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Investigating the Effects of Vestibular Rehabilitation on Balance Function in Cochlear Implant Recipients

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ABSTRACT

Background: Cochlear Implantation (CI) is an effective surgical approach to rehabilitate the severe to profound hearing-impaired patients. However, the insertion of CI electrodes into the cochlea may adversely affect vestibular receptors, resulting in vertigo or dizziness. The present study aimed to investigate the impacts of Vestibular Rehabilitation Therapy (VRT) exercises on dizziness symptoms of patients who underwent CI.

Methods: A total of 21 consecutive patients (age range: 28 to 61 years) with profound sensorineural hearing loss undergoing CI operation participated. The VRT therapy plan consisted of a habituation and adaptation exercises in combination with gait and balance exercises. The handicapping influences of dizziness was measured using a Dizziness Handicap Inventory (DHI) scale to measure the level of respondent's performance on physical, emotional, and functional dimensions. Visual Analogue Scale (VAS) was also conducted to assess the severity of dizziness symptoms. The DHI and VAS scales were conducted before VRT and at "one-week", "two-week", and "four-week" following the last rehabilitation session.

Results: A repeated-measure analysis of variance demonstrated a significant decrement and a consequent improvement in DHI scores after vestibular exercises in all emotional, physical and functional domains ($p < 0.001$). We also found that the influence of implanted ear ($p=0.076$) and gender ($p=0.094$) variables on DHI scores were not statistically significant. The mean VAS score was 5.87 ± 2.27 at baseline stage and it reduced significantly during the course of the therapy (second week, 2.02 ± 1.75, $p < 0.001$; and forth week, 1.51 ± 1.29, $p < 0.001$).

Conclusion: The findings of this study showed that vestibular rehabilitation therapy has a positive impact on the symptoms of the patients who underwent CI surgery. These exercises lead to an improvement in balance and postural stability, and a reduction in the self-report measure of handicaps. These findings provide the basis for better pre-operative counseling and postoperative vestibular rehabilitation to CI recipients.

Keywords: Vestibular rehabilitation, cochlear implant, balance function.

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INTRODUCTION

In recent years, Cochlear Implantation (CI) gained greater popularity as a beneficial method for rehabilitation of patients with severe-to-profound Sensorineural Hearing Loss (SNHL)[1,2]. In general, CI is a safe procedure with minimal risk of postoperative disorders. However, the vestibular system is anatomically and phylogenetically connected to the cochlea from the end organ to the central pathways. Then, inserting the CI electrodes into the intra-cochlear fluid may interfere with the vestibular structures and lead to vestibular dysfunction, such as dizziness and balance disorders[3-6]. In addition to the direct injury to the vestibular system, electrical stimulation of the vestibular organs by the inserted electrodes can influence the balance function of CI recipients[7]. Dizziness or vertigo are common complication following CI, and its incidence varies quite widely from 2% to 75%. The types of dizziness reported in the CI literature vary from a gradual sense of unsteadiness or light headedness to immediate, acute attacks of vertigo[8-11]. There are various therapeutic methods to treat dizziness symptoms, including pharmacological, surgical, and vestibular rehabilitation methods. Among these approaches, vestibular rehabilitation therapy (VRT) is now widely used as a non-invasive method in the management of patients with peripheral or central vestibular disorders[12,13]. Previous studies have shown that VRT programs could accelerate the natural process of central vestibular compensation, lead to the elimination of symptoms and earlier return to the usual lifestyle activities. These exercises also reduce the risk of falls, which can have troublesome or sometimes fatal results in people of older age[14-17].

