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Preliminary results of video Head Impulse Testing (vHIT) in children with cochlear implants

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ABSTRACT

Objective: To evaluate the lateral semicircular canal high frequency vestibulo-oculomotor reflex (LSC HF VOR) in children with cochlear implant.
Methods: 16 children (10 females and 6 males, age range = 5–17 years) receiving a unilateral (n = 12) or a bilateral (n = 4) cochlear implant were included and compared to a control group of 20 age-matched normal-hearing (NH) children. Both implanted and NH children received a vestibular function test battery, including a Vestibulo-Ocular Reflex (VOR) gain assessment by means of a video-Head Impulse Test (vHIT), which represented the main outcome measure. In implanted subjects, vHIT was measured on both sides in the "CI-ON" and "CI-OFF" conditions.
Results: Overall, no significant LSC HF VOR gain difference was found between CI users and NH peers. In the unilaterally implanted group, the LSC HF VOR gain measured in the "CI-ON" condition was significantly higher than in the "CI-OFF" condition, both in the implanted and in the non-implanted ear. In the bilaterally implanted group there was no such a difference between the two conditions, on either side.
Conclusion: This is the first study investigating the LSC HF VOR gain in children with unilateral and bilateral CI. The study demonstrates that the LSC HF VOR of bilaterally implanted children is comparable to normal hearing children.

1. Introduction

Cochlear implants (CIs) restore hearing in adults and children affected by profound deafness. In early-treated congenitally deaf children, they allow a near normal development of speech understanding and production abilities.

Over the last years, concerns have arisen that CI surgery and CI electrical activity may negatively affect vestibular function, both in adult [1] and child recipients [2], by disrupting the delicate endolabyrinthine microenvironment. According to these speculations, bilateral CI surgery could impair the function of both vestibular labyrinths and cause a bilateral vestibular deficit, with severe implications on balance, postural control and daily life activities.

However, these studies do not seem to be consistent with routine clinical practice, where children's balance and neuromotor development is hardly ever affected by CI surgery.

Assessing the effect of CI on the vestibular function of pediatric subjects can be a challenging task because of poor cooperation, lack of normative data and frequent pre-operative vestibular impairment due to the underlying cause of deafness. The video-Head Impulse Test (vHIT) is a simple bedside test that allows evaluation of lateral semicircular canal (LSC) function, as well as the vertical canals, at high frequency stimulation (HF) with high efficiency also for children [3–5]. Its outcome measure is the HF Vestibulo-Ocular Reflex (VOR) gain, i.e. the ratio of eye velocity to head velocity, which in a perfectly functioning vestibular system is "1" for constant gaze during head rotation. Healthy subjects typically have a HF LSC VOR gain between 0.8 and 1.2 according to the normative data [6].

The aim of this observational, cross-sectional cohort study is to assess lateral semicircular canal (LSC) function in pediatric CI implant users, and to compare it to a control group of normal hearing (NH) children.

The study hypothesis is that cochlear implantation in pediatric age does not affect HF LSC VOR negatively, and is therefore a safe procedure as far as LSC function is concerned.

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2. Materials and methods

2.1. Ethical considerations

The procedures followed were in accordance with the ethical standards of the Institution's Review Board and with the Helsinki Declaration. Parents of all included children gave their written informed consent to participation in the study.

2.2. Study population

Patients were enrolled with the following inclusion criteria:

- ➢ Pediatric age (<18 years);
- ➢ Absence of inner ear malformations/ossification as assessed by pre-operative CT scan and MRI;
- ➢ Parents' willingness to participate in the study.

2.3. Procedures

Both implanted and NH children received a vestibular function test battery, including:

- Basic bedside vestibular examination by means of Infrared Goggles System: spontaneous Nystagmus; positional Nystagmus (left and right side, supine); positioning nystagmus (Dix-Hallpike maneuvre, Roll-supine test); Head-Horizontal Shaking nystagmus;
- Basic Bedside balance evaluation: Stretched arms test; Romberg test; Unterberger Fukuda test;
- High frequency stimulation of Horizontal Vestibulo-Ocular Reflex (HF VOR) gain assessment by means of a vHIT, which represented the main outcome measure because of its feasibility in implanted children and high sensitivity in detecting canalar function [4,5]. In implanted subjects, vHIT was performed on both sides and in the "CI-ON" and "CI-OFF" conditions.

