Tr-ENT 2019;29(4):187-195

**Original Article**

# Which approach is better for the protection of vestibular receptors in cochlear implant surgery: Round window or standard cochleostomy?

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***ABSTRACT***

**Objectives:** This study aims to compare electrode insertion techniques in cochlear implantation (CI) as the standard cochleostomy approach (SCA) versus the round window approach (RWA) on five vestibular end-organ functions and vertigo in the pre- and postoperative period.

**Patients and Methods:** In total, 51 patients (22 males, 29 females; mean age 38.2 years; range 16 to 70 years) with normal vestibular function and operated with single-sided CI were included in this study between January 2015 and December 2019. Of the patients, 30 were operated with the RWA and 21 with the SCA. All of the patients were evaluated with the Dizziness Handicap Inventory (DHI) and a complete vestibular test battery including the video head impulse test (vHIT), cervical vestibular-evoked myogenic potential (cVEMP), and ocular vestibular-evoked myogenic potential (oVEMP) at one week preoperatively and one month postoperatively.

**Results:** Patients in the RWA group had a statistically significantly better protected vestibular functions and fewer subjective vertigo symptoms in the postoperative period ($p<0.05$). Deterioration in at least one of the five vestibular end-organ functions was observed in eight of 21 patients (38.09%) in the SCA group, compared to three of 30 (10%) in the RWA group. A significant correlation was detected between the vestibular tests and DHI in both groups ($r=0.686$, $p=0.001$ in the SCA group and $r=0.630$, $p<0.001$ in the RWA group).

**Conclusion:** Our study results suggest that RWA for CI may minimize damage to vestibular receptor functions and vertigo symptoms than SCA.

***Keywords:*** Cervical vestibular-evoked myogenic potentials, dizziness handicap inventory, ocular vestibular-evoked myogenic potentials, vertigo, video head impulse test.

Cochlear implantation (CI) is a safe surgical method for hearing rehabilitation of severe or profound sensorineural hearing loss (SNHL); however, it may also cause postoperative vestibular dysfunction and vertigo.[1-5] In the literature, the reported vestibular receptor dysfunction rate varies from 14.2 to 74%,[5-9] and postoperative vertigo symptoms vary from 9.5 to 49%.[5,10-12] Although the reasons for impairment of vestibular receptor function after

**Received:** December 09, 2019 **Accepted:** January 11, 2020 **Published online:** January 31, 2020

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**Doi:** http://dx.doi.org/10.5606/Tr-ENT.2019.76376

***Citation:***
Dağkıran M, Tuncer Ü, Sürmelioğlu Ö, Tarkan Ö, Özdemir S, Onan E, et al. Which approach is better for the protection of vestibular receptors in cochlear implant surgery: Round window or standard cochleostomy?. Tr-ENT 2019;29(4):187-195.

CI are still unclear, possible causes include trauma due to electrode insertion, intraoperative perilymph leakage, labyrinthitis due to a foreign body, endolymphatic hydrops, and postoperative perilymph fistula.[10,12-16] Histopathological studies have also shown that the cochleostomy site has an effect on the vestibular function.[16]

Currently, there are two techniques which are commonly used for the cochleostomy site: the standard cochleostomy approach (SCA) and the round window approach (RWA). The CI electrode placement into the scala tympani was first described using the RWA, and the SCA was, then, described as an alternative method, particularly in cases where there are difficulties in visualizing the round window.[17] At the present time, the RWA is the method which is more commonly used, since many studies have shown that the SCA can cause damage to the basal structure of the cochlear endosteum, leading loss of residual hearing.[18-20] The RWA is further investigated not only for protection of residual hearing, but also for the preservation of vestibular function. As yet, there is no consensus in the small number of studies in the English literature.[21-24] None of these studies have evaluated the function of all five vestibular end-organs; Therefore incomplete evaluation of the vestibular system has been performed in previous studies. In our earlier study, we used a complete vestibular test battery and investigated the relationship between the Dizziness Handicap Inventory (DHI) and vestibular functions before and after CI.[5]

