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Vestibular function after cochlear implant surgery

Elif Tuğba SARAÇ[1], **Hüseyin DENİZ**[2], **Şemsettin OKUYUCU**[3], **Ertap AKOĞLU**[3], **Özge BERBER**[4]

[1]Department of Audiology, Hatay Mustafa Kemal University, Hatay, Turkey
[2]Department of Audiology, Gaziantep University, Gaziantep, Turkey
[3]Department of Ear-Nose-Throat, Hatay Mustafa Kemal University, Hatay, Turkey
[4]Department of Ear-Nose-Throat, Kırıkhan State Hospital, Hatay, Turkey

ABSTRACT

Aim: Aim of this study is analyzing the effects of cochlear implant (CI) surgery on vestibular function.

Material and Methods: CI users who had no vertigo complaints pre-op, and who experienced vestibular problems post-op were included in the study group. Healthy individuals who did not have vestibular or hearing problems were included in the control group. The users' peripheral and central vestibular pathways were evaluated with videonystagmography (VNG).

Results: The participants who use cochlear implants and the control group were compared, no statistically significant difference was found between the two groups, except for right saccadic accuracy and saccadic latency parameters in tracking and saccadic tests. In the CI and control groups, spontaneous and head shake nystagmus were not observed, it was determined that the two different implant electrodes did not exert a different effect on the VNG test battery.

Conclusion: Vestibular evaluation in determining the CI side better guides the CI team and can reduce vestibular dysfunction which may occur after surgery.

Keywords: cochlear implantation, vestibular evaluation, videonystagmography, vertigo, oculomotor tests, positional and positioning tests

ÖZ

Koklear implant cerrahisi sonrası vestibüler fonksiyon

Amaç: Bu çalışmanın amacı koklear implant (KI) cerrahisinin vestibüler fonksiyon üzerindeki etkilerini incelemektir.

Gereç ve Yöntemler: Ameliyat öncesi vertigo şikâyeti olmayan ve ameliyat sonrası vestibüler problem yaşayan CI kullanıcıları çalışma grubuna dâhil edildi. Vestibüler veya işitme problemi olmayan sağlıklı bireyler kontrol grubuna dâhil edildi. Periferik ve santral vestibüler yolaklar videonistagmografi (VNG) ile değerlendirildi.

Bulgular: Pursuit ve sakkadik testlerde koklear implant kullanan katılımcılar ile kontrol grubu karşılaştırıldığında, sağ sakkadik doğruluk ve sakkadik latans parametreleri dışında iki grup arasında istatistiksel olarak anlamlı bir fark bulunmadı. Çalışma ve kontrol gruplarında spontan ve head shake nistagmus gözlenmedi, iki farklı implant elektrodunun VNG test bataryası üzerinde herhangi bir etkisinin olmadığı bulundu.

Sonuç: CI tarafının belirlenmesinde vestibüler değerlendirme, CI ekibine daha iyi rehberlik eder ve ameliyat sonrası ortaya çıkabilecek vestibüler disfonksiyonu azaltabilir

Anahtar Kelimeler: koklear implantasyon, vestibüler değerlendirme, videonistagmografi, vertigo, okulomotor testler, pozisyonel testler

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INTRODUCTION

Hearing loss is a frequently seen disorder. It is changed between 1 and 3 every 1000 lives at birth. In cases where hearing aids are not beneficial or sufficient, cochlear implant (CI) surgeries are the standard procedure for the treatment of hearing loss (Sorkin, 2013). Ever since their FDA (food and drug administration) approval in the mid-1980s, CI have become a very effective option for the rehabilitation of hearing. The advancements in technology and changes in surgical techniques (electrode design, surgical methods...) have allowed the expansion of CI guides. So CI surgery is easier recently. However, there are still surgical complications after CI surgery. One of the frequent complications of cochlear implantation after surgery is changes in vestibular function (Gnanasegaram, et al., 2016)

