Qualification of unilateral cochlear implant recipients for a second device

ABSTRACT:

Introduction: Although it is recommended to perform cochlear implantation in both ears at the same time for management of profound hearing loss in children, many centers prefer to perform sequential implantation. There are many reasons as to why a simultaneous bilateral implantation is not commonly accepted and performed. The major risk is the possibility of bilateral vestibular organ impairment. However, it is beyond doubt that children who received the first implant should be given a chance for binaural hearing and associated benefits. In the literature, there are no homogenous criteria for bilateral implantation, and it is hard to find uniform and convincing algorithms for second cochlear implantation. The aim of this study is an attempt to identify a safe way of qualifying for second cochlear implantation in children.

Material and methods: Forty children with one cochlear implant were qualified for the second implantation. During qualification, the following were taken into account: time of the first implantation, audiometry results, use of the hearing aid in the ear without an implant and benefit of the device, speech and hearing development, and vestibular organ function.

Results: Fifteen out of forty children (38%) were qualified for the second implantation. In 35% of children, the decision was delayed with possible second implantation in the future. Eleven children (27%) were disqualified from the second surgery.

Discussion: During evaluation according to the protocol presented in our study, 38% of children with a single cochlear implant were qualified for the second implantation with a chance for an optimal development and effective use of the second cochlear implant. We are convinced that sequential implantation with a short interval between surgeries and with an examination of the vestibular organ, hearing and speech development as well as an assessment of potential benefits from the second implant (bimodal stimulation) before the second implantation is the safest and most beneficial solution for children with severe hearing loss.

KEYWORDS: bilateral vestibular loss, cochlear implant, children, deafness, qualification for bilateral implants

ABBRVIATION USED IN THIS STUDY

TBVL – total bilateral vestibular loss (total bilateral vestibular areflexia)

INTRODUCTION

Since the first cochlear implant program was established, the cochlear implants have become a safe and effective method for treatment of children with severe to profound sensorineural hearing loss, which gave them a chance for normal development and access to the world of sounds. Today, it is beyond doubt that children should receive their first cochlear implant as soon as possible, and early implantation brings more benefits [13, 19].

Binaural hearing is associated with several mechanisms such as the squelch effect, head shadow effect, and summation effect, which bring many benefits such as better speech discrimination in silence and noise as well as better localization of sounds [7, 12, 26, 27]. In recent years there has been a visibly increased interest in the benefits of binaural hearing as well as a growing trend for bilateral simultaneous implantation in children [24].

Binaural hearing can be restored in two ways: through bimodal stimulation combining cochlear implant in one ear with hearing aid in the other ear, or through bilateral implantation [32]. Leaving the non-implanted ear without possible sound reception or any form of stimulation using either a hearing aid or cochlear implant, is not the optimal solution in the light of the current medical knowledge, and thus should not be accepted [23]. Every child with a single cochlear implant should be given a chance for bimodal hearing by means of a hearing aid to the non-implanted ear. Hearing aid may bring significant benefits, when the residual hearing function is preserved, and the child is willing to use this device [14]. Symmetric stimulation with sounds and constant stimulation of the auditory pathway is crucial for central auditory processing [14]. It also prevents hearing deprivation in the non-stimulated ear.
Many centers around the world still prefer sequential implantation, despite general recommendations and a visible tendency for simultaneous bilateral cochlear implantation [18, 21, 25], which has the advantage of early symmetric stimulation of the auditory pathway.

There are many reasons why bilateral implantation is not commonly accepted and performed. The first implant guarantees development of speech and hearing, while the second implant is meant to improve the quality of life, sound localization and hearing in noise. The potential benefit from the second cochlear implant in children with severe hearing loss is incomparably less significant than benefits of the first implant, both in the quality of life and the economic aspect [2]. Implantation of the second / both implants without proper qualification may also cause irreversible damage.