The video head impulse test (vHIT) was used for all three semicircular canals (SCCs), and the cervical vestibular-evoked myogenic potential (cVEMP) was used for saccule function and the ocular vestibular-evoked myogenic potential (oVEMP) for utricle function. In addition, the DHI was used to evaluate subjective vertigo symptoms. To the best of our knowledge, this is the first study to evaluate all five vestibular end-organs for the effects of the RWA and SCA on vestibular functions. In the present study, we aimed to compare the electrode insertion techniques in CI (SCA versus RWA) and to evaluate their effects on five vestibular end-organ function and vertigo before and after CI.

## PATIENTS AND METHODS

This double-blind, prospective study was conducted at Department of Otorhinolaryngology, Çukurova University, Faculty of Medicine between January 2015 and December 2019. Patients with profound to severe SNHL who did not benefit from conventional hearing aids and underwent single-sided CI for the first time were included in the study. In total, 51 patients (22 males, 29 females; mean age 38.2 years; range 16 to 70 years) were included of whom 30 were operated with the RWA and 21 with the SCA. *Exclusion criteria were as follows:* having preoperative abnormal vestibular test results, having preoperative vertigo symptoms, the presence of abnormal otoscopic findings (e.g., stenosis or adhesive tympanic membrane), and having previous surgery on the operated ear. A written informed consent was obtained from each patient. The study protocol was approved by the Local Ethics Committee of Cukurova University. The study was conducted in accordance with the principles of the Declaration of Helsinki.

One week before CI and at one month postoperatively, all patients were evaluated with the Video Head Impulse Test (vHIT) for anterior, lateral, and posterior SCC functions, oVEMP for utricle function, cVEMP for saccule function, and DHI for subjective vertigo symptoms.

### Surgical technique

All patients were operated by three experienced surgeons. Med-EL synchrony ST + Medium electrode (MED-EL GmbH, Innsbruck, Austria) and Nucleus CI422 with Slim Straight electrode (Cochlear Ltd., Sydney, Australia) branded cochlear implants were used. The main surgical intent was to perform a cochleostomy via the round window. When the round window was unable to be visualized, a promontorial cochleostomy was preferred. In total, 30 patients were operated with the RWA, while 21 patients were operated with the SCA. A minimally invasive surgical approach was followed for all patients. The drill rate was reduced to 5,000 rpm during drilling for cochleostomy in both surgical approaches. An incision was performed at the round window by protecting the membrane, and perilymph was not suctioned. Electrode insertion into the scala tympani was done slowly and carefully without any resistance. The electrode insertion area was sealed with the temporal muscle fascia to prevent perilymph leakage. Systematic and local prednisolone was used in all patients.

## Objective vestibular evaluation

### *vHIT evaluation*

The vHIT was performed to measure the vestibulo-ocular reflex. The ICS Impulse® vHIT system (GN Otometrics, Copenhagen, Denmark) was used. This system utilizes specially designed, very light (60 g) glasses with a computer software to analyze the data recorded. Twenty impulses were performed for each SCC and the average gain value was calculated. Normal values of gain were accepted as 0.8 for horizontal canals and 0.7 for vertical canals. Gain results below these values were considered to indicate a pathological nature.

### *cVEMP and oVEMP evaluation*

The GSI AuderA™ standard auditory brainstem response equipment (Grason-Stadler, Eden Prairie, MN, USA) was used for cVEMP and oVEMP measurements. Tests were performed with an air-conduction tone burst in a quiet room, while the patient was in the sitting position. The electromyographic (EMG) responses of the sternocleidomastoid muscle were recorded ipsilaterally via the surface electrode for cVEMP, while EMG responses of the contralateral eye were recorded contralaterally for oVEMP measurements.

