Sensorineural hearing loss after suffering bacterial meningitis in children

Pérdida auditiva neurosensorial después de sufrir meningitis bacteriana en niños

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Abstract

This study is dedicated to identifying the complications of sensorineural hearing loss (SHL) after bacterial meningitis (BM) in children to optimize diagnosis and timely treatment. Complications of sensorineural hearing loss (SHL) after bacterial meningitis (BM) in children were studied using screening observation of patients who had BM from 2015 to 2018. A cohort study was conducted to detect CHT in patients with meningitis after discharge with the mandatory audiological examination. Out of all 167 treated children, 103 children underwent an audiological examination, with a diagnosis of "Bacterial meningitis" – 60.7% (n = 65) and "Enterovirus meningitis" - 73.3% (n = 52). Patients were monitored for 1 year, the corresponding clinical history data, a diagnostic procedure, preoperative imaging data, the time interval between the diagnosis of bilateral deafness and cochlear implantation, computed tomography data with fibrosis or ossification were taken. Evaluation of hearing was evaluated based on the latest available results of pure tone and speech audiometry for children.

Keywords: meningitis, sensorineural hearing loss, acquired deafness, cochlear implantation, children.

Resumen

Este estudio está dedicado a identificar las complicaciones de la pérdida auditiva neurosensorial (SHL) después de la meningitis bacteriana (BM) en niños para optimizar el diagnóstico y el tratamiento oportuno. Las complicaciones de la pérdida auditiva neurosensorial (SHL) después de la meningitis bacteriana (BM) en niños se estudiaron mediante la observación de detección de pacientes con BM de 2015 a 2018. Se realizó un estudio de cohorte para detectar CHT en pacientes con meningitis después del alta con examen audiológico obligatorio. De los 167 niños tratados, 103 niños se sometieron a un examen audiológico, con un diagnóstico de "meningitis bacteriana": 60,7% (n = 65) y "meningitis por enterovirus": 73,3% (n = 52). Los pacientes fueron monitoreados durante 1 año, se tomaron los datos de la historia clínica correspondiente, un procedimiento de diagnóstico, datos de imágenes preoperatorias, el intervalo de tiempo entre el diagnóstico de sordera bilateral y la implantación coclear, datos de tomografía computarizada con fibrosis u osificación. La evaluación de la audición se evaluó sobre la base de los últimos resultados disponibles de tono de pureza y audiometría del habla para niños.

Palabras clave: meningitis, hipoacusia neurosensorial, sordera adquirida, implantación coclear, niños.

Introduction

It is estimated, that the annual frequency of bacterial meningitis (BM) in the western world is 2–5 cases per 100 000 populations[1]. This indicator in less developed countries can be 10 times higher. BM worldwide takes one of the first positions in the list of 10 causes of deaths, associated with infectious diseases, 30–50% of survivors have neurological consequences that persist for a long time[2].

The use of the pneumococcal conjugate vaccine (PCV13) in the national immunization schedule also resulted in a decrease in the incidence of pneumococcal meningitis in countries with an active immunization program[3]. It should be noted, that in Kazakhstan from 2010 to 2015 began to introduce phased vaccination with an anti-pneumococcal conjugate vaccine (PCV13)[4].

According to foreign scientists LuksicI, MulicR, Falconer R (2013), the incidence of BM and its etiology cannot be objectively assessed globally due to the lack of etiological interpretation and incomplete statistics[5]. According to official statistics, a similar situation is observed in Kazakhstan, there is general information about the incidence of BM, without identifying the etiological factor, as a result of which there is practically no epidemiological surveillance system and there is no official registration of BM. According to statistics, monitoring the incidence of BM in Kazakhstan from 2012 to 2017 is characterized by variability of indicators, for 6 years, an average of 2.17% per 100 thousand children (900 cases). The highest peak in the incidence of BM in Kazakhstan as a whole was in 2014, 5.52% (242 cases). In subsequent years, there was a tendency to decrease in this indicator: by 2015 - by 1.2 times, and by 2016 - by 1.3 times, at the end of 2017, the incidence rate of BM (compared to 2014) decreased - 2.5 times[6,7].