The peripheric vestibular organs give basic information about head movements and orientation. The three semi-circular canals and the two otolith organs perceive rotational and translational movement and contribute to the carrying out of daily activities in which they are involved. Vestibular dysfunction may cause dizziness and imbalance. Bilateral vestibular hypofunction

Correspondence Address/Yazışma Adresi: Elif Tuğba SARAÇ, Hatay Mustafa Kemal Üniversitesi, Odyoloji Bölümü, Hatay, Turkey
E-mail: tugbasarac2901@yahoo.com

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decreases the quality of life in a drastic manner (Agrawal, Pineault, & Semenov, 2018; Dobbels, et al., 2019; Khan & Chang, 2013; T. A. Nguyen, et al., 2016).

Although the effects of CI surgery on residual cochlear function have been studied thoroughly, its effects on vestibular function have not been sufficiently considered. Vestibular influence is a result of the area involved in CI surgery being closer anatomically to the vestibular organ. During or after CI surgery, different mechanisms that might cause vestibular function disorder have been suggested: direct trauma caused by the placement of electrodes, acute serous labyrinthitis due to cochleostomy, reaction to foreign objects in the labyrinth, endolymphatic hydrops, and electrical stimulation.

The most frequently observed reasons for vertigo are traumatic labyrinth damage in the placement of electrodes, foreign object reactions, post-operative perilymphatic fistula, benign paroxysmal positional vertigo (BPPV), and endolymphatic hydrops. Surgical techniques, anatomical structure, and electrode design can cause post-operative vertigo as well (Sosna, et al., 2019; Yong, et al., 2019)

The vestibular symptoms seen after CI usually appear as dizziness and/or imbalance. In general, the symptoms emerge immediately after surgery and decrease shortly after (FDA, 2018; Shoman, et al., 2008). CI users have reported different forms of dizziness after the surgery (beginning time of dizziness, duration of dizziness, how long does it take…) (Katsiari, et al., 2013; Kluenter, Lang-Roth, & Guntinas-Lichius, 2009; Tsukada, Moteki, Fukuoka, Iwasaki, & Usami, 2013). After CI surgery, the etiology of age and hearing loss can also affect vestibular function. The possible effects of CI surgery on the vestibular system should be explained to CI candidates prior to surgery (Ibrahim, da Silva, Segal, & Zeitouni, 2017; Kubo, Yamamoto, Iwaki, Doi, & Tamura, 2001).

All CI candidates should be informed about the CI's possible effects on the labyrinth's function and the clinical symptoms that may arise and accompany these types of functional changes. For bilateral implantation, more careful pre-operative vestibular evaluations should be performed (Kuang, Haversat, & Michaelides, 2015).

Both central and peripheric vestibular pathways in adult patients with sensorineural hearing loss who had been using CI devices for at least 3 months and had undergone unilateral cochlear implantation were examined in this study, as it was aimed at analyzing the effects of CI surgery on vestibular function.

MATERIAL AND METHODS

Ethical approval was granted by the Ethics Committee of Hatay Mustafa Kemal University (05.03.2020/4). All of the participants were asked to sign the voluntary consent form. 15 CI users aged 18-55 and 15 healthy individuals aged 26-45 were included in the study. CI users who had no vestibular complaints prior to the Cı surgery, however experienced vestibular proplems after the surgery were included in the study group. The patients were included in the study group were analyzed at least after 3 months later after surgery. The patients' vestibular complaints after surgery were evaluated subjectively. The average time from surgery to inclusion of this study (to VNG testing) was 13.1 ± 13.2 months. Healthy individuals who did not have vestibular or hearing problems were included in the control group. In order for the tests conducted in our study to not be affected by the age factor, patients over 55 years old were excluded in the study. The electrode was placed to the scala tympani using the round window method in all of the patients. The hearing loss etiology of the users and the CI information that they used are shown in Table 1.

The users' peripheral and central vestibular pathways were evaluated with the VNG device. During the test, the participants in both groups did not have vestibular complaints.