The major threats, which the physician should be aware of, include the following: total bilateral vestibular loss (TBVL), loss of residual hearing and adverse management of the limited resources, i.e. when the patient does not use the implants [4, 6, 8, 10, 30]. Sequential implantations may be performed with a short time between them – so-called ‘short interval’ implantations (when the interval between the first and the second implantation is less than one year), or with a long time between them – ‘long interval’ (more than a year). In the case of the long-interval sequential implantation it is typical that the first implant is more effective than the second one for a long period of time (providing better speech discrimination). The patient must learn to use the second implant through intensive rehabilitation, and sometimes refuses to use it. As the time between those two implantations becomes longer, the differences between implants tend to be bigger as well.

The advantage of sequential implantation is that it prevents bilateral impairment of the vestibular organs. It is possible after detailed examination of both vestibular organs and confirmation of possible vestibular loss (areflexia) in the implanted ear, and an assessment of the benefits of the first cochlear implant and hearing aid. In addition to the clinical implications, ethical and financial considerations are also associated with a second cochlear implantation, as this implantation may limit the number of patients who have access to a first implant. The roles of the first and second cochlear implant in such cases are incomparable. A second cochlear implant is not as crucial for overall development as the first device.

Because of possible significant benefits from binaural hearing, patients with a single cochlear implant should be given a chance and be subject to qualification for the second surgery. Children with severe bilateral hearing loss are a heterogeneous group including children with residual hearing in the non-implanted ear. The aim of this study is to present a safe and consistent way of patient qualification for implantation of the second cochlear implant in children and to present the results of qualification performed at our facility.

**MATERIALS AND METHODS**

The study was conducted in compliance with ethical requirements for human research and the Declaration of Helsinki. The Bioethical Commission approved the study under the file No. KB 275/2017.

**MATERIAL**

Forty children aged between 21 months and 13 years with a single cochlear implant were evaluated during qualification for the second implant.

The study group consisted of 16 girls and 24 boys. The mean age of the children was 7 years (standard deviation: 2.97). Seven children had cochlear implant in the left ear, while 33 – in the right ear. Children underwent first surgery at the age between 1 year and 10 years (3.1 years on average with standard deviation of 2.38).

1. During the qualification process, all children underwent an audiological evaluation preceded by an otoneurological examination aiming to assess the tympanic membrane and the presence of cerumen or other debris that could possibly affect the audiological testing.

The audiological evaluation included:

- pure tone audiometry performed using Madsen audiometer; the patient was exposed to pure tones through headphones at 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 6 kHz, 8 kHz, and the hearing thresholds for air conduction were determined;
- pure tone audiometry in free acoustic field with the speaker at the distance of 1 meter from the head, hearing ± 90 degrees for both ears; the examination was performed to assess the absolute threshold of hearing with the warble tone at 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4kHz frequencies for both ears (implanted and non-implanted), with and without the hearing aid on;
- speech discrimination in silence and noise was examined using two-syllable words for children aged 5 to 8 years, and one-syllable words for children aged 8 to 15 years.

During evaluation of speech perception, the speech was presented at 65 dB SPL at the distance of one meter from the head in the sitting patient through a speaker (bearing ±90 degrees) to both ears. During evaluation in noise, the signal was presented at 55 dB SPL at a distance of one meter from the patients’ head through a speaker, bearing ±180 degrees. The evaluation included the implanted ear, the non-implanted ear, and both ears simultaneously.

2. In 38 out of the 40 children, otoneurological evaluation was conducted using the following balance tests: Romberg’s test, Underberger’s test, Dix-Hallpike test, head impulse test, and electronystagmography (ENG) or videonystagmography (VNG), which assessed saccadic eye movements, eye tracking, positional and optokinetic nystagmus, positioning tests, caloric test (monothermal and bithermal caloric tests). Two patients were not cooperating during those tests, and thus a complete evaluation was impossible.

