Accepted manuscripts are the articles in press that have been peer reviewed and accepted for publication by the Editorial Board of the Vojnosanitetski Pregled. They have not yet been copy edited and/or formatted in the publication house style, and the text could still be changed before final publication.

Although accepted manuscripts do not yet have all bibliographic details available, they can already be cited using the year of online publication and the DOI, as follows: article title, the author(s), publication (year), the DOI.

Please cite this article: VIDEO HEAD IMPULSE TEST IN CHILDREN AFTER COCHLEAR IMPLANTATION


UDC:

DOI: https://doi.org/10.2298/VSP170427093L

When the final article is assigned to volumes/issues of the Journal, the Article in Press version will be removed and the final version appear in the associated published volumes/issues of the Journal. The date the article was made available online first will be carried over.
Title: Video head impulse test in children after cochlear implantation

Authors: *Slobodanka N Lemajić-Komazec, Zoran S Komazec, Ljiljana M Vlaški, Maja M Buljčik-Čupić, Slobodan N Savović, Dunja M Mihajlović, Ivana V Sokolovac,

Affiliations:
1 Faculty of Medicine, University of Novi Sad
2 Clinical centre of Vojvodina, Otorhinolaryngology Clinic
3 Emergency centre of Vojvodina, Department of anesthesia and reanimation

*Corresponding author: Slobodanka Lemajić-Komazec; Clinical centre of Vojvodina, Otorhinolaryngology Clinic, Hajduk Veljkova 1-3, 21000 Novi Sad, Serbia; e-mail: slobodanka.lemajic-komazec@mf.uns.ac.rs
Abstract

**Aim:** Evaluate the lateral semicircular canal function using a high frequency video head impulse test in children after cochlear implantation.

**Methods:** A prospective descriptive study. The study included 28 children (6 - 17 years old) with profound sensorineural hearing loss and unilateral cochlear implant. The control group included 20 healthy children with normal hearing. The measurement of vestibular function of the lateral semicircular canal was performed using video head impulse test. After cochlear implantation, the children underwent vestibular testing. Values vestibulo-ocular reflex of lateral semicircular canal were measured using video head impulse test in children with cochlear implant and control group. Values of vestibulo-ocular reflex were compared between the group of children with cochlear implant and control group. Also, in children with cochlear implant values of vestibulo-ocular reflex were compared between the non-implanted ear and the ear with embedded cochlear implant.

**Results:** All 28 children with sensorineural hearing loss underwent placement of cochlear implant through cochleostomy at an average age of 4.8±2.92 years. Children with cochlear implant had significantly lower gain vestibulo-ocular reflex of the lateral semicircular canal measured by high frequency video head impulse test compared to the control group of children with normal hearing (T test; t= 3.714; p= 0.001). There was no statistically significant difference of gain vestibulo-ocular reflex lateral semicircular canal measured in ears with embedded CI and non-implanted ears (T test; t= 0.419; p= 0.677).

**Conclusion:** Values of gain vestibulo-ocular reflex lateral semicircular canal evaluated by video head impulse test are significantly lower in children with profound sensorineural hearing loss compared to children with normal hearing. Cochlear implants did not appear to have a negative impact on the lateral semicircular canal.

**Key Words:** Cochlear Implantation- Head Impulse Test- Semicircular Canals- Video Recording- Hearing Loss – Child
Sažetak

**Cilj:** Ispitivanje funkcije lateralnog polukružnog kanala upotrebom visokofrekventnog video head impuls testa kod dece nakon kohlearne implantacije.


**Rezultati:** Kod svih 28-oro dece sa senzorineuralnim gubitkom sluha je načinjena kohlearna implantacija kroz kohleostomu, sa prosečnom starošću dece 4.8±2.92 godine. Deca sa kohlearnim implantom su imala signifikantno manju vrednost vestibulo-okularnog refleksa lateralnog polukružnog kanala koji je meren visoko frekventnim video head impuls testom u poređenju sa kontrolnom grupom dece sa urednim sluhom (T test; t= 3.714; p= 0.001). Ne postoji statistički značajna razlika između vrednosti vestibulo-okularnog refleksa lateralnog polukružnog kanala kod ušiju sa ugrađenim CI i neimplantiranih ušiju (T test; t= 0.419; p= 0.677).

**Zaključak:** Vrednost vestibulo-okularnog refleksa lateralnog polukružnog kanala procenjena video head impuls testom je značajno niža kod dece sa dubokim senzorineuralnim gubitkom sluha u poređenju sa decem urednog sluha. Kohlearna implantacija nema negativan uticaj na lateralni polukružni kanal.