The resulting impedance of the recording electrodes was below 5 k . The acoustic stimulus (95 dB nHL and 500 Hz; rate=5.1/s; rise and fall time=2 ms; plateau=1 ms; duration=5 ms) was delivered through an earphone. The analysis time was 120 ms for cVEMP and 100 ms for oVEMP. The EMG signal was bandpass-filtered in the range 10 Hz to 750 Hz Every set of 100 stimuli was averaged and repeated twice to verify the reproducibility of the response. If an acceptable wave form was seen, oVEMP was considered positive; otherwise, oVEMP was considered negative.

## Subjective vestibular evaluation

### *DHI evaluation*

In previous studies, the Turkish version of the DHI questionnaire has been proven to be valid and reliable for the evaluation of vertigo.[25] It was developed using a translation-back translation method. The Cronbach alpha for DHI total was 0.92. The DHI questionnaire and its aims were carefully explained to each patient, and all were asked to complete it. The test consists of 25 questions including seven physical, nine emotional, and nine functional

**Table 1.** Demographic data of SCA and RWA groups

| | SCA group (n=21) | | | RWA group (n=30) | | |
|---|---|---|---|---|---|---|
| | n | % | Mean±SD | n | % | Mean±SD |
| Demographics | | | | | | |
| Age (year) | | | 39.1±18.682 | | | 37.5±17.844 |
| Gender | | | | | | |
| Female | 12 | 57.1 | | 17 | 56.7 | |
| Male | 9 | 42.9 | | 13 | 43.3 | |
| Right ear | 13 | 61.9 | | 20 | 66.7 | |
| Left ear | 8 | 38.1 | | 10 | 33.3 | |
| Type of electrode | | | | | | |
| MED-EL | 12 | 57.1 | | 16 | 53.3 | |
| Nucleus | 9 | 42.9 | | 14 | 46.7 | |

SCA: Standard cochleostomy approach; RWA: Round window approach; SD: Standard deviation.

questions.[26] Scoring is based on the following answers: "always", "sometimes" or "never", scoring 4, 2, and 0, points, respectively. The maximum score is 100, and the minimum score was 0. A change in the total DHI score above 6 is considered meaningful.[27]

### Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 20.0 statistical software (IBM Corp., Armonk, NY, USA). Categorical variables were expressed in number and percentage, while continuous variables were expressed in mean ± standard deviation (SD) or median (min-max). The chi-square test was used to compare categorical variables between the groups. The normality of the distribution for continuous variables was confirmed with the Kolmogorov-Smirnov test. For comparison of continuous variables between the two groups, the Student's t-test or Mann-Whitney U test was used, depending on whether the statistical hypotheses were fulfilled. For comparison of pre- versus postoperative measurements within the groups, the paired samples t-test or Wilcoxon test was used. A $p$ value of <0.05 was considered statistically significant with 95% confidence interval.

## RESULTS

Demographic data and type of electrode used for the SCA and RWA groups are shown in Table 1 and the causes of deafness are summarized in Table 2. There were no statistically significant differences between the groups in terms of age, gender, left/right ear, brand of implant, and cause of deafness (p>0.05).

Both objective and subjective postoperative vestibular test results were statistically significantly lower in the SCA group, compared to the RWA group (p<0.05). Deterioration in at least one of the five vestibular end-organ functions (lateral SSC, posterior SSC, anterior SSC, utricle, saccule) postoperatively was observed in eight of 21 patients (38.09%) in the SCA group (p<0.003), whereas this was only observed postoperatively in three of 30 patients (10%) in the RWA group (p=0.237) (Figure 1). Postoperative vestibular functions were significantly worse in the SCA group compared to the RWA group (p=0.016).

Preoperative gain results were normal in both groups. The mean postoperative gain for the three SSC functions was significantly lower in the SCA group, compared to the RWA group. Also, the mean postoperative decrease in the gain results was significantly greater in the SCA group for all three SSC functions (p<0.05) (Table 3).