The evaluation was conducted using VNG-Ulmer or ICS Chartr 200 VNG/ENG system. The VNG examination was performed always when possible. When the subject was a toddler or a non-cooperating child, the ENG examination was performed instead, as it includes eyeball movement recording regardless whether the...
eyes are open or closed. The primary test was the bithermal caloric test, however, in cases of limited cooperation a monothermal test was preferred. It consisted of water administered at 30°C and then 44°C. The time lapse between water administration to the right and then left ear was 5 minutes. The interval between administration of cold water to both ears and then administration of hot water was 15 minutes. The duration of water injection was monitored automatically by the device and lasted 20 s. Nystagmus was recorded for as long as it was present. The analysis and interpretation of the study was based on the result given out by the digital system of the device.

Both methods allowed to evaluate the vestibular organ function, as well as to record and analyze eyeball movements, which has been proved in numerous studies to correlate with and be useful in evaluation of the vestibular organ dysfunction in children [3, 4, 10, 22, 28, 30, 31].

3. Also, it was verified whether the child is wearing a hearing aid in the non-implanted ear and whether he or she has objective or subjective benefits from it.

4. The next step was speech evaluation covering communication skills, language skills (overall speech development), and individual hearing abilities. Diagnostic tests were adjusted to the child’s age, hearing and psychomotor development. Development of children younger than 4 years was evaluated using the Integrated Scale of Development and included areas of listening, receptive and expressive language, speech, cognition, and social communication. In children older than 4 years, we used the qualitative speech questionnaire by D. Emiluta-Rozya, which assesses basic language skills such as listening, language development (passive voice, active voice, vocabulary) as well as phoneme realization [5]. Each examination was preceded by conversation with the child’s caregivers about his or her everyday habits.

The qualification process consists of three stages:

1. Stage one includes vestibular system evaluation. Implantation can have a negative influence on balance and cause its dysfunction [11, 28, 29, 30]. In worst-case scenario, it may lead to total bilateral vestibular loss having a considerable negative impact on the quality of life and the child’s development [30].

2. Stage two includes evaluation of subjective and objective benefits from the already applied devices. Objective benefits from the hearing aid is defined as every measurable result on speech discrimination. Subjective benefits from the hearing aid used by small child have been defined, for the sake of this study, as: willingness to use it on the contralateral ear. Older patients also evaluated benefits on interviews.

3. Stage three consists of an assessment of the child’s development after the first implantation.

Patients with normal balance, hyporeflexia or congenital bilateral vestibular loss can be qualified for the second implantation.

In the case of non-cooperating children, a decision on the second implantation should be postponed until the function of the vestibular organ is evaluated. However, those are rare cases.

Methods – Qualification Protocol

Qualification protocol is based on several assumptions:

- the qualification protocol must identify children at risk of developing total bilateral vestibular loss following cochlear implantation – such children are disqualified from the second implantation;
- children, who benefit from the first implant but have no chance for binaural hearing due to lack of residual hearing in the non-implanted ear or do not accept hearing aids – they are good candidates for the second implantation;
- poor management of the limited resources should be avoided, especially in facilities where children are waiting for the first implantation. An example of such a situation is the decision to disqualify or postpone implantation in children who benefit from hearing aids, for whom bimodal stimulation is effective and sufficient. A similar decision is made in the face of no developmental benefits following the first implantation.

Differences in benefits between bimodal stimulation and bilateral implantation are still controversial. When a child wants to wear the hearing aid and there are clear benefits, bimodal stimulations is an effective way of reaching binaural hearing.

However, the objective benefits from hearing aids should not be the only criteria for qualification for the second implantation. Even with poor speech discrimination and lack of an objective benefit from a hearing aid, the quality of hearing the surrounding sounds and music can be reported by the patient as good, while the benefits are only subjective. The patient reporting subjective benefits may refuse to undergo the second implantation. Hence, it is hard to clearly define the absolute hearing and discrimination cut-off points for the second implantation qualification. In older children, the decision also depends on the patient’s feelings [6].

Patients who refuse to wear or get no benefits from hearing aids are good candidates for the second implantation.

The second implantation is not recommended in children who willingly wear and use a contralateral hearing aid.

