CASE REPORT

Balance versus hearing after cochlear implant in an adult

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SUMMARY
The effect of vestibular rehabilitation (VR) on anxiety, dizziness and poor balance that developed after cochlear implant (CI) surgery is described. A 54-year-old woman, with profound hearing loss since the age of 2 years, underwent right CI surgery 2 years previously. On implant activation, the patient immediately felt dizziness and imbalance, which affected the ability to perform activities of daily living and increased anxiety to where the patient considered the CI removal. Prior to VR the patient was evaluated with the Dizziness Handicap Inventory and the Visual Vertigo Dizziness Questionnaire and clinically with the Zur Balance Scale and Video Head Impulse Test. The patient underwent 14 VR sessions over 4 months that included compensation, adaptation and habituation exercises. After VR the patient was able to maintain good balance while using the CI. Dizziness and anxiety improved dramatically. This report increases awareness that a CI could compromise balance, which can be overcome with personalised VR.

BACKGROUND
A clinical case is presented of a middle-aged woman who encountered a balance disorder on cochlear implant (CI) activation. Since this peculiar phenomenon was also related to vestibular–ocular reflex, we decided to investigate whether a vestibular rehabilitation (VR) programme would improve the patient's situation. A CI is meant to facilitate hearing ability, but in this patient's case it negatively affected balance, forcing the choice of restored hearing with accompanying dizziness or having normal balance control but with attendant hearing loss.

A CI is a surgically implanted electronic device intended to replace the function of damaged hair cells in people with severe-to-profound sensorineural hearing loss. The CI is inserted under the skin behind the ear, with an extension to the cochlea thus bypassing the normal hearing process. It contains a microphone and electronics, which transmit electronic signals to stimulate the cochlear nerve directly.[1 2] Studies have shown that the use of a unilateral CI can improve speech perception and quality of life in adults, and even more so in the case of bilateral implantation.[1 3] The surgical procedure rarely results in major complications, although risks include mastoiditis, otitis media, facial nerve palsy, tinnitus[4] and damage to the chorda tympani. The most common minor complications reported, which can persist up to a few months after the procedure, are vestibular disorders including vertigo and balance impairment. Postoperative side effects of vertigo and imbalance occur in 34% of all CI patients.[5] Stevens *et al* reported that the risk of falls increases postoperatively in 40% of patients who had normal balance prior to the CI and in 56% of all patients.[6] Thus, these particular patients need to choose between improved hearing or balance. Ito reported dizziness in 2 of 80 patients (2.5%) when the CI was activated.[7] Despite these findings, few studies have reported on the effect of rehabilitation interventions to combat these impairments.[5] The objective of this report is to introduce VR as a means of enabling a patient to regain balance when using a CI.

CASE PRESENTATION
The patient provided signed informed consent and the case study was approved by the University of Haifa Institutional Review Board, number 034/17. Since undergoing a right CI procedure, 2 years ago, the patient experienced dizziness and imbalance during the time that the CI was activated. Objective findings revealed a 54-year-old woman, who, due to rubella, had profound hearing loss since the age of 2 years.

The patient had been using two hearing aids and had CI surgery 2 years prior to this report. Previous to the CI surgery, the patient reported no vestibular complaints or balance dysfunction. After surgery, when the implant was activated, the patient immediately experienced dizziness and loss of balance. Due to her dizziness and balance problems, the patient underwent physiotherapy for general balance rehabilitation and readjustments of the CI shortly after the surgery. The surgeon rechecked the placement of the CI, but could not upgrade the signal volume because she did not wear the implant. Therefore, the patient could not proceed with speech–language therapy. All attempts to improve the patient's balance when the CI was activated failed. The imbalance affected activities of daily life and increased anxiety to the point where the patient considered having the CI removed. Vestibular assessment included a battery of oculomotor examinations: spontaneous nystagmus and pursuit and saccadic eye movements to evaluate central vestibular deficit.[8] Clinical examinations included evaluation of peripheral vestibular deficits, the Dynamic Visual Acuity test,[9] Head Impulse Test[10] and the Head Shaking Nystagmus test.[11] The patient also had caloric testing performed. The test results were all consistent with a right vestibular disorder. The patient was offered a gentamicin

injection to destroy the residual function of the auditory canal, which was refused. Finally, the patient was referred to the Israeli Center for Treating Dizziness and Balance Disorders.

