Long-term changes in music perception in Korean cochlear implant listeners

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The purpose of this study was to assess long-term post-implant changes in music perception in cochlear implant (CI) listeners using the Korean version of the Clinical Assessment of Music Perception (K-CAMP) test and questionnaire for music listening. Twenty-seven patients, including 5 men and 22 women participated in this prospective study. Their music perception ability was evaluated with the K-CAMP test which consists of pitch discrimination, melody, and timbre identification. Also, a questionnaire was used to quantify listening habits, and level of musical experience. Median postoperative durations of the first and second test were 12.8 and 30.9 months. Participants were divided into two groups: good or poor performance in the first test with reference to the average of each performance. Among the demographic factors, the good performance group was younger than the poor performance group at the time of the test, and the ability of pitch discrimination decreased with aging at 262 Hz for the first test and at 391 Hz for the second test. Pitch discrimination in the second test in the good performance group showed no difference with the first test, but in the poor performance group, the pitch discrimination score significantly improved. Similarly, timbre test results significantly improved in the poor performance group. In the melody identification test, the two groups showed no change at the second test. Scores for listening habit and level of musical experience significantly decreased postoperatively and did not recover during the follow-up period. The pitch discrimination and timbre identification ability improved in the CI listeners who had poor ability shortly after surgery. However, the ability of melody identification showed no difference in both groups after the lapse of time. Age was related to pitch discrimination and younger people showed good performance. Listening habits and level of musical experience decreased after CI surgery without time-dependent improvement.

INTRODUCTION

While cochlear implants (CIs) are remarkably effective in speech perception, they are less adequate for listening to music. However, music appreciation and perception is quite important in the daily life of CI recipients. Thus, music perception is challenging for CI listeners and the majority of CI users reported music to sound strange, noisy, unnatural, and mechanical. As music is connected with the everyday environment and

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emotional communication, perceptibility of music for CI recipients is related to quality of life and social integration (Gfeller and Knutson, 2003). Efforts to develop technology for music perception are underway, and further researches are warranted to better define the music perception and appraisal in CI users.

Most studies compared the music perception ability of CI listeners with normal-hearing listeners. Adult CI recipients showed poorer results than normal-hearing persons or hearing aid users on recognition of pitch, melody, and timbre except simple rhythmic patterns (Kong *et al.*, 2004; Gfeller *et al.*, 2008; Looi *et al.*, 2008). Regarding rhythmic perception, CI users can perceive simple rhythm patterns as well as normal-hearing listeners (McDermott, 2004; Looi *et al.*, 2012) as their temporal resolution skills are similar to normal listeners. However, CI listeners are definitely poorer on pitch and spectral-based tasks than normal-hearing listeners (Limb and Rubinstein, 2012).

The Korean version of the Clinical Assessment of Music Perception (K-CAMP) test (Jung *et al.*, 2010) is a modified version of the University of Washington's Clinical Assessment of Music Perception (UW-CAMP) test (Nimmons *et al.*, 2008), which consists of pitch discrimination, melody identification, and timbre identification.

A number of studies were conducted to establish the effectiveness of the CAMP test with post-lingually deafened patients. Kang *et al.* (2009) reported a validity and test-retest reliability of the CAMP test. The CAMP test is feasible in a clinical setting because of relatively short test time of about 30-40 minutes and excellent test-retest reliability.

Various literatures proved significant improvement in speech perception ability during the post-implantation follow-up (Krueger *et al.*, 2008; Lenarz *et al.*, 2012). However, there are few evidences which proved the improvement of music perception according to the post-operative periods. In a longitudinal cohort study, Gfeller et al Gfeller *et al.* (2010) revealed modest improvement in familiar melody recognition and recognition of melody excerpts with lyrics (MERT-L) from year 1 to year 2. The suggested predictors of improvement were hearing aid use, bilateral CI use, and musical training experience.

The present study aimed to investigate long-term changes of music perception in post-lingually deafened adult CI listeners using the K-CAMP test after implantation. Also authors evaluated musical listening patterns with questionnaires for listening habits and level of musical experience.

MATERIAL AND METHODS

Patients

A total of 27 post-lingually deafened adults (mean age 49 years at the time of surgery; range from 19.2 to 69.9 years; SD = 12.7) who underwent CI surgery unilaterally at a tertiary referral center between October 2001 and January 2013 were enrolled in this study. CI devices from 3 manufacturers (Cochlear®, Advanced Bionics®, and Med-El®) were implanted. After cochlear implantation, 8 patients were bimodal users. The

K-CAMP test was scheduled to be conducted at annual follow-up visits, and the patients were evaluated at least two times after cochlear implantation. They were also asked to complete a questionnaire to quantify listening habits and level of musical experience. The Institutional Review Board of the Samsung Medical Center approved this study (IRB No. 2010-01-080).