MATERIALS AND METHODS

Participants: A total of 21 patients (age range: 28 to 61 years) who experienced vertigo and dizziness following unilateral CI were included. The etiology of deafness was idiopathic (n=11), meningitis (n=3), head trauma (n=2), autoimmune inner ear disease (n=1), Meniere's disease (n=1) and chronic otitis media (n=3). CI operation was conducted in 62% of patients (n=13) in the right ear. For all patients, the CI electrodes were inserted via a cochleostomy performed anterior to the round window niche. During the operation, no steroid drugs were administered via intravenous, intra-tympanic or intra-cochlear methods. All electrodes were fully inserted in the cochlea and after surgery, insertion of the electrodes array was confirmed by X-ray imaging. Patients with a history of central nervous system disease or orthopedic disorders were excluded. The patients with inner ear anomalies determined on temporal bone Computed Tomography (CT) and magnetic resonance imaging (MRI) were also excluded. The experimental procedures of this study were approved by the ethics committee of the local research committee (Ethics Code: IR.AJUMS.REC.1398.582), which were in complete agreement with the ethical regulations of human studies set by the Helsinki declaration. After the enrolment of subjects and before the beginning of the investigation, objectives and protocols of the study and possible advantages and disadvantages of the treatments were clearly explained to all cases, and then, the participants filled and signed a written consent form on their cooperation in the study.

Experimental Procedures: After taking a detailed case history, and performing a physical and vestibular function assessments, an exercise plan was developed for each patient. The VRT intervention was tailored to each patient's impairments that related to dizziness, oculomotor function, and gait and balance performance. The therapy plan consisted of a habituation (compensatory) and adaptation exercises in combination with gait and balance exercises. Habituation exercises utilize repetitive movement's stimuli. The movements that provoke patients' symptoms are identified and the participant performs these exercises until they no longer respond adversely to the stimuli[13-15]. Adaptation exercises are repeated head and eye movements which assist the central nervous system by adapting to a loss or an alteration in vestibular system input. All patients were asked to perform the exercises 4 to 5 times daily for a total of 25 minutes per day plus 20 minutes of balance and gait exercises. The dizziness handicap inventory (DHI) and visual analogue scale (VAS) were utilized to quantify the impacts of the VRT exercises on vestibular system recovery. The DHI is a 25-item self-report questionnaire to measure the physical, emotional, and functional disability associated with vestibular disturbance. Each question provides a choice of 3 responses: no (0 point), sometimes (2 points), or yes (4 points). The total DHL score range from 0 to 100, with 0 being "no disability" and 100 indicating "significant" self-perceived disability. Patients were categorized as having mild, moderate, or severe DHI scores if they had scores between 0 and 30, 31 and 60, and greater than 60; respectively[18]. The VAS scale was used to evaluate the degree of distress of patients resulted from vestibular dysfunction. For this study, we utilized a 10-cm line oriented vertically with "worst possible distress" corresponding to top of the line (10 score) and "no distress" at the bottom of the line (zero score). The patients were asked to indicate the severity of their symptoms that occurred before and after the therapy course on a 10-cm vertical line.

Statistical Analysis: Statistical analysis was conducted using statistical package of SPSS version 24 (SPSS Inc. Chicago, Illinois, USA). Descriptive statistics were used to characterize the study population (mean and standard deviation, and percentage). Independent t-tests were used to compare continuous variables and Chi-square tests for categorical variables across gender. A repeated-measure analysis of variance was conducted for evaluating changes in DHI and distress (VAS score) across different time points. The value of $p<0.05$ was considered as statistically significant.

RESULTS

A total of 21 CI patients (males: 10; females: 11) participated in this study. The mean age of participants was 44.57 ± 7.52 years. The CI operation was performed in 13 cases (61.90%) in the right ear. For the primary outcome parameter, DHI, we found that total DHI score was improved about 16 points after 2-week and 23 points after 4-week vestibular rehabilitation exercises (Table 1). A repeated measure ANOVA revealed a significant reduction and a consequent improvement in DHI scores after vestibular exercises in all emotional, physical and functional domains ($p < 0.001$). Our results also

Table 1: Comparison of severity of disability DHI before and after vestibular rehabilitation therapy (VRT).