All patients had cVEMP and oVEMP responses in the preoperative tests. The loss of cVEMP response rate in the SCA group after CI was significantly higher than in the RWA group (p=0.039). However, there was no statistically significant difference in the oVEMP responses between the two groups after CI (p=0.637) (Table 4).

**Table 2.** Causes of deafness in the SCA and RWA groups

| | SCA group (n=21) | RWA group (n=30) |
|---|---|---|
| | n | n |
| Unknown | 7 | 9 |
| Genetic | 6 | 8 |
| Meningitis | 5 | 6 |
| Traumatic | 1 | 2 |
| Sudden hearing loss | 1 | 3 |
| Otosclerosis | 1 | 2 |

SCA: Standard cochleostomy approach; RWA: Round window approach.

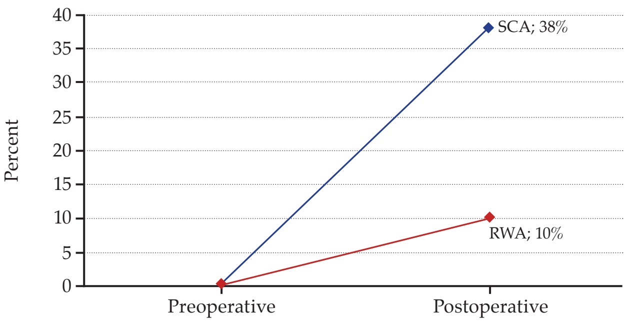


*Figure 1. Rates of postoperative deterioration in at least one vestibular function test in SCA and RWA groups.*

*SCA: Standard cochleostomy approach; RWA: Round window approach.*

 

**Table 3.** Mean pre- and postoperative gain results and decrease in mean gain results of three SCCs

| | SCA group (n=21) | RWA group (n=30) | |
|---|---|---|---|
| SSC | Mean±SD | Mean±SD | *p* |
| Lateral SSC | | | |
| Before CI, mean gain | 0.9±0.1 | 0.9±0.1 | 0.410 |
| After CI, mean gain | 0.8±0.2 | 0.9±0.1 | 0.002 |
| Decrease in mean gain | 0.16 | 0.02 | <0.001 |
| Anterior SSC | | | |
| Before CI, mean gain | -0.9±0.1 | -0.8±0.1 | 0.068 |
| After CI, mean gain | 0.7±0.1 | 0.8±0.1 | 0.099 |
| Decrease in mean gain | 0.13 | 0.02 | 0.004 |
| Posterior SSC | | | |
| Before CI, mean gain | -0.9±0.1 | -0.8±0.1 | 0.933 |
| After CI, mean gain | 0.7±0.2 | 0.8±0.1 | 0.002 |
| Decrease in mean gain | 0.16 | 0.03 | 0.008 |

SCCs: Semicircular canals; SCA: Standard cochleostomy approach; RWA: Round window approach; SD: Standard deviation; SSC: Semicircular canal.

The mean DHI scores in the SCA group were 7.23 before CI and 13.23 after CI (p=0.031). The mean DHI scores in the RWA group were 8.13 before CI and 8.8 after CI (p=0.493). The increase in the mean DHI scores in the SCA group was statistically significant (p=0.029), but not in the RWA group (Table 5). A significant correlation was found between the vestibular tests and DHI in both groups (r=0.686, p=0.001 in the SCA group and r=0.630, p<0.001 in the RWA group).

**Table 4.** Deterioration rates of cVEMP and oVEMP responses in the SCA and RWA groups after CI

| | SCA group (n=21) | | RWA group (n=30) | | |
|---|---|---|---|---|---|
| | n | % | n | % | *p* |
| cVEMP loss after CI | 7 | 33.3 | 3 | 10 | 0.039 |
| oVEMP loss after CI | 3 | 14.3 | 2 | 6.7 | 0.637 |

cVEMP: Cervical vestibular-evoked myogenic potential; oVEMP: Ocular vestibular-evoked myogenic potential; SCA: Standard cochleostomy approach; RWA: Round window approach; CI: Cochlear implantation.