K-CAMP test

Three subtests are comprised in the protocol of the CAMP test, which were pitch discrimination, melody, and timbre identification (Nimmons *et al.*, 2008).

The pitch discrimination test was performed with a one-up, one-down procedure (Levitt, 1971) and two-alternative forced-choice using three base frequencies (262, 330, 391 Hz). The tones were presented at 65 dBA and lasted 760 ms (Nimmons *et al.*, 2008; Drennan *et al.*, 2015) and the test started with a 12-semitone interval. The patient chose the higher pitch between two buttons on computer screen. The threshold was calculated with the mean interval size for 3 adaptive tracks.

The melody identification test used 12 isochronous melodies in a close-set task and the test was finished with 36 presentations. In the K-CAMP test, 10 of 12 melodies were changed into familiar melodies for the Korean population (Jung *et al.*, 2010). Melodies were played with 500-ms duration in an 8-note pattern and a tempo of 60 beats per minute.

The timbre identification test consisted of 24 presentations with 8 musical instruments: piano, violin, cello, acoustic guitar, trumpet, flute, clarinet, and saxophone. Melody and timbre identification were estimated with total percent correct score.

In bimodal listeners, the contralateral hearing aid was removed and the test was performed under a CI-only condition.

Questionnaires

Questionnaires to quantify listening habits and level of musical experience were completed at the same time as the K-CAMP test. Music listening habit inquiries were comprised of 4 items with interest in music before hearing loss and after implantation, mean time of music listening hours per week before hearing loss and after implantation. Answers of music listening habit were graded from 1 to 4 using Likert-type scales. Level of musical experience consisted of 5 yes/no questions prior to hearing loss and after implantation. Responders were asked status prior to hearing loss, including enjoying listening to music, enjoying listening to the radio, visiting indoor or outdoor concerts, attending musical ensembles (e.g., band, choir, or orchestra), and participation in musical lessons. Two different items were inquired instead of the second and third questions, such as difficulty in communicating with background music and difficulty in appreciating unfamiliar music. The answer was to score a ‘1’ if that factor improved musical experience.

Variables		Total (N=27)	Good (N=16)	Poor (N=11)	*p*-value
Age at the operation	Mean (SD), years	49.0 (12.7)	45.3 (11.3)	54.2 (13.1)	0.072*
Age at the 1st test	Median (IQR), years	52.5 (15.3)	48.9 (15.4)	60.9 (20.2)	**0.038**†
Age at the 2nd test	Median (IQR), years	53.5 (15.0)	51.7 (14.8)	63.6 (19.9)	**0.030**†
POD at the 1st test	Median (IQR), months	12.8 (16.4)	12.3 (17.3)	13.3 (12.3)	0.790†
POD at the 2nd test	Median (IQR), months	30.9 (26.0)	33.6 (26.5)	26.7 (26.0)	0.942†
Interval of tests (1st to 2nd test)	Median (IQR), months	18.0 (20.2)	18.3 (19.2)	17.2 (22.0)	0.767†
Gender	Male vs. Female, No. (%)	5 : 22 (18.5 : 81.5)	3 : 13 (18.8 : 81.2)	2 : 9 (18.2 : 81.8)	1.000‡
Final education	Elementary, No. (%)	3 (11.1)	2 (12.5)	1 (9.1)	
	Middle school	4 (14.8)	1 (6.2)	3 (27.3)	0.323‡
	High2 school	14 (51.9)	8 (50.0)	6 (54.5)	
	College	6 (22.2)	5 (31.2)	1 (9.1)	
Duration of deafness	Median (IQR), years	10.0 (15)	7.5 (19)	10.0 (15)	0.618†
CI manufacturer	Cochlear, No. (%)	11 (40.8)	4 (25.0)	7 (63.6)	
		6 (22.2)	5 (31.2)	1 (9.1)	
	Med-El	10 (37.0)	7 (43.8)	3 (27.3)	0.116‡
	Advanced Bionics				
Year of implantation	Before 2008, No. (%)	8 (29.6)	5 (31.2)	3 (27.3)	1.000‡
	From 2008	19 (70.4)	11 (68.8)	8 (72.7)	

Abbreviations. CI: cochlear implant, IQR: interquartile range, POD: post-operative day, SD: standard deviation

* Two-sample t-test, † Mann-Whitney test, ‡ Fisher's exact test

Table 1: Demographic data of patients. Univariate analysis of the good and poor performance group based on the mean of pitch discrimination.