The qualification protocol must identify children at risk of developing total bilateral vestibular loss following cochlear implantation – such children are disqualified from the second implantation; children, who benefit from the first implant but have no chance for binaural hearing due to lack of residual hearing in the non-implanted ear or do not accept hearing aids – they are good candidates for the second implantation; poor management of the limited resources should be avoided, especially in facilities where children are waiting for the first implantation. An example of such a situation is the decision to disqualify or postpone implantation in children who benefit from hearing aids, for whom bimodal stimulation is effective and sufficient. A similar decision is made in the face of no developmental benefits following the first implantation.
There is a group of children who, despite proper and early implantation, never develop correct speech and hearing due to many reasons and comorbidities, and they will eventually communicate non-verbally. Some patients with a single cochlear implant, despite having implant for many years, still communicate using sign language and lip reading. In our opinion, the second implantation is unreasonable in such cases.

Speech development was evaluated with speech examination, which was adjusted to the child’s age. The following patients’ subgroups were distinguished:

- Children who did not develop appropriate hearing and speech and continued to communicate non-verbally despite the first implantation – such patients were not qualified for the second implantation. It would be associated with an additional risk due to another surgery with very little expected benefits. Patient’s parents were fully informed;
- Children with possible and achievable but delayed development of the speech and hearing. In such cases intensive rehabilitation was recommended, while the decision about the second implantation was postponed. Further management was based on regular speech assessment;
- Children with normal development of speech and hearing, developing properly after the first implantation – are good candidates for the second implantation.

RESULTS

General results

1. Hearing examination:
   - Implanted ear: all children were diagnosed with profound hearing loss (> 90 dB at frequencies 125-8000 Hz);
   - Nonimplanted ear hearing thresholds obtained for the study group by pure tone audiometry allowed us to categorize children into the following 4 groups based on hearing level:

<table>
<thead>
<tr>
<th>Group</th>
<th>Hearing Loss (dB)</th>
<th>Number of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&gt; 90</td>
<td>25</td>
</tr>
<tr>
<td>II</td>
<td>75-90</td>
<td>15</td>
</tr>
<tr>
<td>III</td>
<td>91-120</td>
<td>10</td>
</tr>
<tr>
<td>IV</td>
<td>&lt;75</td>
<td>4</td>
</tr>
</tbody>
</table>

2. Proportions of children wearing hearing aids (Fig. 1.):
   - 25 children (62.5%) wore a hearing aid on the second ear,
   - 15 children (37.5%) did not wear a hearing aid.

Among children wearing their hearing aids, five children (12.5%) did not get any subjective or objective benefits from the device, fifteen (37.5%) got subjective benefits, while in five cases (12.5%) an objective benefit was noted (Fig. 2.).

In children with objective benefits, the level of speech discrimination in the implanted ear was 100% while in the ear with hearing aid the following values were obtained: 60%, 60%, 50%, 30%, 10%. In children with subjective benefits from the hearing aids, the speech discrimination level was between 0 and 20% with an absolute threshold of hearing between 40 and 45 dB.

3. Among children whose vestibular organ was evaluated, twenty children (52.6%) were examined using the VNG test (bithermal caloric test), and four (10.5%) were examined with the ENG test (bithermal caloric test). Some patients were, due to the lack of cooperation and difficulties with performing the tests, examined with monothermal caloric stimulation; two of them (5.3%) with VNG and twelve (31.6%) with ENG.

Due to the results of caloric examination and the level of hyporeflexia, the patients were divided into three subgroups:

- I – 0–20%,
- II – 21–85%,
- III – total vestibular loss or severe hyporeflexia >85%.

Vestibular hyporeflexia in group I was found in 25 children (66% of patients who underwent vestibular organ evaluation); in group II, it was diagnosed in eight children (21%); in group III it was diagnosed in five children (13%) (Fig. 3.).

4. Patients who underwent speech examination were divided into 3 groups:
   - I – normal development of speech and hearing, verbal communication – 26 (65%) of children,
   - II – delayed but progressive speech development, verbal communication – 5 (12.5%) of children,
   - III – insufficient development of speech, non-verbal communication – 9 (22.5%) children.

