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Binaural integration abilities in bilateral cochlear implant user

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Abstract

Bilateral Cochlear implants (CIs) improved speech intelligibility, speech perception in background noise, and sound localization in quiet and noisy situations. However, it is unclear whether these advantages essentially result in binaural integration of acoustic stimuli from each ear. In this study, we investigated the effectiveness of binaural integration by bilateral CIs placement using binaural hearing tests and subjective auditory perceptual assessment. A 61-year-old bilateral CIs subject underwent the following four tests: the Japanese Hearing in Noise Test (HINT-J), the dichotic listening test (DLT), the Rapidly Alternating Speech Perception (RASP) test, and subjective auditory perceptual assessment. The HINT-J score was significantly higher for bilateral CIs than for a unilateral CI. However, DLT and the RASP test revealed contradictory results. Subjective auditory perceptual assessment revealed active and bright impressions for bilateral hearing, which were also noisy and strong compared with those for unilateral hearing. The results of this study revealed that bilateral CIs improved speech perception in background noise and an improved auditory impression, although the bilateral integration abilities were not improved. This was probably because the patient was required to combine information from the two ears into a single perception in DLT and the RASP test. More longitudinal data should be collected and analyzed in future studies to evaluate the long-term effects of bilateral CIs.

Keywords: Bilateral cochlear implants; Binaural integration ability; Subjective auditory perceptual assessment

1. Introduction

Several studies have documented the advantages of bilateral cochlear implants (CIs) over unilateral CIs. Bilateral CIs improved speech intelligibility, speech perception in background noise (Ramsden et al., 2005; Litovsky et al., 2009), and sound localization in quiet (Verschuur et al., 2005; Litovsky et al., 2006, 2009) and noisy situations (Kerber and Seeber, 2012). Further, hearing was better with bilateral CIs than with bimodal hearing (CI and a hearing aid) for speech lateralization and for perception of semantically unpredictable sentences in speech noise (Luntz et al., 2014). Then, these advantages of binaural hearing were acquired by the simultaneous and sequential short period implants (Ramos-Macías et al., 2013).

However, it is unclear whether these advantages essentially result in binaural integration of acoustic stimuli from each ear. Therefore, we discuss the binaural benefit of CIs from various objective perspectives.

The binaural hearing tests are typically used as a clinical test to diagnose auditory processing disorder (APD). Behavioral tests most commonly used to diagnose APD are divided into five categories: dichotic speech test, monaural low-redundancy speech tests, auditory temporal processing and patterning tests, binaural interaction tests, and auditory discrimination tests (Geffener and Ross-Swain, 2006). Dichotic speech tests and binaural interaction tests are psychological methods to need to integrate and separate from two ears. We selected two tests among these, dichotic listening test (DLT) and Rapidly Alternating Speech Perception (RASP).

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The DLT involves simultaneous presentation of different stimuli to both ears. Binaural integration method is required to repeat everything that is heard in both ears. Binaural separation method is required to ignore what is heard in one ear and repeat what is heard in the attended ear (Geffener and Ross-Swain, 2006). In other words, DLT is a binaural hearing test to measure binaural integration and separation abilities for each subject. For RASP, sentences are divided into brief segments that are alternated rapidly between the two ears. Subjects are requested to hear segments from both ears as one sentence. This test is also required to integrate the information from both ears as well as DLT. These tests are related to higher central auditory integration abilities. If the bilateral CI user can integrate adequately stimuli from both ears, the user might show good results in these tests. Therefore these findings are thought to reflect the degree of integration from both ears.

Moreover, subjective auditory perceptual assessments are required to discuss subject's psychological aspects. Noble (2010) indicated that self-rating questionnaire can help identify binaural hearing influences and benefits. Using subjective assessment such as the questionnaire, the effect of bilateral CIs can be examined sufficiently. Therefore, it is important to determine using objective and subjective methods.

In this study, we investigated the effectiveness of binaural integration by bilateral CIs placement using binaural hearing tests and subjective auditory perceptual assessment.

2. Methods

2.1. Subject

A 61-year-old man with postlinguistic onset of bilateral profound sensorineural hearing loss participated in the study. The subject underwent CI surgery with CI-24 (Cochlear Ltd.) for the left ear because of a history of deafness since 17 years. CP810 sound processor with ACE strategy was used. The second implant (Concert, Medel Ltd.) was placed 5 years after the first, and the total duration of bilateral CIs use at the time of assessment was 8 months. For the right ear, the subject used OPUS 2 sound processor with FSP strategy. The subject chose different implants on each ear by himself, because the subject thought to try and compare sounds from different devices. However, the subject did not perceive differences between two devices, and had a preference for using actively as bilateral CIs.

The subject received bilateral CIs mapping regularly. The special rehabilitation for binaural integration did not be conducted, but the subject made efforts to use both devices in daily life. Moreover, the subject did not have any neurological disorders and cognitive disabilities.

