England (98.9 %) or in central Germany (98.8%). However, in these countries the newborn hearing screening is organized centrally at the level of a national program, which is more effective (Rissmann et al., 2018; Szyfter et al., 2013; Wood et al., 2015). On the other hand, it is a higher number than the percentage stated by Sloot et al. (Sloot et al., 2015). They present the effectiveness of the screening related to the Czech Republic in the " > 50% coverage" category.

A statistically significant decrease in positive hearing screening from 9.4% to 6.4% (p = 0.002) after the first year of starting the screening for all neonates in 2008 includes both children who had a TEOAE refer and children who were discharged before the examination (TEOAE not tested). The numbers for both these groups of children gradually declined over the following period. The lowest incidence of positive hearing screening was in the years 2014 - 2015, when in terms of the effectiveness of screening and re-screening, the obtained data approach the ideal state (Table 2), both in terms of the low number of the children with TEOAE refer (2.4% and 2.3%, respectively) as well as a small number of children who did not undergo the screening (0.2% and 0.0%, respectively). Throughout the period 2008-2019, the average negative result of re-screening was 73.3% of children with positive screening. In 2014 and 2015, 63.2% and 54.1% of children, respectively, were re-screened negatively, which proves the reduction of false-positive screening results in the neonatology department. We assume that this reduction was due to improvements in management (involvement of more neonatology nurses), methodology, and greater skill in TEOAE examinations (sealing of the ear canal, reduction of ambient noise, calming the child). The higher number of neonatology nurses trained to perform hearing screening leads to greater substitutability and availability of diagnostics for all children before their discharge. In our study, only one nurse performed hearing screening in 2008, while six neonatology nurses were involved in 2019.

The need to provide screening 365 days a year is one of the conditions for comprehensive screening of newborn hearing (Komínek et al., 2017). Procedures aimed at reducing the number of children with a false-positive result at the screening level are a desirable development in screening programs. These procedures reduce financial costs and organizational burden at healthcare facilities involved in re-screening (Vos et al., 2016). The importance of early screening is also significant for parents who can be assured earlier that their child's hearing is normal. The general practitioner for children and adolescents is informed of the outcome of the children’s hearing screening through a discharge report. This allows the practitioner to notify parents of the need for re-screening early enough (Ravi et al., 2016; Škvrňáková et al., 2016).

During data processing, a statistically significant increase in positive hearing screening was identified between the years 2016 and 2017, with a peak in 2017 of 8.2% ($p < 0.001$). In the same period, higher numbers of false-positive screening results and unilateral hearing impairments in children were recorded. In the years (2016-2017), only one device was used to evaluate TEOAE. A failure was detected in the device, which had caused an increase in the number of children with false-positive hearing screening results. Subsequently, the device was out of operation because of repair and calibration. The importance of correct hearing screening and accuracy of devices is essential for the evaluation of screening and reduction of the error rate in the number of false-positive hearing results at the national and international level (Vos et al., 2016).

A high correlation between positive screening and negative re-screening ($r = 0.977$, $p < 0.001$) shows the importance of organizing a screening system at three levels. It is clear that a large proportion of children that have a TEOAE refer at the first examination, which may be due to fluid in the ear canal or middle ear, anxiety, restlessness of the child during the examination, or impaired acoustic conditions during the examination (Maung et al., 2016). At the second examination, these children often already receive a TEOAE pass. Therefore, it is an important step to re-examine newborns with a “TEOAE refer” by a neonatology nurse while they are still in the hospital. This reduces the number of newborns with positive hearing screening (TEOAE refer). If too many children with TEOAE refer were discharged from the maternity ward, there would be a risk that regional ENT facility would not be able to manage such a number of children in time and examine them using TEOAE or other objective methods (Zeleník et al., 2012).

Practice implications

For proper function of neonatal screening several conditions should be fulfilled, including availability, a clear algorithm, high sensitivity, ease use method, cost benefit, non-invasivity, and convenience for children. The efficiency of the screening program depends on the success of meeting these conditions. Our research has proven that the ratio of false-positive screening corresponds to the local situation at the screening department. By focusing on above-mentioned individual conditions, the performance of neonatal screening can be improved. We proved that the technical equipment and adequate staff management are the most challenging and important (Chrobok et al., 2019).

If one device only is used in the healthcare facility, it is necessary to monitor the number of positive screenings each month. Due to the detected changes (a sudden increase in positive screenings), measures can be implemented to prevent similar problems early enough. If the number of positive hearing screening results increases or device failure is detected, the device must be sent for calibration or repair. It is advisable to contractually arrange for a loan of a replacement device from the seller in the event of a fault or calibration when negotiating the purchase.

Staff management is an important issue in the newborn hearing screening as well as in other medical fields. Nurses should have sufficient knowledge about the screening, should follow a clearly defined algorithm, they need to be practically skilled in measurement procedure (probe insertion, ear canal sealing, soothing the baby). Furthermore, they are irreplaceable in a parents counselling regarding the next level of screening, if necessary. Nurses specialized in newborn hearing screening must be available 365 days a year.

The challenge for the future is to create a new database platform for the newborn hearing screening, which would help with monitoring the screening system efficiency and tracking the children who were lost in a follow up. Experts from neighbouring countries are currently discussing the same intention (Greczka et al., 2019; Matulat & Parfitt, 2018).

Limitations of the study

There are limitations resulting from the retrospective character of the study.

Also, high-risk newborns in the healthcare facility where the study was conducted were not examined using the AABR method. The reason for not using the AABR method was that the hearing screening in newborns was implemented according to the guidelines from 2012, where the requirement for the examination of high-risk newborns using AABR was not defined. An update of the existing guidelines has already been prepared.

Conclusion

The results of this retrospective study show that the effectiveness of the screening program in the healthcare facility in individual years shows variability, the cause of which was most often personnel and equipment problems.

One of the cornerstones for the functioning of a comprehensive newborn hearing screening system is staffing, i.e. a sufficient number of trained neonatology nurses, their mutual substitutability and the availability of hearing screening in the newborn ward every day of the year. The reduction in false-positive results after the first year since the start of the screening program in the healthcare facility can be explained by improved screening management and a gradual increase in the experience of the nurses who performed the examinations.

The second cornerstone of hearing screening in newborns is adequate technical equipment with suitable devices, available even at the time of calibration and recovery. The unexpected increase in the number of “TEOAE refer” results is an indicator of an instrument failure, to which it is necessary to respond as soon as possible, by using a replacement instrument and checking the measurement. The results of our research show the importance of periodic evaluation of the obtained data, thanks to which it is possible to detect any shortcomings in hearing screening in time and respond to them adequately.

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