INVESTIGATIONS

Questionnaires

Initial evaluation included four standardised questionnaires to assess various aspects of self-perception of dizziness, daily life activities, anxiety and quality of life.

1. Dizziness Handicap Inventory (DHI): The DHI was developed to measure the impact of dizziness on quality of life. It contains 25 questions that cover physical, emotional and functional aspects and effects. Patients answer, 'yes', 'no' or 'sometimes' to each question, which is then scored 4, 0 or 2 points, respectively. The total score ranges from 0 (no handicap) to 100 points (maximum handicap), classifications are: ≤30 points for mild impact, 31–60 for moderate impact and 61≤points for severe impact.[12]
2. Visual Vertigo Dizziness Questionnaire (VV_DQ): The VV_DQ addresses real life activities, which magnify dizziness, and is then used to identify visual vertigo (VV).[13] The patient rates dizziness in nine different situations that include the individual moving in a stationary environment or being stationary in a moving environment.[14] The patient scores each situation as 'never' (0), 'rarely' (1), 'sometimes' (2), 'often' (3) or 'always' (4) disturbs. The questionnaire is considered positive when the patient marks a score of at least 'sometimes' (2) in two or more situations. The total possible score is 40 points.[14]
3. Short Anxiety Screening Test (SAST): The SAST screens adults for anxiety by self-grading somatic sensations in 10 items. The patient rates each item from 1 to 4. The ratings add up to the total score, which ranges from 10 to 40. A higher score means greater anxiety, a score of 24 or higher is considered to be 'severe anxiety' and a score of 22–23 indicates borderline anxiety.[15]
4. The University of California Los Angeles Dizziness Questionnaire (UCLA_DQ): The UCLA-DQ provides quantitative information of the impact of dizziness on a patient's life.[16] It is a short, simple, general, self-report questionnaire for clinical practice and includes only five items that measures five aspects of dizziness: frequency, severity, fear, impact on quality life and impact on activities of daily living (ADL). The patient rates each question from 1 to 5. The result of this questionnaire is divided to two parts: Severity according to the UCLA-S (question 1 multiplied by question 2) and ADL UCLA-E (a combination of questions 1–5). Scores range from 5 to 25 (20%–100%). Higher scores indicate greater severity. The score would be 5 when there is no dizziness at all.[16,17]

Clinical assessment procedures

The patient underwent clinical assessments using the Zur Balance Scale (ZBS)[18] and the video Head Impulse Test (vHIT).[19] The ZBS measures the effects of the three main sensory systems (visual, vestibular and somatosensory). Horizontal and vertical head movements are used specifically to assess the dynamic aspects of the vestibular system. It is short and easily administered. Participants are asked to stand on a firm surface or a half cylinder of Styrofoam, in tandem and Romberg positions. The intratester and intertester reliability Intraclass Correlation Coefficient (ICC) are high.[18] The vHIT is a technique of recording eye movements during head movements (figure 1). It provides information about the gain (ie, ratio) between head and eye movements. A gain below 0.8 is considered a positive outcome, indicating a vestibular deficit. Saccadic eye movements are also recorded, if present.[20,21]

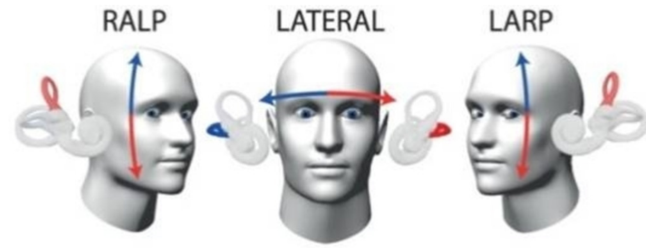

Figure 1 The head movements for left anterior right posterior (LARP), right anterior left posterior (RALP) and lateral semicircular canal stimulation.[18]