According to Bhasin T.K. et al. (2006), BM causes partial or complete hearing loss in 10–20% of cases[8]. The frequency of hearing loss after suffering BM is different, for the causative agents of N. meningitides - 8–11%, H. influenza - 6–11% of cases[9]. Also, the risk of hearing the loss in BM caused by S. pneumonia is 22% and 8% in N. meningitidis[10,11]. The problems of hearing impairment in BM are the most common, whereas they are not observed in viral meningitis[12]. In 25–30% of cases in children, who have undergone BM, a hearing loss is not detected in a timely manner[13]. It is especially difficult to diagnose "sensorineural hearing loss" in children under 3 years of age since their hearing impairment can be detected in a late period either by parents or during a specialized examination. Hearing loss affects the development of speech and psychomotor development of the child[14].

Aim of the Study: To identify the complication of sensorineural hearing loss after suffering bacterial meningitis in children to optimize early diagnosis, prevention, treatment, and rehabilitation.

Materials and methods

The study was conducted as part of the research project "Development of Early Diagnostics and Preventive Measures of Hearing Impairment after Suffering from Bacterial Meningitis in Children" AP05135091 implemented under grant funding at the clinic in the City Children's Infectious Diseases Hospital, Astana, in the center "Life Sciences" NU, "National Laboratory Astana" from 2015 to 2018.

A cohort study was conducted to detect SHL in patients with meningitis after discharge with the mandatory audiological examination. Out of all 167 treated children, 103 children underwent an audiological examination, with a diagnosis of "Bacterial meningitis" – 60.7% (n = 65) and "Enterovirus meningitis" - 73.3% (n = 52). Patients were monitored for 1 year, the corresponding clinical history data, a diagnostic procedure, preoperative imaging data, the time interval between the diagnosis of bilateral deafness and cochlear implantation, computed tomography data with fibrosis or ossification were taken. Evaluation of hearing was evaluated based on the latest available results of pure tone and speech audiometry for children[14].

7 patients of all patients, treated with meningitis, had mild, moderate, severe, or bilateral deep SHL after bacterial meningitis. Therefore, we describe only these patients (n-7). All patients (n-7) received a vaccine against Haemophilus influenza, one patient against Streptococcus pneumonia. All patients showed normal hearing development before the onset of meningitis. All patients had normal physical and psychological development during the onset of meningitis. All patients underwent a complete neurological and otolaryngological assessment. The etiology of meningitis was determined by the culture of cerebrospinal fluid. The audiological assessment consisted of auditory brainstem response (ABR) and otoacoustic emissions (OAE) and, if possible, short-latency auditory evoked potentials (SAEP). Besides, all patients underwent an X-ray evaluation, consisting of a high-resolution computed tomography (HRCT) of the middle ear. One patient underwent cochlear implantation (CI).

Statistical data processing was performed by a statistical method using the SPSS IBM Statistics 20 program. Methods of descriptive statistics and logistic regression were used.

Results

In the study of all studied patients, the leading role in the etiological structure of BM was N. meningitides - 76.4% (n=68), S. pneumonia, - 14,6% (n=13), and isolated cases of pathogens in the form of S. pyogenes, S. agalactiae and S. aureus - 1.2% (n=1), respectively (Figure 1).

By dint of a screening study using a complex of audiology research methods - OAE, SAEP, and audiometry, a decrease in auditory function was detected in 7 children, who underwent BM (Table 1).

Of all examined children with BM (n=65), hearing loss was detected in 10.7% (n=7). According to the parents, no child's hearing impairment was noted before the disease. The age structure of the studied groups: children from 0 to 11 months, from 12 to 59 months with a uniform distribution of patients, who accounted for - 42.8% in

both groups (n=6), the remaining children over 5 years old –14.4% (n=1). All children received vaccination against Hib, and only one child against S. pneumoniae (PCV13) (cases 7). Among children with hearing impairment, pneumococcal meningitis – 71.4% (n=4), in contrast to meningococcal meningitis - 28.6% (n=3), comes to the forefront in etiological aspect. No patient with enterovirus meningitis (n=52) was found to have impaired auditory function after an illness.

In all patients, SHL was detected during follow-up observation. However, when interviewing the parents of one of the patients (cases 6), complaints of hearing loss were noted already during inpatient treatment, in the remaining 85.7% of patients (n=6) for a different period - 6.1±0.2 months (from 20 days to 24 months) after discharge from the hospital.