**Table 5.** Mean pre- and postoperative DHI scores in the SCA and RWA groups

| | SCA group (n=21) | RWA group (n=30) | |
|---|---|---|---|
| | Mean | Mean | |
| Before CI, mean DHI standard | 7.23 | 8.13 | 0.466 |
| After CI, mean DHI | 13.23 | 8.8 | 0.220 |
| Difference in mean DHI | 6 | 0.67 | 0.029 |

DHI: Dizziness Handicap Inventory; SCA: Standard cochleostomy approach; RWA: Round window approach; CI: Cochlear implantation.

In both groups, deterioration of the vestibular functions was more commonly seen in the patients older than 60 years. These patients had a 55.6% deterioration rate in the objective vestibular tests, whereas the patients between 18 and 60 years had a deterioration rate of 14.3% (p=0.015). The patients older than 60 years were at 7.5-times higher risk for objective vestibular deterioration (95% confidence interval: 1.56-36.17).

## DISCUSSION

Unlike most of the studies in the literature, our study using a complete vestibular test battery showed that CI patients in the RWA group had better postoperative vestibular functions than those in the SCA group.[22-24] In addition, postoperative DHI scores were statistically significantly improved in the RWA group, compared to the SCA group. Possible reasons for these findings may be that, in the SCA group, there was more trauma caused by drilling, there were more scala vestibuli insertions, and there was a greater damage to the integrity of the vestibular receptors, compared to the RWA group. A study by O'Connell et al.[28] also showed that scala vestibuli insertion in the RWA group was 70% less than in the SCA group.

There is a consensus in the literature that CI has certain effects on the vestibular functions.[1-9,29] The issue concerning the effects of the RWA and the SCA on vestibular functions is still controversial.[21-24] In our opinion, the differing results of these studies are due to not using a complete vestibular test battery. Only the study by Todt et al.[21] showed that a patient's vestibular functions were better protected using the RWA, consistent with our results. Kluenter et al.[22] used the caloric test combined with dynamic and static postural control tests and found no significant difference in the vestibular function between the RWA and SCA. Nordfalk et al.[23] performed cVEMP, caloric tests, subjective visual vertical/horizontal tests, and subjective