Statistical analysis

Data are expressed as mean ± SD unless otherwise stated. Results were analyzed using SPSS 22 (SPSS, Inc., Chicago, Illinois) using a two sample *t*-test, Wilcoxon's rank sum test or Fisher's exact test, and Spearman correlation analysis with statistical significance set at 0.05.

RESULTS

Demographics

Twenty-seven patients, including 5 men and 22 women participated in this prospective study. Demographic data are shown in Table 1. Median postoperative durations of the first and second test were 12.8 and 30.9 months. Half of the patients (13 patients) completed their first test within one year after surgery. Participants were divided into two groups: good or poor performer in the first test with reference to the average of each performance. Univariate analysis of demographic factors between the good and poor performance group based on the mean of pitch discrimination demonstrated no difference in gender, final education, duration of deafness, CI manufacturer, surgeon, and year of implantation (Table 1). However, the good performance group was younger than the poor performance group at the time of the test ($p = 0.038$ for the first test, $p = 0.030$ for the second test). The ability of pitch discrimination decreased with aging at 262 Hz for the first test ($p = 0.042$, $\rho = 0.765$) and at 391 Hz for the second test ($p = 0.013$, $\rho = 0.473$ by Spearman correlation analysis).

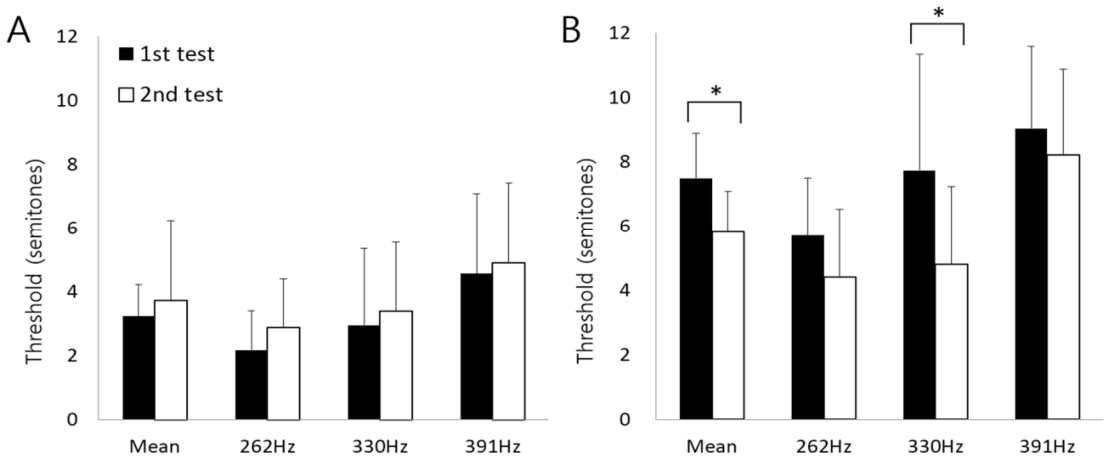

Fig. 1: Average of pitch discrimination: (A) good performance group and (B) poor performance group. * Significance at $p < 0.05$.

K-CAMP scores

Thresholds of pitch discrimination for the first test were 3.61±2.28, 4.90±3.75, 6.38±3.34, and 4.97±2.43 semitones at base frequencies of 262 Hz, 330 Hz, 391 Hz, and on average, respectively. In the second test, thresholds were 3.51±2.23, 3.97±2.53, 6.26±3.02, and 4.58±1.73 semitones at base frequencies of 262 Hz, 330 Hz, 391 Hz, and on average, respectively. Patients were divided into two groups: better or worse than the average performance (4.97 semitones) for analysis. As a

result, pitch discrimination of the second test in the good performance group showed no difference with the first test (p = 0.468) (Fig. 1A), but in the poor performance group, the pitch discrimination score significantly improved (p = 0.005) (Fig. 1B). However, the second test result of the good performance group was 3.73±1.50 semitones which was still better than the poor performance group with 5.81±1.27 semitones (p = 0.001).