Qualification outcomes (Fig. 4.)

1. Finally, 15 out of 40 children (37.5%) were qualified for the second implantation;

2. The decision was postponed in 14 patients (35%) with possible implantation in the future.

This group consisted of 10 boys and 4 girls, with an average age at the time of qualification of 7 years (ranging from 2.5 to 13 years of age, SD: 3 years).

The age at the time of the first implantation ranged between 13 months and 7 years. Mean age at the moment of the first implantation was 3 ± 1.9 years.

Eleven children had hearing aids, while three children did not use it.

In this group, the decision to postpone implantation was based on:

- Reported benefit from a hearing aid and normal development of speech and hearing. In three children (7.5%), objective benefit from the hearing aid was noted, while another three children had subjective benefit from
the hearing aid (despite the fact that objective benefit was not reported). Five of the children (12.5%) presented residual hearing:
- One child (2.5%) did not cooperate, and did not undergo examination of the vestibular organ, however the child used the hearing aid and developed normal hearing and speech;
- Insufficient development of speech and hearing despite the first implantation led to postponing the second implantation in five patients – 12.5%.

Further research of this group of patients will allow to make a decision on the second implantation. Those children have a chance to be qualified to the second implantation if they make progress in speech and the hearing therapy, as long as total vestibular loss in the implanted ear is excluded.

- Abnormal vestibular organ function was present in four patients. Total vestibular loss was diagnosed in one child, two children were diagnosed with severe hyporeflexia and one boy had inherent bilateral loss.

Reasons behind delayed decision in each patient is summarized in Tab. I.

3. Eleven children (27.5%) were not qualified for the second implantation. This group consisted of 6 boys and 5 girls. Their mean age at qualification was 8.5 years (ranging from 3 years and 11 months to 12 years, SD: 2.55). The age at first implantation ranged from 12 months to 10 years, with a mean age of $4.3 \pm 2.6$. Seven children wore their hearing aids on the non-implanted ear, while four children did not.

The decision of disqualification was made due to:
- Diagnosis of total vestibular loss (areflexia) in the implanted ear – three children (7.5%);
of bilateral implantations, despite medical indications due to the lack of implants for children newly diagnosed with hearing loss.

Considering medical aspects, 38% of the examined children with a single cochlear implant were qualified for the second implantation and had a chance for optimal development and effective use of the second implant.

For the rest of the patients, the decision regarding second implantation was postponed or abandoned altogether, because of benefits from bimodal stimulation, vestibular hyporeflexia or areflexia, and the risk of TBVL or insufficient development of speech and hearing, during use of the first implant. Of course, there is a chance for the second implantation in this group, e.g. with progression of speech and hearing development. All decisions were made together with patient’s caregivers, who were presented with possible benefits and negative effects of the second implantation.

Currently, the criteria for qualification for cochlear implantation in children have been extended. Excessively liberal interpretation of the criteria for qualification for cochlear implantation in children has led to decision regarding the second implantation being often controversial and often made against strong pressure, for example by parents of a child who has had a single implant for 7 years, has not developed speech and hearing and their parents want the second implantation, which is supposed to cause rapid development of speech and hearing. On the other hand, costs and waiting queue lead to postponing the optimal choice of bilateral implantations, despite medical indications due to the lack of implants for children newly diagnosed with hearing loss.

The qualification process proposed by us reflects real problems which the institutions performing cochlear implantation in children must cope with. Decision regarding the second implantation is often controversial and often made against strong pressure, for example by parents of a child who has had a single implant for 7 years, has not developed speech and hearing and their parents want the second implantation, which is supposed to cause rapid development of speech and hearing. On the other hand, costs and waiting queue lead to postponing the optimal choice of bilateral implantations, despite medical indications due to the lack of implants for children newly diagnosed with hearing loss.