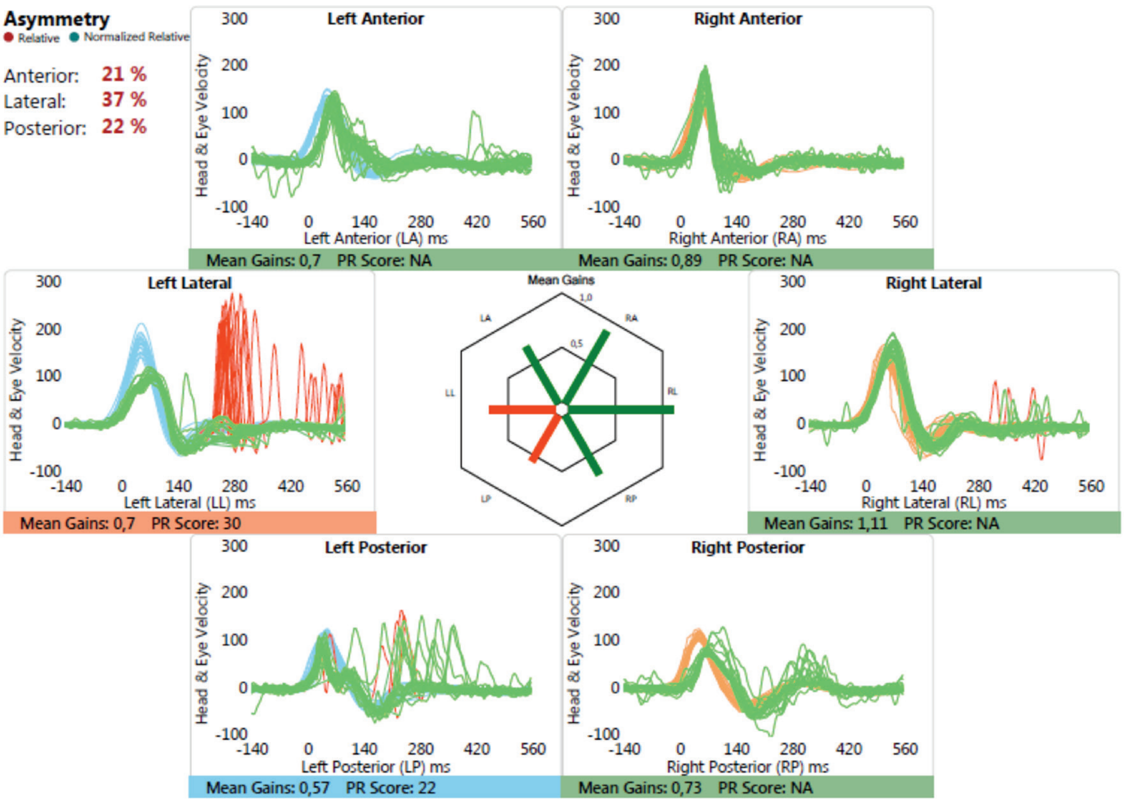


*Figure 2. Video head impulse test results of left ear cochlear implantation in one of the patients. Posterior and lateral semicircular canal gain loss was observed at one month postoperatively.*

 

vertigo assessments before and after surgery and reported that patients with RWA and hearing preservation had more vestibular deterioration, although it did not reach statistical significance. In addition, the aforementioned authors used different electrodes for different groups which might have affected the results. Korsager et al.[24] were the first to use vHIT to evaluate lateral SCC and they were unable to find any difference between the RWA and SCA and no correlation between the objective and subjective tests. In our opinion, these findings are as the superior SCC, posterior SCC, utricle and saccule were not evaluated. All of the previous studies used caloric tests or vHIT to evaluate lateral SCC and neglected the superior and posterior SCC evaluation. In addition, cVEMP was used to evaluate saccule function and the utricle and oVEMP functions were not studied.[21-24]

Our previous study on the effects of CI on vestibular receptor functions showed that horizontal SSC, vertical SSC, utricle and saccule could all be affected.[5] A complete test battery is essential to obtain more accurate results. This prompted us to use a complete test battery to compare the RWA and SCA in our study. We found a deterioration in the functions of all five vestibular end-organs, but only changes in the utricle function were not statistically significant. This can be attributed to the fact that the utricle is more distant to the cochleostomy region than the saccule. Probably, the saccule behaves like a protective barrier between the utricle and the cochleostomy site.

In our study, there was a correlation between the objective and subjective tests, unlike previous studies.[3,9,24] We believe that this is because the test battery is more sensitive, since it evaluates all vestibular end-organs. A vestibular dysfunction can be overlooked, if the test does not evaluate all vestibular receptors in a symptomatic patient; therefore, the result can lead to a false-negative