**Ključne reči:** kohlearna implantacija, head impuls test, polukružni kanali, video snimanje, gubitak sluha,
Introduction

Cochlear implantation (CI) is a therapeutic modality that provides a sense of sound to children and adults with profound sensorineural hearing loss or deafness (1,2). CI ensures and improves speech development, language perception, cognitive functions, providing children the ability to develop and understand spoken language. Children with profound sensorineural hearing loss often have dysfunctions in vestibular nerve system, which plays an important role in the development of motor function (3). There are more studies that investigated the postcochlear implantation vestibular function in adults than in children (4). The testing of vestibular function in children after cochlear implantation is much more difficult than in adults, due to low cooperation, lack of reference data, and preoperative vestibular damage associated with sensorineural hearing loss (5). CI itself may cause lesions of the vestibular system. The main pathogenetic hypothesis for vestibular dysfunction is the damage of the vestibular receptors during surgical insertion of the electrodes in the cochlea (6). The video head impulse test (vHIT) is a new tool directed to the evaluation of the semicircular and vertical canals, by high frequency stimulation, suitable for pediatric population (7). The vHIT also provides important information about the function of the semicircular canal by the assessment of vestibulo-ocular reflexes (VOR). The gain, vHIT output, is calculated by comparing eye and head velocity during fast horizontal head movements in each of the six semicircular canal planes (8). Children without vestibular symptoms show an average VOR gain from 0.8 to 1.02 (9).

The aim of this study is to analyze by high vHIT, the function of the lateral semicircular canal of the non-implanted ear, in children after CI and to compare the results with the control group of children with normal hearing. The second aim is to define whether cochlear implants affect reduction of the VOR gain of the LSC, ie. compare implanted and non-implanted ears in children after CI.

Material and Methods

Sensorineural hearing loss occurs when there is damage to the cochlea, or to the nerve pathways from the inner ear to the brain. In patients with profound hearing loss threshold is equal or worse than 91 decibels Hearing Level (dBHL) (10). The present study included 28 children with profound sensorineural hearing loss. All children underwent CI. The study was performed in accordance with the ethical guidelines of the 1975 Declaration of Helsinki. Specifically, the study was approved by the Institutions Review Board (Faculty
of Medicine, University of Novi Sad, Serbia). Parents of children involved in the study signed informed consent form prior to participation in the study.

The inclusion criteria were as follows: children with profound sensorineural hearing loss under the age of 18 years, unilateral CI, with normal temporal bone (normal morphofunctional inner ear) and computed tomography evaluation. Children with syndromic pathology were not included in the study.

Methods

A prospective clinical study was performed at Clinical center of Vojvodina, Novi Sad, Serbia, a tertiary health institution, main hospital of Vojvodina region. All 28 children underwent CI surgery performed by one of two oto-surgeons; a standard posterior tympanotomy approach was used and electrode insertion was performed through the cochleostomy made anteroinferior to the round window. Each implanted electrode was placed completely, without resistance or complications. Auditory nerve response telemetry was obtained for each child. All embedded implants were Nucleus Freedom cochlear implant speech processors. The cause of hearing loss in all the patients was unknown. Assessment of vestibular function was by a battery of vestibular tests: spontaneous nystagmus test, dynamo-static and orthostatic tests (Romberg, Unterberger) and Dix-Hallpike maneuver for benign paroxysmal positional vertigo. The evaluation of LSC of VOR was done using high frequency vHIT.

The exclusion criteria were: age over 18 years, children with profound sensorineural hearing loss and syndromic pathology and children with bilateral CI. The control group included 20 children with normal hearing.