TREATMENT

The difference between a VR programme compared with physiotherapy for general balance rehabilitation is based on the patient's clinical, vestibular and balance findings. VR is aimed to resynchronise the physiological visual, vestibular and proprioceptive systems, to organise the sensory information that is communicated to the brain. General balance rehabilitation works mainly on strengthening the proprioceptive and visual systems' input and output, the VR programme emphasises challenging the vestibular system by combining specific head movements with gaze stability exercises intended to reduce dizziness and imbalance. The goal was to improve quality of life while using the CI, enable the patient to proceed with hearing and speech–language therapy, and to maintain balance. Therapy sessions were held initially two times a week and were gradually reduced to once a week, and then once every 2 weeks, as signs and symptoms improved. The patient underwent 14 sessions over 4 months. Each therapeutic session lasted approximately 30 min. As the patient progressed and improved, activities and exercises were given for in-home training. Activities and exercises included static and dynamic standing balance exercises with varied foot positions and bases of support, with eyes open or closed and head movements (separate or combined). The exercises were integrated with alternating optokinetic stimulation, visual and vocal stimulation, while walking indoors and outdoors in various environments such as stairs, busy streets and shopping malls.

OUTCOME AND FOLLOW-UP

Before VR, the patient exhibited more corrective saccades (eye movements) per head movement, when the CI was activated than when it was off. Fewer corrective saccades indicate a better vestibular ocular reflex(ie, high gain or gain close to 1.0). After VR, there were fewer corrective saccades per head movement when the CI was activated (figure 2) indicating improvement in the patient's vestibular function (higher gain). The scores from the four questionnaires before and after VR are shown in figures 3 and 4. All questionnaires indicated significant ($p<0.05$) improvement after VR. Figure 3 demonstrates that VR significantly improved self-perceptions of dizziness based on DHI. The outcomes of the DHI subcomponents demonstrate that the scores in the functional, emotional and physical components improved after VR; functional from 36 to 10, emotional from 32 to 2 and physical from 20 to 6 which indicate 72.2%, 93.8% and 70% improvement, respectively. Figure 4 demonstrates the

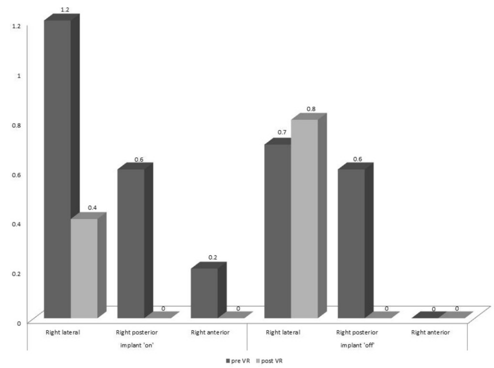

Figure 2 Corrective saccades eye movements demonstrating the right ear semicircular canals with the cochlear implant activated (left side columns) and deactivated (right side columns), before vestibular rehabilitation (VR) and after VR.

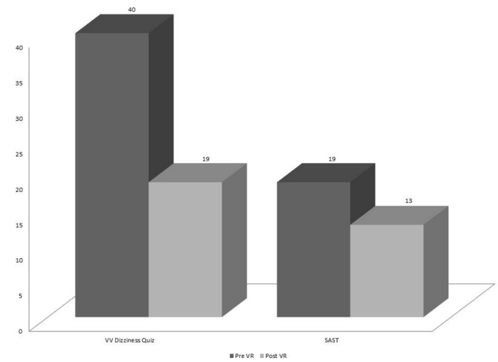

Figure 4 Visual vertigo (VV) dizziness and Short Anxiety Screening Test (SAST) questionnaire results before and after vestibular rehabilitation (VR).

effect of VR on VV. It measures 10 different situations related to the CI 'on'. Before VR, the patient scored the maximum of 40 out of 40 points with all 10 situations that effected ADL at the maximum score each, while after VR she scored only 19 out of 40, with nine situations that effected ADL at half of the maximum score. The anxiety level (SAST) score was 19 out of 40 points before VR and 13 points after VR.