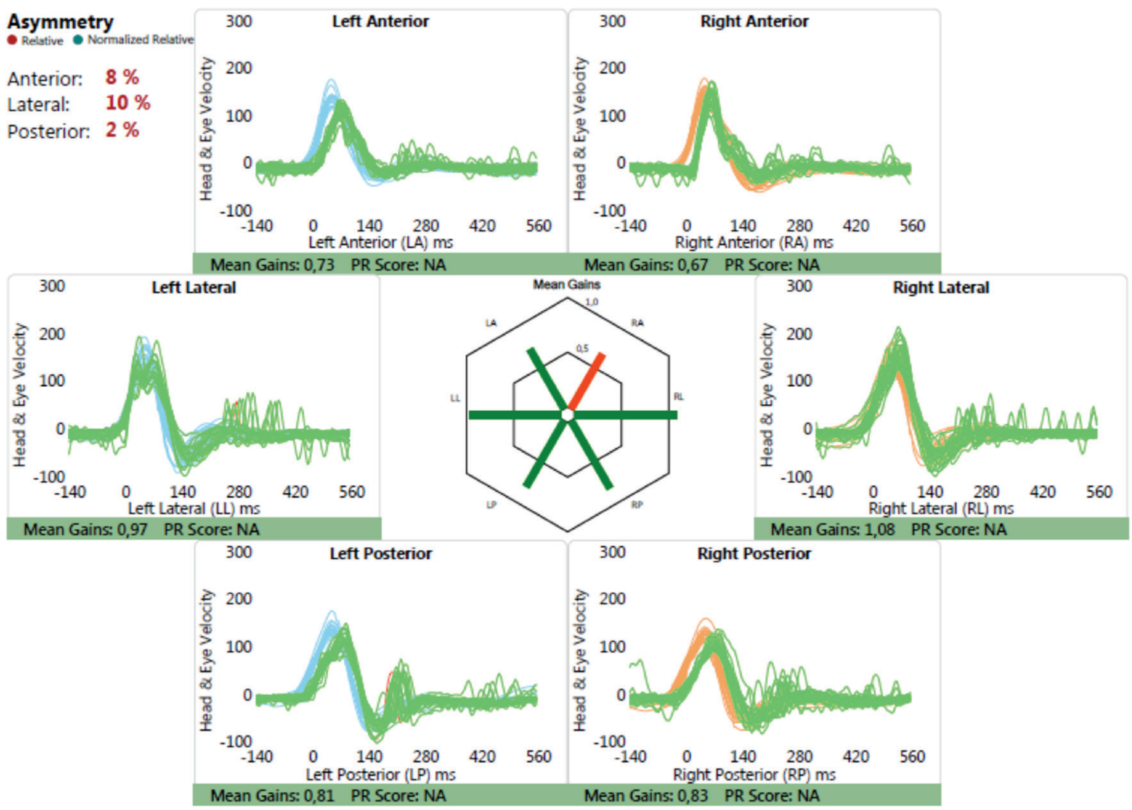


***Figure 3.*** *Results of right ear cochlear implantation in one of the patients. Only anterior semicircular canal gain loss was observed in video head impulse test at one month postoperatively.*

 

diagnosis. In such cases, a correlation the between objective and subjective findings cannot be observed. As shown in Figure 2, the vHIT evaluation in one of our patients showed a loss of gain in both lateral and posterior channels. In Figure 3, the loss of gain was only seen in the anterior channel. If only the lateral canal was evaluated, the loss of gain in the posterior canal in the first patient and the loss of gain in the anterior canal in the second patient would be overlooked, leading to a false-negative result.

In our study, significantly more vestibular deterioration was observed in patients over 60 years of age in both surgical groups, consistent with the literature[30,31] and the risk of vestibular deterioration in this age group was 7.5 times higher than in patients 18-60 years of age. Therefore, the patients over 60 years of age and their relatives should be advised about this.

In recent years, simultaneous or sequential bilateral implantation has been increasingly used. We believe that patients with bilateral implantation or single-sided implantation with vestibular disorders in the contralateral ear should be operated with the RWA. This surgical approach may prevent bilateral vestibular disorder.

Nonetheless, the main limitation of this study is that objective and subjective vestibular tests were able to be performed only one week before CI and one month after CI. We recommend further, large-scale, long-term, prospective studies to confirm these findings.

In conclusion, our study shows that the RWA yields less deterioration compared to the SCA in all five vestibular end-organ functions, except for the utricle in patients undergoing CI. Subjective vertigo symptoms also seem to be less with the RWA and there is a correlation between objective vestibular tests and subjective DHI. Based on these findings, we can speculate that the RWA for CI may minimize damage to vestibular receptor functions and vertigo symptoms.

#### Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

#### Funding

The authors received no financial support for the research and/or authorship of this article.

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