In the children we studied, SHL 1st–2nd degrees (right and left ear) were detected in 28.5% (n=2) followed by observation by audiologist, SHL 2nd–1ts and 4th–2nd degrees in 28.6% (n=2), respectively, and SHL of 3rd-4th degrees with ossification of the cochlea on CT of the temporal bones in 28.5% with pneumococcal meningitis (n=2) and without ossification of the cochlea in 14.3% (n=1). Patient 3 complained of hearing loss late (24 months) and at the outpatient stage, during the examination, there were contradictory diagnoses: the audiologist was diagnosed with "Sensorineural hearing loss?", and CT scan showed no pathological changes in the temporal bones. When re-examining a CT scan, another doctor has already concluded: "Bilateral sensorineural hearing loss of 4th degree with ossification of the cochlea". Also, in another child (cases – 4) with complaints of hearing loss, which turned 14 months after the disease, during the examination, SHL of 3rd–4th degrees were exposed with ossification of the cochlea. Due to the development of ossification of the cochlea of the inner ear, 2 patients failed to undergo a CI. These patients (42.8%) received a disability of group 3.

In the next patient (cases – 5), SHL of 3rd–4th degrees were detected after 20 days, CT imaging demonstrated cochlear fibrosis, and this patient was a candidate for emergency CI. The patient was held CI after 50 days in Astana.

The rest of the patients (cases 1, 2, 6, 7) were recommended auditory prosthetics (binaural).

Figure 1. The etiological structure of bacterial meningitis in children for 2015-2018 in Astana.

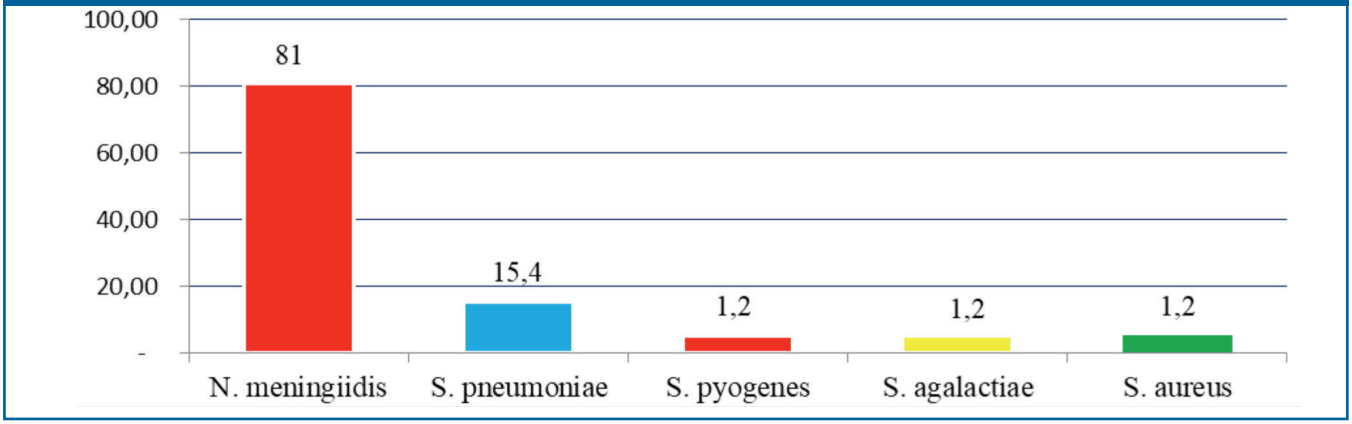


Table 1. The results of hearing impairment in children after suffering BM.

Patient	Microorganism	Age	The interval between meningitis and SHL (days)	Degree of SHL (right and left ear)	The presence of ossification on CT	Medical Conclusion (recommendations)
1	N.meningitidis	11 years, 16 days	60	1–2	«–»	audiologist observation auditory prosthetics
2	S.pneumonae	8 months	91	1–2	«–»	audiologist observation auditory prosthetics
3	S.pneumonae	5 years	300	3rd–4th degrees	«+»	audiologist observation
4	S.pneumonae	10 months	334	3 –4	«+»	audiologist observation
5	N.meningitidis	1 year, 4 months	20	3–4	«–»	audiologist observation. recommended cochlear implantation
6	S.pneumonae	4 months	90	SHL 4–2	«–»	auditory prosthetics recommended
7	N.meningitidis	4 months	30	2–1	«–»	auditory prosthetics recommended

At the next stage of the study, a binary logistic regression method was used to identify the factors that lead to hearing loss.

After the inclusion of all factors into the model, a statistically significant indicator was established (p≥0.001). The final likelihood ratio tests, which show, that the greatest significance among the factors in this model was influenced by such significant indicators as late admission to the hospital (p≥0.001), late untimely diagnosis (p≥0.001), administration of dexamethasone after the first dose of antibiotic (p≥0.001), bacterial etiology of meningitis: PM (p≥0.001) and MM (p≥0.05), Nagelkerk coefficient was –0.736 (73%).