The ZBS results show differences in the patient's ability to maintain balance before and after VR when the CI was activated or not (figure 5). Before VR when the CI was activated, the ZBS score was 80% and after VR it improved to 93%. The ZBS score before VR was 94% when the CI was off and after VR, 96% when the CI still off.

DISCUSSION

This case study concerns a patient who underwent VR for intractable vertigo, dizziness, quality of life and anxiety after a CI. Due to the subjective nature of her complaints, subjective tests were used to evaluate her anxiety and quality of life before and after VR treatment. These included the DHI, VV_DQ, SAST and UCLA_DQ. We also needed to evaluate her subjective complaints with objective examinations. As her situation was very sensitive and complicated, we had to obtain enough objective information before treatment to be able to assess the changes due to VR. The ZBS and vHIT evidence-based objective tests were used to evaluate her vertigo and imbalance.

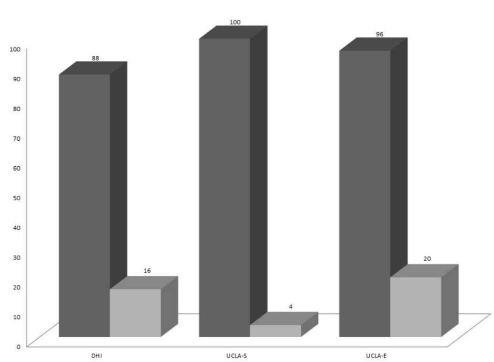

Figure 3 Dizziness Handicap Inventory (DHI), University of California Los Angeles (UCLA) Dizziness Questionnaire-S (question 1 multiplied by question 2) and UCLA Dizziness Questionnaire-E (a combination of questions 1–5) before and after vestibular rehabilitation (VR).

The DHI general score before VR (88%) was high, which taught us about the patient's struggles with dizziness in her daily life. While looking at the different components of DHI before VR, we see that the functional aspect (36%) was the most difficult for her, followed by the emotional aspect (32%) and the physical aspect (20%). The patient was suffering from a mismatch problem in demanding environments when the CI was activated. The sensory confusion (between vestibular, visual and somatosensory) that was found during the CI 'on' had a larger effect on the patient's functional and emotional states than on the physical aspect. Comparing the general and the three component scores of the DHI after VR (16% in the general test), we see that the emotional aspect underwent the most improvement (93.8%), followed by the functional and physical aspects, which improved greatly as well (72.2%, 70%, respectively) post-treatment. From this, we can assume that the high DHI score before VR was directly due to the patient's sudden loss of ability to perform daily activities after the CI surgery and the emotional impact this had on her. The UCLA_DQ scores support the DHI scores and demonstrate great improvement in her severity and quality of life (figure 3).

Although the SAST score was below the anxiety threshold before VR, it improved 27% after VR. It shows that VR also improved anxiety, which is well documented among vestibular patients without a CI.[22–24] The VV-DQ was positive for VV before and after treatment, but by looking at the patient's individual scores and by adding the scores of each question, we see that the frequency of symptoms decreased, which can also explain the improvement in her quality of life. Before VR, each of the 10 visual stimulation situations that caused her symptoms were marked the maximum score of 4 ('always'), after VR she

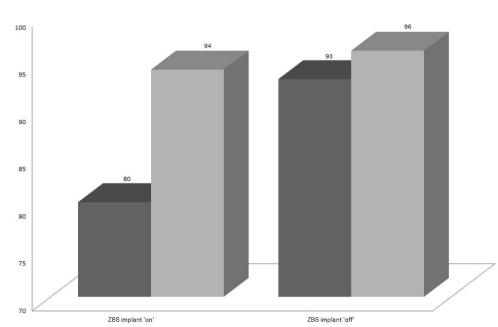

Figure 5 Zur Balance Scale (ZBS) before and after vestibular rehabilitation (VR) with cochlear implant activated and deactivated.

marked nine situations 2 ('sometimes'), and one situation was marked 1 ('rarely').

