European Annals of Otorhinolaryngology, Head and Neck diseases 133S (2016) S7–S11

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Original article

Interest of vestibular evaluation in sequentially implanted children: Preliminary results

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ARTICLE INFO

Article history:
Received 28 October 2015
Accepted 28 April 2016

Keywords:
Cochlear implant
Vestibular function
Caloric test
VEMP's
Pediatric

ABSTRACT

Introduction: An early acquired or congenital absence of sensory input of the vestibule will lead to severe delayed posturomotor milestones. Previous studies have proven modifications and even complete ipsilateral loss of vestibular function after unilateral cochlear implantation. The objective of this study was to evaluate whether sequential cochlear implantation has an impact on vestibular function.

Methods: Retrospective study from January 2012 to January 2015 including 26 patients. The first stage consisted of determining the vestibular status of 26 hearing impaired children who were candidates for a second cochlear implant. Three months after contralateral implantation, we reevaluated the vestibular function of the same patients. The vestibular evaluation consisted of multiple tests for canal and otolith function. A complete clinical vestibular evaluation was performed, including the head thrust test. This was followed by an instrumental assessment composed of the classic bicaloric test and vestibular evoked myogenic potentials testing with tone bursts.

Results: A high prevalence of vestibular dysfunction (69%) was found in our group of unilaterally implanted children. Three patients had a unique functional vestibule at the not yet implanted ear. Vestibular evoked myogenic potentials responses stayed present in 15 of the 19 patients with a VEMP-response before contralateral implantation. Results of the caloric test changed for 6 patients after contralateral implantation.

Conclusions: After contralateral implantation, 37% of our patients manifested modifications of their vestibular status. Intrasubject comparison of bicaloric and vestibular evoked myogenic potentials testing before and after contralateral cochlear implantation showed that canal function was better preserved than saccular function. Seeing the high prevalence of vestibular dysfunction in our test group of unilateral implanted children, sequential implantation must be preceded by a vestibular assessment to prevent complete bilateral vestibular areflexia and its potential consequences. Presence of hyporeflexia at the yet-to-be implanted ear seems to be a situation particularly at risk.

1. Introduction

A complete absence of vestibular information, whether congenital or acquired at very young age, will lead to severely delayed posturomotor milestones, such as stabilizing the head, sitting and walking independently [1–3]. Vestibular end-organs and the cochlea share a common embryological origin and develop thereafter a direct anatomical relationship in the inner ear. As a result, children with profound sensorineural hearing loss may also display vestibular dysfunction, with prevalences ranging from 20 to 85 percent [4–7].

In the last decades, cochlear implants have been the gold standard for treating severe sensorineural hearing loss. At present, bilateral implantation is considered to be of greater value than unilateral implantation, as this gives access to binaural hearing, providing children with better sound localization, better speech detection in noisy environment, and quality of life improvement [8,9].

On the other hand, cochlear implantation has been shown to lead to postoperative modifications of the vestibular function [1,7,10–12]. For instance, Wiener-Vacher et al. reported postoperative vestibular modifications in half of their patients and ipsilateral vestibular areflexia in 10% of them after unilateral

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http://dx.doi.org/10.1016/j.anorl.2016.04.012
1879-7296/

cochlear implantation. For this reason, implanting both ears instead of one constitutes a significantly greater risk of iatrogenic vestibular dysfunction, as it may cause harm to the entire bilateral vestibular system.

Currently most Belgian ENT surgeons favour sequential bilateral cochlear implantation, which means there is a certain time-delay between both surgical procedures. There is however an increasing tendency for simultaneous bilateral implantation. This latter approach may offer operative benefits but it also prevents assessing the child's vestibular status after the first implantation, which might be an important factor in the decision for a second implantation.

The first objective of this study is to identify the percentage of children with a unique functional vestibule at the not yet implanted ear before they receive their second implant. The second objective is to assess the vestibular status of all children after the second implantation to determine the impact of a sequential implantation procedure on the vestibular function.