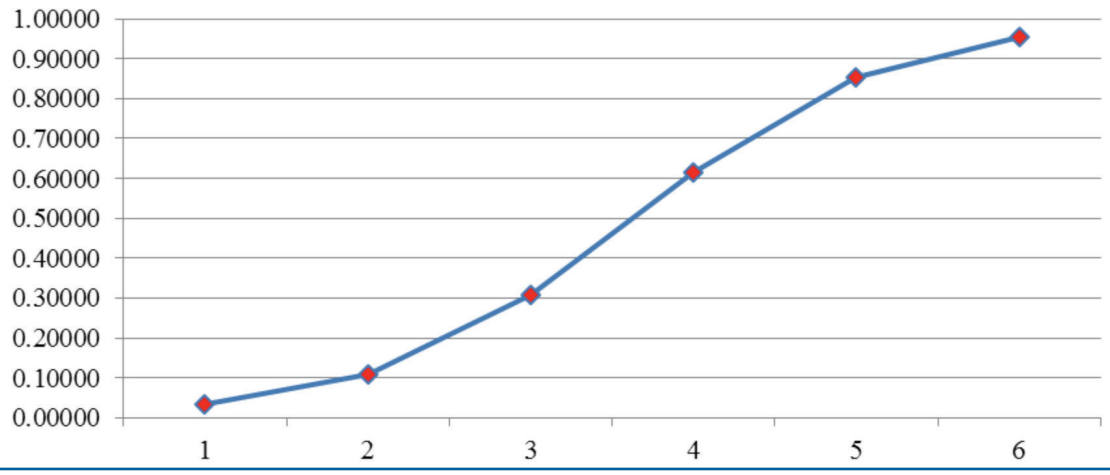
Regression analysis showed, that hearing loss is observed only after BM has been transferred, and in the case of viral meningitis, in particular, enterovirus meningitis etiology, hearing loss was not detected in any of the cases.

The development of hearing impairment in the late diagnosis of BM, where the chance is measured from 0 to 1, that is, 1 unit indicates the probability of an event occurring (Figure 2). As a result of the statistical calculation of the binary logistic regression, it was found, that the risk of developing hearing loss increases with late treatment at the hospital. If the patient turns on day 2 of the illness, then the probability of developing a hearing loss is - 10% (0.1), if on day 3 of the disease – 30% (0.3), on day 4 of the illness – 60% (0.6), on day 5 – 85% (0.85), on day 6 of the disease –95% (0.95).

Table 2. The results of building a binary logistic regression model.

Consequences: diminished hearing	B(n)	Std. Error	Wald	Dgr. Of sv.	Value.	95% CI for Exp (B)	
						Lower bound	Upper bound
Free member	28,928	1288,9	,001	1	,982		
Degree of severity	24,36	12566	0,5	1	,781	,125	288
Premorbid background	12,25	1545	054		,511	,28	15
Appeal to hospital	15,746	901,01	511,000	1	,005	0,001	.[b]
Late diagnosis	2,477	2,054	1454,000	1	,000	,213	667,526
Number of bed – days	1,084	1,469	,544	1	,001	,166	52,660
full term or not full term	0[c]			0			
dexamethasone after 1 dose of antibiotic	13,548	2,744	,849	1	0,001	,289	32,789
1-11 months	15,569	1090,4	,000	1	,005	0,000	.[b]
12–59 months	1,800	1,979	,083	1	,030	,003	7,990
5–14 years	0[c]			0			
PM	14,736	687,27	,190	1	,001	0,001	.[b]
MM	15,178	687,27	,750	1	,001	0,05	.[b]
EM	0[c]			0			

Figure 2. Development of hearing impairment depending on the length of hospitalization in children with BM.



Discussion

BM is the most common cause of acquired hearing loss in children and the cause of SHL in adulthood[15]. In the literature, there are various data on the frequency of occurrence of hearing impairment after BM. In patients with bacterial meningitis, a constant from 5% to 35% of SHL develops and the consequences result in deep bilateral hearing loss in 4% of patients[16]. Thus, according to A. Davis and K. Davis (USA, 2011), hearing loss varies between 2–31%[17], although the data from L.J. Baraff (USA)[18] suggests that the incidence with persistent hearing loss is closer to 10%. In our case, the SHL after the BM was 9.3% of all cases (n=65) (n=7), of which the total loss was 57% (n=4) and SHL of 1st-2nd degrees (n=3).