Severity of disability	Before VRT	After VRT	P-value
Normal	0	10	
Mild	8	7	X^2=9.16, p-value=0.01
Moderate	9	4	
Severe	4	0	

Table 2: Comparison of the mean dizziness handicap inventory (DHI) scores at different time points of vestibular rehabilitation therapy (VRT)

	Vestibular rehabilitation phase		
Parameter	Pre-VRT	Post 2-week VRT	Post 4-week VRT
DHI-physical	15.14 (±3.43)	11.62 (±2.33)	7.43 (±2.67)
DHI-emotional	16.86 (±3.97)	11.24(±2.40)	5.90 (±1.94)
DHI-functional	19.05 (±3.50)	14.38 (±3.07)	9.14 (±2.76)
DHI-total	53.87 (±8.53)	38.26 (±5.51)	30.06 (±4.43)

Table 3: Comparison of the mean visual analogue scale (VAS) at different time points of vestibular rehabilitation therapy (VRT)

	Vestibular rehabilitation phase		
Parameter	Pre-VRT	Post 2-week VRT	Post 4-week VRT
VAS score	6.81 (±0.75)	4.52 (±0.60)	2.67 (±0.65)

demonstrated that the effect of implanted ear (p=0.076) and gender (p=0.094) factors on DHI scores were not statistically significant. With respect to the DHI score, 61% (13/21) of patients reported moderate or severe degree of vestibular impairment at the initial visit. However, at the end of the therapy course only 4 patients (19.05%) showed moderate or severe degree of impairment (Table 2). The mean VAS score was 5.87 ± 2.27 at the initial testing and decreased significantly during the course of the VRT (second week, 2.02 ±1.75, $p < 0.001$, and forth week, 1.51 ± 1.29, $p < 0.001$). The VAS scores showed the treatment in 16 patients (76.2%), whereas 5 patients showed no change (23.8%) (Table 3). No statistical difference was observed between age (years), gender (male/female) and laterality of implanted ear (right/left) following the VRT intervention.

DISCUSSION

Cochlear implantation is a common treatment option for patients with severe to profound SNHL. Although CI is considered to be surgically a safe procedure, it could be associated with vestibular function impairments. The recent evidence has demonstrated that implantation may cause trauma through the insertion of the electrodes into the inner ear, which may lead to an intraoperative loss of perilymph, labyrinthitis, perilymph fistula, and/or endolymphatic hydrops. It has been also indicated that the electrode insertion during the surgery may induce the osseous spiral lamina, basilar membrane, and vestibular end-organ lesions[19-25]. Recent evidence has shown that dizziness after CI occurs quite frequently, with a reported incidence among series of between 2% and 60%. The types of dizziness reported in the literature substantially vary ranging from a gradual sense of unsteadiness or light headedness to immediate, acute attacks of vertigo[26-28]. In this study, following two weeks of supervised exercise program, a fast recovery was found in CI patients. We also found a significant reduction and a consequent improvement in VAS and total DHI scores between the second and fourth week of the therapy. Nearly, 84% of the CI recipients showed improvement in their symptoms with respect to both VAS and DHI scores. VRT is an exercised-based designed approach to increase postural stability, to improve dizziness/vertigo symptoms, and to promote activities of daily living. The most important mechanisms of recovery from vestibular disorders are “vestibular adaptation” and “vestibular substitution”. These exercises are supposed to accelerate and improve central compensation via the mechanisms of habituation training, which maximize adaptation of the Vestibulo-Spinal Reflexes (VSR) and Vestibulo-Ocular Reflex (VOR), as well as increase substitution. The current investigation exhibited that the majority of patients had a well-compensated condition so that they reported a fully functional recovery. However, 4 patients (19.05%) described a partial recovery.

CONCLUSION

The findings of this study demonstrate that vestibular rehabilitation has a positive effect on the symptoms of the patients who underwent CI. These exercises lead to an improvement in balance and postural stability, and a reduction in the self-report measure of handicaps.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest on publishing this paper.

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