2.2. Procedures

The subject underwent the following four tests: the Japanese Hearing in Noise Test (HINT-J), the dichotic listening test (DLT), the Rapidly Alternating Speech Perception (RASP) test, and subjective auditory perceptual assessment.

In many countries, the HINT is used to measure the ability to hear speech in the presence of noise. The Japanese version of HINT is used in this study. The test is performed under three noise conditions: 1) noise front (speech and noise both at 0° azimuth) 2) noise right (speech at 0° azimuth and noise from the right side at +90° azimuth), and 3) noise left (speech at 0° azimuth and noise from the left side at 270° azimuth). The stimuli for the HINT-J were 65dBA speech spectrum noise and 20 sentences. The subject was asked to repeat the sentences he heard. In this test, the sentences were varied adaptively with a 1-up and 1-down rule so that the speech recognition thresholds (SRT) yielding 50% correct performance could be measured. The SRT was assessed under three conditions: left CI, right CI, and bilateral CIs. The results of the subject in HINT-J were compared with mean scores of normal hearing persons in previous study (Obuchi et al., 2013).

DLT is a noninvasive technique in which different stimuli are simultaneously presented to both ears to measure binaural integration and separation abilities. The dichotic presentation of verbal auditory stimuli typically yields right ear advantage (REA) indicating left-hemispheric language dominance, when subjects are requested to report what they perceive on each trial. Stimuli used in this study were Japanese two syllable words. During DLT, the subject was specifically instructed regarding the direction of attention: divided attention (listen to stimuli from two ears with same attention) and focused attention (listen to stimuli with focus only on the right or left ear) conditions. The stimuli were presented in a random order. The next stimuli were presented only after the subjects reported what they had heard at the previous instance. The DLT had 40 trials. All normal hearing adults showed the ceiling effects on both ears, because the DLT used by Japanese two syllable words is very easy tests.

For the RASP test, sentence stimuli were divided into 300-ms segments that were rapidly alternated between the two ears. The subjects were instructed to listen and repeat the test sentences. Subjects needed to perceive and integrate the whole sentence. In normal hearing subjects, this sentence is easily understood. The RASP had 5 trials. All normal hearing adults could hear perfectly all sentences of this test.

For these auditory tasks, the subjects were seated in a sound-attenuated chamber. The stimuli presented to the subjects were played on a personal computer (Windows 7) and the subject heard these stimuli through a loudspeaker for the HINT-J and open headphones for the DLT and RASP under the CIs. The stimuli were presented at the most comfortable level. The subject responded orally to the test words or sentences he heard and the answers were checked and scored.

For subjective auditory perceptual assessment, the subject's auditory impression in terms of bilateral and unilateral hearing in daily life was assessed using the semantic differential technique. This technique measures subject's perception with unilateral and bilateral CIs in terms of ratings on bipolar scales defined with contrasting adjectives such as bright-dark, hard-soft, and silent-noisy. The subject is asked to choose where his impression lies on 15 scales between two bipolar adjectives.

We compared the auditory impression of bilateral CIs with that of unilateral CI.

3. Results

Fig. 1 shows the results of HINT-J under unilateral and bilateral CIs conditions. The results of bilateral CIs were better than those of unilateral CI for each noise condition. The scores of the right CIs declined from the left CIs with noise front conditions; however, both did not differ in other noise conditions.

The DLT performances for divided and focused attention are presented in Fig. 2. The score for the left ear was significantly lower than that for the right ear in each attention condition, namely the subject exhibited a significant REA. Usually, normal hearing subjects show ceiling effect for both ears in DLT using word stimuli. However, subjects with bilateral CIs of this study did not show high scores for each ear.

With respect to the RASP results, the subject showed 40% hearing in contrast 100% that is observed in normal hearing subjects.

Fig. 3 shows the results of auditory perceptual assessment in unilateral and bilateral CIs conditions. The subject felt active, lively and bright impressions for bilateral hearing, which were also noisy and strong compared with those for unilateral hearing. The subject felt soft, silent, and unnatural impressions for unilateral hearing.

4. Discussion

Bilateral CIs had better scores than unilateral CI in the HINT-J, and this result was consistent with those of previous studies. However, the scores in the DLT and RASP were considerably low even in the bilateral CIs condition. These results revealed that it was difficult to integrate auditory information from both ears.