Table 1. The implant characteristics of CI users

	Implant side	Implant type	Etiology	Duration of CI (months)
1st patient	Left	Slim straight	Genetic	42
2nd patient	Right	Slim straight	Idiopathic	6
3rd patient	Right	Synchrony Medium	Genetic	4
4th patient	Right	Slim straight	Chronic otitis	5
5th patient	Right	Slim straight	Genetic	18
6th patient	Right	Slim straight	Idiopathic	6
7th patient	Right	Slim straight	Chronic otitis	4
8th patient	Left	Slim straight	Chronic otitis	3
9th patient	Left	Synchrony Medium	Genetic	25
10th patient	Right	Synchrony Medium	Progressive, idiopathic	3
11th patient	Left	Synchrony Medium	SHL	20
12th patient	Right	Slim straight	SHL	19
13th patient	Right	Synchrony Medium	Genetic	33
14th patient	Right	Slim straight	Genetic	6
15th patient	Right	Slim straight	SHL	8

The VNG measurement was taken with the Genetics Otometrics device (ICS, Denmark). After measuring the distance between the patient and the light bar, the horizontal and vertical planes were calibrated. All of the participants in the study and control groups had the following battery of tests applied: saccadic test, gaze test (right-left-up-down),tracking test, optokinetic test, spontaneous nystagmus, head shake test (active and passive), positioning tests.

In the gaze test, 20-second records were made in both directions (right-left-up-down). In the optokinetic test, a 20°/sec. speed was preferred for the patients to better follow the light. In the dynamic positioning test, the Dix–Hallpike test in both directions (right and left) was carried out. In the static positioning test, the head's 90° eye movements in right and left rotations were analyzed.

Statistical Analysis

Statistical analyses were done with IBM SPSS 22 software (USA). Normal distribution was checked with the Shapiro-Wilk test. The significance level was accepted as $p<0.05$. For the data with normal distribution, the comparison between the groups was carried out with the independent t-test, and the comparison of the data without normal distribution was analyzed using the Mann-Whitney U test.

Pearson correlation test was used to determine whether the age between the two groups was correlated.

RESULTS

Demographic Characteristics

A total of 30 people participated in the study. 15 of the participants constituted the study group as the implant users and 15 constituted the healthy control group. The average age of the participants who used CI was 38.1± 17.1 and the control group's average age was 32.4± 4.7. There were 7 females and 8 males in the study group and 9 females and 6 males in the control group (Table 2). Statistically, a significant difference was not found between the two groups' average ages. In terms of age, both groups were correlated.

VNG Result

Oculomotor tests

When the two groups were evaluated in terms of age, no statistically significant difference was found between the two groups (Table 2). In terms of tracking and saccadic tests, when the participants who use cochlear implants and the control group were compared, no statistically significant difference was found between the two groups, except for right saccadic accuracy and saccadic latency parameters (Table 3).

Table 3. Saccadic and tracking test findings

	CI (Study) average	Control average	p
Tracking right	0.64	0.73	0.314
Tracking left	0.66	0.76	0.254
Saccadic peak velocity right	422.6	429.2	0.781
Saccadic peak velocity left	441.2	438.3	0.901
Saccadic accuracy right	88.6	92.6	0.037
Saccadic accuracy left	86.6	91.8	0.126
Saccadic latency right	200.9	165.6	0.037
Saccadic latency left	188.7	169.5	0.142

The right and left optokinetic tests were done symmetrically in both groups as well. In the CI and control groups, nystagmus was not observed in the right gaze, left gaze, up gaze, and down gaze tests.

Spontaneous Nystagmus, Head Shake Test, Static and Dynamic Tests

In the CI and control groups, spontaneous nystagmus and head shake nystagmus were not observed. In addition, nystagmus was not observed in positional tests and Dix-Hallpike tests in the groups either.

Electrode Type and VNG results

In our study, in which two different electrodes were used, it was determined that the two electrodes did not exert a different effect on the VNG test battery.