Despite some redundancy among some of the questionnaires used for this rare and complicated case report, the added value of using a different questionnaire was to get a further validation and a stronger support of the findings. UCLA_DQ scores supported the DHI scores and showed great improvement in both severity and quality of life components (figure 3).

One must also consider that a misdiagnosis can also effect healing after a medical problem or surgery. This patient decided to proceed with a CI 50 years after sustaining profound hearing loss in order to achieve a better quality of life. After surgery, she was left with a new problem. All the doctors she met with to find a solution, determined that the CI surgery was successful and the electrodes were located correctly, as documented with MRI. Thus, 'undiagnosed patient' is an issue that must be considered, in addition to the success of the VR.[25]

CIs enable effective hearing for many patients. The vestibular system is situated in the labyrinth of the inner ear, close to the cochlea. It provides afferent input to the brain about angular and linear acceleration of the head. Erroneous sensory input that is transferred from the vestibular system to the brain is associated with sensory confusion and might affect balance and gaze stability.[4–7] This study reports a rare side effect where the CI affected balance and was associated with dizziness. The problem was reversed by VR. This phenomenon could be explained through 'external' factors and/or 'internal' factors. The 'external' factors relate to the operative procedure, such as the electrodes and the electrical stimulation. In this case, MRI demonstrated that the CI was properly situated in the cochlear organ. The 12 electrodes were calibrated to attain optimal hearing quality, yet the dizziness and imbalance remained. Histological changes such as fasciae adherence, soft-tissue changes and the CI electrical activity are commonly seen after implantation and might result in impaired vestibular function. The relation between the CI and compromised balance could be related to electrical stimulation.[26] The CI contains 12 electrodes providing different hearing frequency ranges. The intracochlear electrodes are close to the temporal bone, and as such, it is possible that one or more of the 12 channels sent electrical pulses through the temporal bone directly to the vestibular system.[27] Bance *et al* did not think this was the reason for dysfunction. However, our patient avoided using the CI because the electrical pulses produced a feeling of 'motion' along with the ability to hear sound before VR.[27] Another possible explanation for the vestibular dysfunction is an 'internal' factor, relating to the interaction of four sensory systems: visual, vestibular, somatosensory and hearing. Maintaining balance is, in part, a function of afferent information from the peripheral labyrinth system that is then processed in the cerebellum, brainstem, hippocampus and other areas of the brain in order to provide gaze and postural stability.[28] When there is a change in this chain, either peripheral or central, it can affect balance. Once a CI is activated, it might add new peripheral input to the brain that requires reorganisation of the information processing system. Melzer *et al*[29] reported significantly decreased balance while performing dual compared with single tasks in both young and older subjects. Shumway-Cook *et al*[30] compared healthy subjects with stability-impaired subjects and concluded that a slight change in cognitive demands for a stability-impaired patient can impact balance. This could explain how the new sensory information from the CI could affect a patient with a damaged vestibular system preoperatively more than it would an individual with a healthy vestibular system. In this case, while preoperative balance tests were not performed, positive postoperative results on the vHIT were found when the implant was activated, and normal balance noted when the CI was deactivated. This may indicate that the vestibular system was already damaged, and centrally compensated before the CI. A slight change in the already impaired system may have resulted in impaired balance. This theory, however, does not correspond with reports, which found that external noise could result in better balance,[31] but those reports were based on studies with hearing subjects whose vestibular systems were not tested.

The results presented here indicate that VR was an appropriate and effective method for treating such a patient. By giving the patient the tools to act and react in synchronisation to different situations, the VR improved her ability to perform ADL and her overall emotional state.

Learning points

- Cochlear implant (CI) usually solves hearing difficulties with minor complications. However, it can have a negative effect on vestibular function, causing dizziness and imbalance.
- CI improves hearing; however, it might compromise vestibular function.
- This rare effect reported after a CI is potentially reversible with vestibular rehabilitation.

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Competing interests None declared.

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