Video head impulse test procedure

The vHIT is a test for assessing the function of LSC, described by Ulmer and Chays in 2005 (11). Head impulse test is a passive test using high-frequency head movements, amplitude between 10 and 20°, peak 200°/s, used for testing the vestibulo-ocular reflex of each semicircular channel. The anatomical components of VOR are semicircular canals in the peripheral vestibular system, vestibular and oculomotor nuclei of the brain stem, and the extraocular muscles. The VOR functions to stabilize images on the retinas during head movement by producing eye movements in the direction opposite to head movement. The VOR gain is defined as the ratio of the eye movement response to the head movement.
stimulus (12). The vHIT was measured using ICS impulse type 1085 (GN Otometrics, Taastrup, Denmark) with a small high-speed (~250 frames/s) monocular digital infrared video camera on the goggles (weighing 60 g) recording the movements of the right eye. The eye was illuminated by low level infrared light emitted by the light emitting diode (LED). A small sensor on the goggles measured head movements. Before starting vestibulo-ocular testing, a brief calibration was performed. The testing is done in small, sound- and light-proof rooms, in a sitting position, where the child is looking at an eye-level target at a minimum distance of 1 m in front of it, and activation of the convergence system may interfere with the VOR (12). The head movement velocity is measured by a sensor on the goggles, and high-speed camera is incorporated for superior eye tracking. Each head movement and eye response are simultaneously shown on the screen, so the clinician can see whether the stimulus and the response are adequate (13). The horizontal vHIT stimulus consists of rapid, passive and unpredictable head movements in both directions (the clinician places both hands on the head of the patients, and rotates the head abruptly and unpredictably to the right or left, 20 impulses at random to the right and 20 to the left), whereas every impulse is very short (14). Some authors believe that passive impulses are much more sensitive in the identification of VOR deficit (15). The parameters evaluating LSC vestibulo-ocular reflex are the mean gain (the ratio of the eye movement response to the head movement stimulus).

Statistical data analysis

Statistical data analysis was performed using a software package Statistical Package for Social Sciences - SPSS 21. Quantitative variables were presented as mean values (arithmetic mean) and measures of variability (range of values, standard deviation) and qualitative variables by using frequencies and percentages. The comparison of quantitative variables between the two groups was performed using the Student's t-test. The differences in frequency of qualitative variables were assessed using $\chi^2$ test.
Results

This study included a cohort of 28 children with CI, mean age 12.9±3.09 years (range from 6 to 17 years). On average, the children underwent CI at the age of 4.8±2.9 years. All children were implanted unilaterally. The right ear was implanted in 18, and left in 10 children. All patients underwent preoperative CT of the temporal bone, showing normal morphology of the inner ear, and the cause of deafness was unknown. The control group included 20 children with normal hearing, average age 10.7±4.2 years (from 4 to 16 years).

We found that the results of the vestibular function tests, defined as spontaneous nystagmus, oto-neurological tests, Dix Hallpike maneuver for benign paroxysmal positional vertigo, were normal in children with CI and the control group (Table 1). There was no significant difference in presence of vertigo in children with CI and children in control group (Table 1). However, the children with CI had significantly lower values of LSC VOR gain vHIT compared to the control group: 0.89±0.18 vs. 1.04±0.09 (t= 3.714; p= 0.001) (Figure 1). Statistically significant difference was not obtained (t= 0.419; p= 0.677) for the values of VOR gain vHIT between the implanted (0.91±0.14) and non-implanted ears (0.86±0.26) (Figure 2).

Discussion

The mechanisms of vestibular function damage after CI are still unknown. However, they may be related to a number of etiological factors, as well as trauma caused by electrode insertion, labyrinthitis, perilymphatic postoperative fistula, endolymphatic hydrops, intraoperative perilymph gusher, electrical stimulation of the vestibular implant, benign paroxysmal positional vertigo (16-19). It has been reported that postoperative vestibular damage after CI occurs in 6-80% of adult patients, and in 9-50% of implanted children (4,20,21). Post-mortem histological examination of the cochlea of the temporal bone, showed that CI leads to structural damage to the inner ear, and in particular cochlear hydrops caused by endolymphatic flow obstruction and posterior labyrinth (22). The impact of CI on the postoperative vestibular function is difficult to assess if it was not preoperatively evaluated. Literature describes the vestibular dysfunctions in 30-70% children with hearing loss (4). Although CI affects the vestibular function, after implantation children show rapid compensation of the sensory deficit, and thus the
vestibular damage may not be detected at all (21). This is the reason for discrepancy between subjective symptoms and results of vestibular tests, which are objective.

Vestibular function tests are more difficult to perform in children than in adults, no matter if children have CI or not. So far, only one study evaluated vestibular function (LSC VOR gain) in children after the CI using vHIT. Our results show that LSC VOR gain evaluated by vHIT of the non-implanted ears in children with sensorineural hearing loss was significantly lower compared to the control group. These data can be explained by the fact that in congenital bilateral sensorineural hearing loss, vestibular dysfunction is common, and that it was present before surgery as well. Nassif et al. published the first paper on the examination of LSC high frequency VOR using vHIT in children after bilateral CI and presented different results (5). They found that LSC high frequency VOR gain in 16 children with unilateral and bilateral CI did not differ between the non-implanted ears in children with CI and profound sensorineural hearing loss, and the control group of children with normal hearing. Another important finding of this study is that there was no statistically significant difference in VOR gain high frequency vHIT between implanted and non-implanted ears in unilaterally implanted children with profound sensorineural hearing loss. The same conclusions were reported by other authors, using low-frequency caloric stimulation test in adults after CI (23-25). In their study on children after CI, Nassif et al. (5) also found that there were no statistically significant differences of LSC VOR gain between implanted and non-implanted ears. Migliaccio et al. (26) established that significant vestibular dysfunctions after CI were very rare. Wolter and associates (27) reported different results; namely, children with CI showed significantly more LSC function abnormalities than children without CI.