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• Lack of cooperation with impossible vestibular organ examination, as well as lack of any improvement of speech and hearing three years since the first implantation – one child (2.5%);
• Insufficient development of speech and hearing despite the first implant. Nine children (22.5%) were diagnosed with insufficient speech development and they would communicate non-verbally.

DISCUSSION

The qualification process proposed by us reflects real problems which the institutions performing cochlear implantation in children must cope with. Decision regarding the second implantation is often controversial and often made against strong pressure, for example by parents of a child who has had a single implant for 7 years, has not developed speech and hearing and their parents want the second implantation, which is supposed to cause rapid development of speech and hearing. On the other hand, costs and waiting queue lead to postponing the optimal choice of bilateral implantations, despite medical indications due to the lack of implants for children newly diagnosed with hearing loss.

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Tab. II. Causes of disqualification.

<table>
<thead>
<tr>
<th>NO.</th>
<th>AGE (YEARS)</th>
<th>AGE AT THE IMPLANTATION (YEARS)</th>
<th>HEARING AID USE</th>
<th>VESTIBULAR FUNCTION</th>
<th>SPEECH AND HEARING DEVELOPMENT</th>
<th>CAUSES OF POSTPONING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>1</td>
<td>No</td>
<td>I</td>
<td>III</td>
<td>Insufficient development of the speech and the hearing during use of the first implant for 5 years, non verbal communication, mental disability</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>3</td>
<td>Yes</td>
<td>III</td>
<td>I</td>
<td>Areflexia in ear with the implant, correct development of the speech and the hearing, objective benefit from the hearing aid</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>3</td>
<td>No</td>
<td>I</td>
<td>III</td>
<td>Insufficient development of the speech and the hearing during use of the first implant for 6 years, discrimination of the speech with the implant 40%</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>3</td>
<td>No</td>
<td>I</td>
<td>III</td>
<td>Insufficient development of the speech and the hearing during use of the first implant for 8 years, non verbal communication</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>3</td>
<td>Yes</td>
<td>II</td>
<td>II</td>
<td>Insufficient development of the speech and the hearing during use of the first implant for 5 years, hyporeflexia in the ear with the implant</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>2</td>
<td>Yes</td>
<td>III</td>
<td>I</td>
<td>Areflexia in ear with the implant</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>5</td>
<td>Yes</td>
<td>II</td>
<td>III</td>
<td>Insufficient development of the speech and the hearing during use of the first implant for 5 years</td>
</tr>
<tr>
<td>8</td>
<td>3 yrs 11 mo</td>
<td>3</td>
<td>No</td>
<td>I</td>
<td>III</td>
<td>Insufficient development of the speech and the hearing during use of the first implant</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>6</td>
<td>Yes</td>
<td>I</td>
<td>III</td>
<td>Insufficient development of the speech and the hearing during use of the first implant</td>
</tr>
<tr>
<td>10</td>
<td>11 yrs 8 mon</td>
<td>10</td>
<td>Yes</td>
<td>III</td>
<td>III</td>
<td>Insufficient development of the speech and the hearing during use of the first implant for 5 years, areflexia in ear with the implant</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>3</td>
<td>Yes</td>
<td>Not performed</td>
<td>III</td>
<td>Insufficient development of the speech and the hearing during use of the first implant for 3 years, lack of a cooperation — examination of the vestibular organ was not performed</td>
</tr>
</tbody>
</table>

those criteria may lead to implantation in children who do not need the second implant at all, or it may lead to adverse medical sequelae.

The first implantation is especially important, and it is crucial for child’s development. The second implantation is also important, because of the binaural hearing benefits. However, it must be noted that benefits from the second implant are modest in comparison to the benefits from the first one, therefore second implantation should not be performed if a potential risk, for example of total bilateral vestibular loss or residual hearing loss, is greater than the expected benefits.

Considering the vestibular organ function and child’s development, qualification for bilateral implantation should consist of two stages and include a period of bimodal stimulation.