The vHIT was administered using ICS Impulse, GN Otometrics A/S, Denmark [technological characteristics: Inputs Head: 9 Axis Motion Sensor; Inputs Eye: Monocular (Right eye only); Sampling Rate: 250 fps – Impulse; Eye Tracking: 100 × 100 pixels - Impulse; OTOsuite® Vestibular software: Windows Graphical User Interface; High Performance Analysis Software; Database; Storage of Test Data; Sophisticated Patient and Test Data Management; Vision Denied for Testing in Complete Darkness; Patient calibration: Goggles have 2 built-in calibration lasers]. Subjects were seated 1 m from a visual target mounted at eye level on the wall. The examiner stood behind the participant and delivered randomized (timing and direction) head impulses (100°/sec to 250°/sec peak head velocity) in the plane of the lateral semicircular canal, until approximately 20 acceptable head impulses were recorded. Responses were considered in terms of gain (eye velocity/head velocity), which was automatically calculated by the device software by dividing the area under the curve for eye velocity (with reset saccades removed) by the area under the curve for head velocity [7].

2.4. Statistical analysis

A Kolmogorov-Smirnov test was run in order to verify the normal distribution of continuous variables. In order to compare outcome variable changes within and between groups, both Student's *t*-test and two-way repeated-measures ANOVA (where possible) were conducted, the latter with Greenhouse-Geisser's sphericity correction for epsilon values < 0.75. Significance was accepted for *P* values < 0.05. The Medcalc® statistical software v12 (MedCalc Software bvba, Marienkerke, Beligum) was used.

3. Results

The CI group consisted of 16 patients, 10 F and 6 M, aged 5–17 years (mean age 10 ± 4 years), receiving their first CI at 6 ± 4 years (range = 1–13 years). In this group, 4 patients were implanted bilaterally (3 of them simultaneously and 1 sequentially). Thus, a total of 20 implanted ears were considered. The demographics of implanted children included in the study are detailed in Table 1.

The control group consisted of 20 subjects aged 10 ± 3 years (range = 6–16 years), for a total 40 ears.

Results of bedside vestibular and balance function tests were normal both in the CI group (both CI-ON and CI-OFF conditions and in the non-implanted ear) and in the NH subjects.

First, in order to ascertain that implanted and NH subjects were matched well, LSC HF VOR gain was compared between non-implanted ears in deaf children and all ears in the NH group: the difference was not statistically significant (mean gain in the deaf group = 0.93 ± 0.08, mean gain in the NH group = 0.89 ± 0.07) ($P = 0.2$).

Secondly, in order to assess the effect of surgery, LSC HF VOR gain was compared between implanted and non-implanted ears in the 12 unilaterally implanted children, and the difference was not statistically significant (t = 1.32, $P = 0.2$), as shown by Fig. 1.

Last, the effect of CI switch-on and laterality were assessed by means of a two-way ANOVA model with Bonferroni correction, considering VOR gain in all the 20 implanted ears (12 of the unilateral CI users and 8 of bilateral CI users) as the continuous outcome variable, CI status ("ON" vs "OFF") as within-subject factor and laterality of CI (unilateral vs bilateral) as between-subject factor. Results are illustrated in Fig. 2. While no effect of "laterality" on LSC HF VOR gain was observed [F (1.36) = 0.07, $P = 0.8$)], a significant effect of "CI configuration" was found [F (1.36) = 6.63, $P = 0.01$]; no significant interaction resulted between the within-subject and the between-subject factor ($P = 0.3$). Specifically, in the "CI ON" condition LSC HF VOR gain was higher than with the "CI OFF" condition both in unilaterally (1.02 ± 0.17 vs. 0.89 ± 0.08, $P = 0.01$) and bilaterally (0.97 ± 0.05 vs. 0.92 ± 0.08, $P = 0.08$) implanted children.

4. Discussion

Changes in vestibular function after cochlear implantation have been investigated by several studies in the literature. In adults, changes are reported to occur in 20–40% of cases [1,8,9], while in children the prevalence ranges from 9 up to 50% [2,7,10–12]. This variability seems to be independent from surgical technique [13,14] even though minimally invasive electrode insertion techniques are now considered mandatory also for vestibular function preservation [15,16].

However, as far as pediatric age is concerned data are available mainly for school-aged children and adolescents, due to better cooperation during vestibular examination, while very little is known on implant-related vestibular function changes in younger prelingually deaf babies.

Moreover, most studies report vestibular outcome many years after CI [2,7], so that it is not possible to establish whether the higher prevalence of vestibular dysfunction in CI children as compared to NH ones is an effect of CI or is due to the underlying disease.

Post-mortem temporal bone studies suggest that CI does cause structural damage to the inner ear, including the posterior labyrinth [17,18].

Finally, studied populations generally include both unilaterally and bilaterally implanted children, but numbers are so small that it