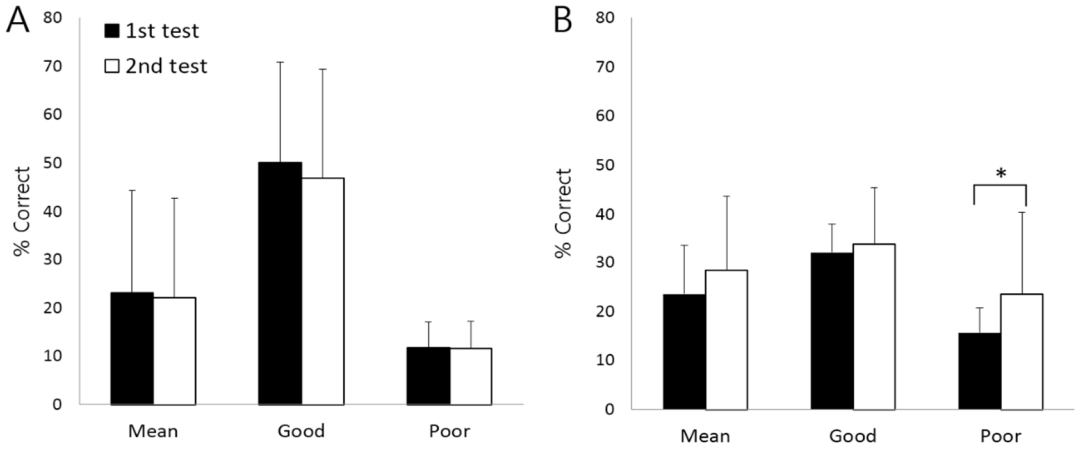

Fig. 2: K-CAMP subtest scores: (A) melody identification and (B) timbre identification. * Significance at $p < 0.05$.

The timbre identification scores of the first and second test were 23.6±9.9% and 28.4±15.2% correct, respectively. Patients were also divided into two groups: better or worse than the average performance (23.55%). Similar to the pitch test, the performance in the timbre test in the poor performance group significantly improved from 15.7±5.1% to 23.5±16.9% correct in the second test (p = 0.029) (Fig. 2B).

In the melody identification test, the average of correct identification was 23.1±21.3% for the first test and 22.0±20.7% for the second test. The patients were also divided into two groups based on the mean performance of the first test (23.1%): good performance group (50.1±20.6%) and poor performance group (11.7±5.3%). In the second test, the melody identification performance changed to 46.9±22.5% and 11.6±5.7%, respectively (Fig. 2A), and the changes were insignificant (p = 0.596).

Questionnaires

Scores for listening habit and level of musical experience significantly decreased post-operatively (p = 0.06 and $p < 0.001$ respectively). In the first and second follow-up tests, these scores did not recover during follow-up periods as shown in Fig. 3.

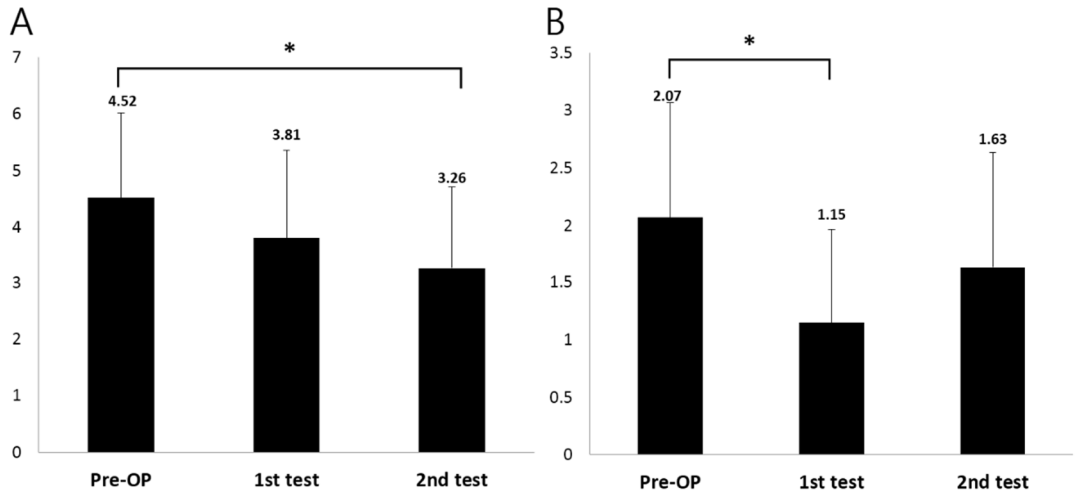

Fig. 3: Questionnaires: (A) listening habits before hearing loss and after implantation and (B) level of musical experience before hearing loss and after implantation. * Significance at $p < 0.05$.

CONCLUSIONS

The pitch discrimination and timbre identification ability improved in the CI listeners who had poor ability shortly after surgery. However, the ability of melody identification showed no difference in both groups after the lapse of time. Age at the test was related to pitch discrimination and younger people showed good performance. Listening habits and level of musical experience decreased after CI surgery without time-dependent improvement.

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