According to Thierry et al. (21) after CI, 50% of children had normal bilateral vestibular responses, whereas the other 50% showed various kinds of anomalies: unilateral or bilateral vestibular dysfunction, 19% of children had asymmetry of vestibular function on the side of CI, while one third of them had abnormal findings in the contralateral ear. Jutila et al. (28) used a motorized head impulse test after CI and found a significantly lower LSC gain only in 4 patients, of 44 adults with CI in the early and in 2 patients in the late postoperative period; they concluded that high-frequency loss of vestibular function or vestibular symptoms are rare, but possible after CI. Batuesca-Caletrio et al. (13) reported that one third of adult patients with CI had changes in LSC gain. Vestibular function after CI was examined by HIT only in 4 studies (29). Basta and associates found no loss of
saccular function by HIT after CI (30). It is assumed that persistent postsurgical instability may be due to possible co-activation of the inferior vestibular nerve by electrical stimulation.

The literature data show many controversies regarding the impact of surgical approach in CI, through the round window or cochleostomy, on the vestibular function (31). Some Authors believe that electrode insertion through the round window is less traumatic than through cochleostomy (32). Although in our study CI was performed through cochleostomy, it showed no negative effects on the vestibular function.

**Conclusion**

Evaluation of vestibular function lateral semicircular canal by video head impulses test in children is non-invasive, objective method. It is hard to explain the impact of cochlear implant on vestibular function, and findings of vestibular tests do not correlate with subjective symptoms. Results of this study imply that cochlear implant has no effect on reduction of gain vestibulo-ocular reflex lateral semicircular canal measured by high frequency video head impulses test. Cochlear implant is a safe surgical procedure with a low complication rate.

**REFERENCES**


Table 1: Investigated parameters in group of children with CI in comparison to control group

<table>
<thead>
<tr>
<th>Variables</th>
<th>Groups</th>
<th>Children with CI (n=28)</th>
<th>Control group (n=20)</th>
<th>Statistical significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td>12.9±3.09</td>
<td>10.7±4.2</td>
<td>p=0.042</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td></td>
<td>11 (39.3%)/17 (60.7%)</td>
<td>13 (65%)/7 (35%)</td>
<td>p=0.079</td>
</tr>
<tr>
<td>VOR gain vHIT</td>
<td></td>
<td>0.89±0.18</td>
<td>1.04±0.09</td>
<td>p=0.001</td>
</tr>
<tr>
<td>Vertigo</td>
<td>(positive/negative)</td>
<td>1 (3.6%)/27 (96.4%)</td>
<td>0 (0%)/20 (100%)</td>
<td>p=1.00</td>
</tr>
<tr>
<td>Spontaneous nystagmus</td>
<td>(positive/negative)</td>
<td>0 (0%)/28 (100%)</td>
<td>0 (0%)/20 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>Romberg’s test</td>
<td>(positive/negative)</td>
<td>0 (0%)/28 (100%)</td>
<td>0 (0%)/20 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>Unterberger’s test</td>
<td>(positive/negative)</td>
<td>0 (0%)/28 (100%)</td>
<td>0 (0%)/20 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>Dix Hallpike maneuver test</td>
<td>(positive/negative)</td>
<td>0 (0%)/28 (100%)</td>
<td>0 (0%)/20 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>Suppine roll test</td>
<td>(positive/negative)</td>
<td>0 (0%)/28 (100%)</td>
<td>0 (0%)/20 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>Deep Head Hanging maneuver</td>
<td>(positive/negative)</td>
<td>0 (0%)/28 (100%)</td>
<td>0 (0%)/20 (100%)</td>
<td>-</td>
</tr>
</tbody>
</table>

Data are presented as mean± SD (standard deviation) or numbers (n) and percentages (%)

CI- cochlear implantation

VOR vestibulo-ocular reflex; vHIT- video head impulse test

p- statistical significance
Figure 1. Values of LSC VOR gain vHIT between children with CI and the control group

Figure 2. Values of LSC VOR gain vHIT between implanted and non-implanted ears

Received on April 27, 2017.
Accepted on June 27, 2017.