Early bilateral implantation is optimal for the symmetric stimulation of the central nervous system, and we understand that the interval between the first and the second implantation is important in our algorithm [9]. The shorter the interval, the better are the final outcomes; if the interval is too long, the benefits from the second implantation may be smaller compared to the first implantation, or even the second implant may be ineffective [21]. If a child uses a hearing aid in the unimplanted ear, then the delay time is less significant [23]. Every child admitted to our clinic is given a hearing aid for the second ear for bimodal stimulation following the first implantation. However, it may not be well tolerated by every patient, especially when a much better stimulation is provided by the cochlear implant or if there is no residual hearing. Disorders of the vestibular organ coexist with sensorineural hearing loss before the implantation, while implantation of the cochlear implant may also affect the vestibular organ and, in some cases, lead to vestibular areflexia [4, 10, 30].

Information obtained during vestibular organ examination in children is reliable and many institutions conduct this examination routinely [3, 4, 10, 20, 22, 28, 30, 31]. According to Wiener-Vacher, even half of the patients had changes in vestibular organ function, while in 10% of them ipsilateral vestibular loss was diagnosed [30]. We obtained similar results during qualification of the children for the second implantation. According to Wiener-Vacher, simultaneous bilateral implantation leads to total bilateral vestibular loss in 2% of the cases. Thus, simultaneous bilateral implantation is the main cause for total bilateral vestibular areflexia with all its consequences, including damage to the implant [31]. Unilateral total vestibular loss or hypofunction, which may result from unilateral implantation, have no impact on the patient because of the compensatory mechanisms. Total bilateral vestibular loss acquired at an early age may cause significant delay of motor development and may hamper achieving developmental milestones such as holding head up, sitting without support, or walking [1, 10, 15]. Children may never be able to learn how to ride a bike. Oyewumi et al. concluded that TBVL, which occurs in a substantial number of bilateral cochlear implant recipients, increases the odds of device failure, probably due to repeated damage to the device resulting from head trauma [20]. Wolter et al. analyzed the medical history of 35 children with damaged implants and found that the absence of bilateral horizontal canal function increased the odds of cochlear implant damage 7.6 times [17, 31].
Otolaryngologists must be aware of the TBVL risk [17]. Examination of the vestibular organ and examination excluding total vestibular loss after the first implantation should be conducted before the second implantation. It does not imply significant delay of the second implantation. Wiener-Vacher recommends examination of the vestibular organ and making a decision about the second implantation three months after the first implantation [30].

The decision about the second implantation despite areflexia in the implanted ear should be made very carefully because of the risk of bilateral areflexia, and only after discussing it with parents and older children, all benefits and risks included. In our clinic, the second implantation in such cases is not performed, except for a very strong motivation by the patient or his/her parents.

Congenital bilateral areflexia or areflexia in the non-implanted ear with functional vestibular organ in the implanted ear, of course, is a very strong motivation by the patient or his/her parents. The decision about the second implantation despite areflexia in the implanted ear is not a contraindication for implantation, because in this situation the function of the vestibular organ cannot get worse. We prefer sequential bilateral cochlear implantation, similar to many other surgeons and facilities [4, 14]. Sequential implantation allows for an assessment of benefits from bimodal stimulation before the second implantation. It also allows to evaluate child’s development after the first implantation and to assess cooperation between the patient or his/her parents and the medical team. Another advantage is an examination of the vestibular organ in each ear, which prevents total bilateral vestibular loss. It is also possible to evaluate subjective and objective benefits from a hearing aid.

Taking into account all the above-mentioned elements of the patients’ assessment during qualification for the second implantation of the cochlear implant, 38% of the patients with the first implant may be successfully implanted again with a good chance for the optimal effect of rehabilitation and binaural hearing.

**CONCLUSIONS**

Sequential implantation with examination of the vestibular organ, development of hearing and speech, as well as evaluation of benefits form a contralateral hearing aid is the optimal and safe way to bilateral cochlear implantation in children. The recommended time of the second implantation in qualified children should be as short as possible.

**REFERENCES**

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