2. Materials and methods

The medical files of all the patients who were candidates for a second cochlear implant between January 2012 and January 2015 in our ENT department were examined. We found 26 first implanted patients corresponding to these criteria (Table 1). The patients had a mean age of 6.75 years at the time of the first vestibular testing (range: 1–13 years old). We could not perform a vestibular assessment after second implantation in two of these patients, as one child's parents refused the examination, and the other child was diagnosed with a unique functional vestibule on the not yet implanted ear prompting the decision not to implant the second ear. All 24 children with both a pre- and postoperative vestibular evaluation received a Cochlear Nucleus System cochlear implant on the contralateral ear, inserted through an anteroinferior cochleostomy, by the same surgeon. Intramodiolar electrodes were not used in these patients.

Hearing loss causes were determined as follows:

- as part of a clinical syndrome ($n = 7$);
- genetic mutations ($n = 7$);
- postmeningitis ($n = 1$);
- CMV infection ($n = 1$);
- auditory neuropathy spectrum disorder ($n = 2$);
- unknown ($n = 8$).

Imaging studies showed normal inner ear anatomy ($n = 19$), isolated vestibular malformation ($n = 3$), cochleo-vestibular malformation ($n = 3$), and isolated cochlear malformation ($n = 1$).

Table 1
Demographics of the 26 patients.

Population characteristics ($n = 26$)	
Mean age at first examination	6,75 (range: 1–13)
Brand of implants	Cochlear
Cochleostomy insertion site	Antero-inferior
Etiology	
Syndromic	6
Genetic	7
Postmeningitic	2
CMV	1
ANSD	2
Unknown	8
CT scan, NMR	
Normal	19
Vestibular malformation	3
Cochlea malformation	1
Cochleo-vestibular malformation	3

All patients underwent vestibular status assessment before and 3 months after second implantation, which consisted of a complete vestibular clinical evaluation, horizontal canal testing, and otolithic function testing. Clinical evaluation included medical history, short neurological examination and observation of the child's balance and eye movements. Horizontal canal function was assessed through vestibulo-ocular reflex (VOR) using videoscopy, Halmagyi's clinical head thrust test, and bicaloric irrigation. Otolithic function was evaluated by vestibular evoked myogenic potential (VEMP) testing with tone bursts.

2.1. Caloric testing

Most patients were exposed to alternate bithermal caloric stimulation, which consists of irrigation of each ear during 30 s at 30 °C and at 44 °C. A limited number of patients had insufficient cooperation and received a monothermal caloric stimulation instead. Moreover, patients suspected to be areflective underwent ice-water irrigation to confirm their vestibular status.

After irrigation, eye movements were observed during 30 s by videonystagmoscopy while the patient lay in supine position with the head at a 30° angle relative to the horizontal plane to put the horizontal semicircular canal in a vertical position.

Results were classified in 4 categories: normal, weak, elevated or no responses.

For a bithermal caloric irrigation, we used Jongkees' formula and defined unilateral canal paresis as a result higher than 20% [13].

When a monothermal stimulation was used, unilateral weakness was determined by the following formula:

$$UW\% = \left\{(R30 - L30)/(R30 + L30)\right\} \times 100$$

The cut-off value is 27% for cold stimulation [14].

2.2. VEMP testing

Vestibular evoked myogenic potentials were recorded using standard auditory brainstem response (ABR) equipment and 500 Hz tonebursts at 74 dB nHl intensity via bone conduction. The potential was recorded ipsilaterally using surface electrodes. Every set of 100 stimuli was averaged and the procedure repeated twice to confirm the reproducibility. Contralateral head turn was used to activate the sternocleidomastoid muscle contraction.

Considering that the first generation EMG monitoring used in this study could not monitor the contraction level for each stimulation separately (biofeedback), we therefore decided to interpret responses as either present or absent, without mentioning VEMP amplitudes and latencies. As thresholds could not be measured for every patient, they were excluded from our results.

Based on the observed responses to these tests, we defined 3 categories of patients and we compared their vestibular status before and after second implantation:

- areflective patients who showed a catch-up saccade at the clinical Halmagyi test, no VOR responses on the rotary chair and no responses to caloric and VEMP testing;
- hyporeflective patients who displayed either a weak response to caloric testing with normal VEMP testing or an absence of VEMP responses with a normal or weak response to caloric testing.
- normal patients when responses to canal and otholithic tests were in the normal range.

2.3. Data analysis

Statistical analysis of the data was performed using GraphPad Prism software. Categorical variables were expressed as