DISCUSSION

Numerous complications are related to the restoration of CI hearing, although it is used worldwide. While skin-flap necrosis, wound infection, undesired nerve stimulation caused by erroneous electrode placement, temporary facial nerve paralysis, and meningitis are accepted as major complications, tinnitus, device failure, infection, and vertigo are among the minor symptoms (Farinetti, et al., 2014).Although cochlear implantation has been used as a suitable and effective rehabilitative method for years on those with sensorineural hearing loss(SNHL), it can cause vestibular dysfunction and imbalance, particularly in the early post-operative period. It has been shown in many studies that CI surgery affects the vestibular system, but the data obtained from these studies vary significantly. In extant literature, the rate

Table 2. Demographic characteristics of the participants

	CI (study)			Control			p
	Min.	**Max.**	**Average**	**Min.**	**Max.**	**Average**	
Age	18	55	38.1±17.1	26	45	32.4±4.7	0.222
Gender	Female	Male	Total	Female	Male	Total	
	7	8	15	9	6	15	

of vestibular receptor dysfunction can range between 30–74% (Batuecas-Caletrio, et al., 2015; Dagkiran, et al., 2019; Devroede, Pauwels, Le Bon, Monstrey, & Mansbach, 2016). The frequency of subjective vertigo after CI surgery ranges is between 12-49% (Krause, et al., 2009; Kubo, et al., 2001; Melvin, Della Santina, Carey, & Migliaccio, 2009). This difference might arise due to the test measurement methods used, number of patients, and testing times.

Some patients complain about vertigo after cochlear implantation, which rarely causes long-term vestibular dysfunction. However, these complaints have increased in recent years (Colin, Bertholon, Roy, & Karkas, 2018). In the early post-operative period, while loss of vestibular reception improves over time, it is more possible that loss of saccule function will continue (Dagkiran, et al., 2019). In the morphological study, while morphological changes are seen more frequently in the saccule and utricle, it was determined that they are seen less often in the semi-circular canals (Tien & Linthicum, 2002).

Although we did not find a statistically significant difference in terms of latency and accuracy in the central vestibular pathways, we obtained better results in the control group compared with the study group when the numerical data were analyzed. Although CI does not cause subjective complaints in the long-term, it affects the central peripheral pathways. This can be explained by the anatomical and morphological structure caused by the cochlear implant's presence in the ear for a long time, but the need for histological and morphological studies to prove this remains.

After cochlear implantation, vestibular receptor loss and imbalance are seen more often in the older population. Although early period vestibular function loss tends to improve overtime, there is a risk of permanence, as vestibular function loss is higher in the older population (Dagkiran, et al., 2019). Therefore, this should be evaluated in adults prior to CI and patients and their families should be informed about possible vestibular disorders.

While deciding on cochlear implantation, although vestibular symptoms primarily are ignored, these symptoms should be evaluated as well and should be effective in deciding on cochlear implantation. In the determination of CI side, vestibular evaluation should be given place to as well in cases where it is remained undecided. In terms of decreasing the risk of morbidity or mortality arising from falling due to imbalance in adults – particularly the geriatric population – it is important that vestibular evaluation be done prior to CI.

Slow and pain-free implantation is an effective method in terms of protecting both residual hearing and vestibular functions (S. Nguyen, et al., 2016). In protecting vestibular function, placement of the electrode in the scala tympani is more effective than scala vestibule placement (Coordes, Ernst, Brademann, & Todt, 2013). The vestibular dysfunctions during CI are due to the perilymphatic fluid leak after dislocation between the two scales and the fibrosis that occurs afterward. Therefore, the round-window approach is more protective than cochleostomy (Todt, Basta, & Ernst, 2008). According to findings from extant studies on CI users in the adult population, the monolithic organs and canal functions can be endangered after CI surgery, potentially causing clinical findings such as imbalance, vertigo, and falling post-operatively (Lammers, van der Heijden, Pourier, & Grolman, 2014; Perez-Martin, Artaso, & Diez, 2017; Yong, et al., 2019). After the histopathological analysis, it was observed that the electrodes placed in the scala vestibuli caused vestibular fibrosis, distortion of the saccule membrane, and the formation of new bones and reactive neuroma. In addition, the risk of development of basilar membrane rupture resulting from these histological changes is high (Krause, Louza, Wechtenbruch, & Gurkov, 2010; Louza, Mertes, Braun, Gurkov, & Krause, 2015; Tien & Linthicum, 2002).