The final diagnosis of SHL 4th degree was established on average 140 days after an episode of meningitis in 3 of 7 patients (cases 3 through 5), which is much later than the timeline described in the literature: 4–28 days. Therefore, infectious disease physicians, pediatricians, and general practitioners should be fully aware of this complication, and it is mandatory to recommend consultation of an audiologist to children, who have had meningitis[19].

Studies in patients with sensorineural hearing loss conducted in 2010 by D. Philippon, et al. using CT of temporal bones found, that a more pronounced degree of ossification of the cochlea is more often determined after suffering meningitis caused by S. pneumoniae[20]. In our series, CT scan of the temporal bones revealed the ossification of the cochlea in three patients and cochlea fibrosis in one patient. Patients with ossification of the cochlea addressed very late periods (900; 300; 334 days).

The use of corticosteroids (dexamethasone) before antibiotic therapy in bacterial meningitis reduces the risk of cochlear ossification[21]. The meta-analysis evaluated the value of dexamethasone in the treatment of bacterial meningitis: dexamethasone did not reduce the mortality or incidence of neurological lesions, but the risk of deafness was lower in surviving patients[22]. However, SHL is not always clinically detected, so the hearing loss may not be diagnosed for a long period of time[23]. All the patients we observed, dexamethasone was obtained after the administration of the antibiotic.

In our country, the lack of consultation of a specialist audiologist in the clinical protocol for diagnosis and treatment of BM is fraught with late detection of SHL in a child, which ends with ossification and the inability to perform a cochlear implant and, as a result, leads to disability of a child with complete hearing impairment.

The problems of hearing impairment in BM are the most common, whereas they are not observed in viral meningitis[24]. Also, the results of our study confirmed that in the case of enteroviral meningitis SHL no cases were detected.

When BM in the inner ear there are significant pathological changes, the final stage of which is the development of ossification of the cochlea. The process of development of the ossification of the cochlea consists of three stages: acute, fibrous, and the stage of ossification. The acute phase coincides with the onset of meningitis and is characterized by purulent inflammation and the formation of serous-fibrous exudate mainly in the perilymphatic space, without affecting the cavity filled with endolymph[25]. After 2 weeks from the beginning of the infection process, the second stage of neurosensory hearing loss develops - fibrous, which is accompanied by a proliferation of fibroblasts in the perilymphatic spaces, then angiogenesis begins. The third stage of neurosensory hearing loss ends with ossification proper[26]. At the stage of ossification, bone tissue is formed, which is primarily found in the basal curl, starting from the second month after the development of the labyrinthitis. The formation of bone tissue, followed by calcification and remodeling, obliterates both peri-and endolymphatic prostration. Therefore, before the first stage of the ossification of the cochlea in BM, it is necessary to detect SHL as soon as possible to recommend cochlear implantation to patients[27]. In our case, two patients with complete hearing loss were examined late in 300 and 334 days at the ossification stage, therefore, they did not undergo CI. It is especially difficult to diagnose "sensorineural hearing loss" in children under 3 years of age since their hearing impairment can be detected in a late period either by parents or during a specialized examination. Hearing loss affects the development of speech and psychomotor development of the child[28,32-34].

Ossification of the cochlea can progress and jeopardize the success of cochlear implantation[12]. The limited capabilities of the high-tech assistance system, such as, for example, in our country, as well as the remoteness of patients from the CI centers, do not always allow for surgical intervention in such a short time.

Also, it should be borne in mind, that at the present stage, the prevention of the development of disability in the form of complete hearing loss after BM can be ensured only by surgical intervention in the form of a cochlear implant. Moreover, the earlier implantation of the cochlear apparatus to the patient, i.e. before the formation of the 2nd and 3rd stages of ossification of the cochlea, will allow to fully restore hearing[29,30].

Conclusions

In the etiological structure of BM complicated by hearing impairment in children, pneumococci dominated (71.4%). All children with hearing impairment were not vaccinated against pneumococcus and meningococcus (100%) and dexamethasone injection was administered after the first dose of antibiotic (100%). Statistical analysis of logistic regression revealed, that with

late treatment, late diagnosis and the presence of bacterial meningitis there is a high risk of developing hearing impairment.

We propose the following observation protocol: all patients after suffering bacterial meningitis should be prescribed audiologic tests for 1 year. Audiometry should be repeated 1,3,6,9 and 12 months.

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