A previous study on binaural integration for CI users with unilateral hearing loss and normal hearing demonstrates significantly improved speech recognition under dichotic

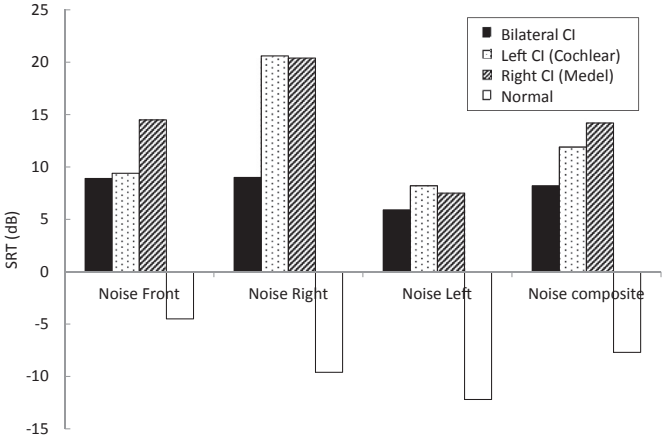

Fig. 1. Results of Japanese Hearing in Noise Test (HINT-J).

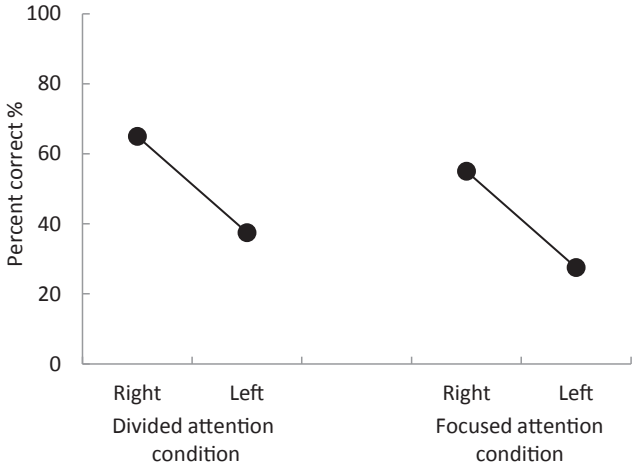

Fig. 2. Results of dichotic listening test.

compared to monotonic listening conditions (Wesarg et al., 2015). The finding of this study indicates that the central auditory system at the brainstem and cortical level can integrate information derived from bimodal input consisting of acoustic stimuli via the normal hearing ear and electric stimuli via the CI ear to auditory units. This study did not examine bilateral CIs, but similarly integrated different information derived from bimodal input.

Bilateral CIs produced positive effects in CI users, but it might take a long time to obtain binaural integration abilities by using bilateral CIs. The subject of this study did not receive the special rehabilitation for binaural integration, but made efforts to use actively both devices in daily life. Therefore, the subject's ability might improve in future. We need to conduct a longitudinal study of binaural integration abilities in bilateral CIs users.

The auditory perceptual assessment revealed the subject's auditory psychological impression for unilateral and bilateral CIs hearing. Unilateral CI produced silent, inharmonious,

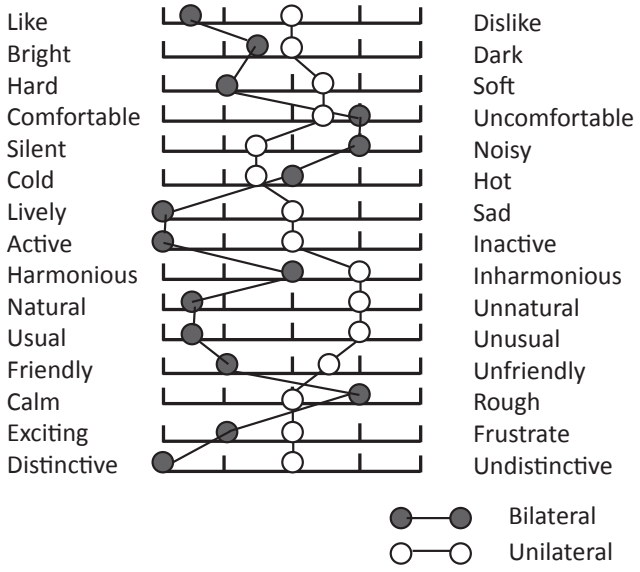

Fig. 3. Results of subjective auditory perceptual assessment.

unnatural, and unusual hearing, and these adjectives had negative impression. However, bilateral CIs produces noisy and rough hearing but lively, active, and distinctive hearing. Bilateral CIs resulted in better impression than unilateral CI. A previous study (Dwyer et al., 2014) using the Speech, Spatial and Qualities of Hearing scale (SSQ) indicated the ratings for bilateral cochlear implant and/or cochlear implant plus hearing aid users were significantly higher than those of the unilateral hearing loss group for speech in quiet, speech in noise, localization, distance and movement, listening effort, and the spatial domain.

From the above, the psychological effects using bilateral CIs were particularly significant. To assess bilateral CI effects, we need to use psychological impression assessment in addition to objective auditory tests.

In the future, it might be necessary to conduct such a study in a large population and we need to verify the findings of this study. Further, binaural integration abilities for bilateral CIs might improve with bilateral CIs use, and we need to examine longitudinal changes of that function.

Conflict of Interest

No funds were received in support of this study.

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