One study found that the electrode-placement depth does not cause vertigo or affect vestibular symptoms. The study found that the placement area is more responsible for vestibular dysfunction than placement depth.

The emergence of vestibular symptoms after cochlear implantation depends on the method used for implantation and the trauma experienced by the cochlea and, in turn, neighboring structures during implantation, rather than the electrode type. Therefore, the surgery's effect on vestibular dysfunction after cochlear implantation cannot be denied. Surgical placement of the cochlear implant in atraumatic and slow manner is extremely important in terms of preventing vestibular symptoms.

In our study, all patients were operated on using the slow-round window approach. In all the patients, the electrodes were placed in the scala tympani. This helps explain why the patients did not experience vestibular dysfunction, which originated peripherally or centrally. Since the round-window approach and electrode placement in the scala tympani were used on all patients, the cochleostomy and round-window approaches could not be compared.

The vestibular dysfunctions that take place after cochlear implantation are usually short-term, but late-onset vestibular symptoms can emerge a month later. These usually entail clinical findings similar to the Meniere disease. In such cases, the vestibular dysfunctions that take place after cochlear implantation usually appear as hydrops in the labyrinth after short operations (Fina, et al., 2003; Kubo, et al., 2001). They start a month later because the electrode puts minimal, but continuous, pressure on the basilar membrane (Frodlund, Harder, Maki-Torkko, & Ledin, 2016).

In our study, we did not come across vestibular nystagmus in any of the patients, as the surgical techniques used clinically do not cause nystagmus. Although the minimally invasive techniques used in surgery cause imbalance or vestibular symptoms, they do not cause vestibular damage, which can cause nystagmus.

It is known that straight electrodes protect vestibular function better than flexible electrodes. It was observed that no vestibular complaints were reported a year after cochlear implantation by CI users in whom straight electrodes were used, and that the VNG findings were better when compared with flexible electrodes as well (Frodlund, et al., 2016).

We found in our study that the two different electrode types did not exert an effect on the test results, but that the structural characteristics of the electrodes used were similar. As both of their effects on the cochlea and surrounding tissues are the same, similar results were obtained in relation to the vestibular system. In addition, inequality in the number of electrode types compared can affect research results.

Additionally, some extant studies have argued that the electrical stimulation from cochlear implantation improves abnormal vertical perception, thereby improving vestibular function as well (Colin, et al., 2018; Gnanasegaram, et al., 2016; Yong, et al., 2019).

There are some limitations of this study. These are; we have only 15 adult patients with CI. So there is small number of participants. We used only VNG testing to evaluate ‘peripheral and central vestibular pathways’. However; peripheral and central vestibular pathways are not evaluated with onlyVNG, others test batteries (video head impulse test, vemp, rotary chair) should be used for evaluation these pathways for future studies. In addition, number of participants should be increased.

CONCLUSION

The vestibular symptoms that emerge after cochlear implantation are short-term, with long-term vestibular dysfunction rarely seen. However, there is still a risk of falling and mortality in relation to vestibular dysfunction, particularly in the adult population, which affects their quality of life in this short period of time. Therefore, vestibular evaluation also should be done prior to CI, especially when deciding on which side cochlear implantation is to be performed, if there is indecision about certain patients, vestibular symptoms also can be taken into consideration. In this manner, vestibular evaluation in determining the CI side better guides the CI team and can reduce vestibular dysfunction or imbalance, which may occur after surgery.

Ethics Committee Approval: Ethical approval was granted by the Ethics Committee of Hatay Mustafa Kemal University (05.03.2020/4).

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Informed Consent: All of the participants were asked to sign the voluntary consent form.

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