博 士 学 位 論 文

難聴患者における潜在的 EAS 手術適応の割合

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Doctoral Dissertation

Prevalence of potential candidates for electric-acoustic stimulation implant in a hearing-impaired population

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論文題目

Prevalence of potential candidates for electric-acoustic stimulation implant in a hearing-impaired population

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Prevalence of potential candidates for electric-acoustic stimulation implant in a hearing-impaired population

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ABSTRACT

Objective: To estimate the prevalence of potential electric-acoustic stimulation (EAS) implant candidates in a hearing-impaired population through a review of auditory examinations.
Methods: In total, 7356 patients underwent audiometric examination in our department between 2011 and 2014. The prevalence of patients meeting the audiometric criteria for EAS and standard cochlear implant (CI) was assessed.
Results: The percentage of EAS implant candidates meeting the pure-tone audiometric criteria was 0.71% (n = 34) among the hearing-impaired individuals (n = 4758) examined in our department, whereas 2.52% (n = 120) met the criteria for standard CI. Among the 34 EAS implant candidates, 2 individuals (5.83%) received EAS implant surgery after approval of the EAS device in Japan.
Conclusions: There was a lower prevalence of EAS implant candidates than standard CI candidates. Nevertheless, healthcare professionals should carefully examine the audiograms of patients with high frequency hearing loss with regard to meeting the indication criteria for EAS implant. This will enable patients to gain access to adequate information relating to further examinations and treatment options.

1. Introduction

Electric-acoustic stimulation (EAS) implant is an innovative hearing implant device combining functions of cochlear implants (CI) and hearing aids [1,2]. It uses a shorter electrode than standard CI for the preservation of residual low frequency hearing after implantation. The mechanism of EAS is to deliver auditory signals in the low frequency range by acoustic stimulation and those in the middle to high frequency range by electric stimulation. EAS implant is mainly implanted for individuals with a mild to moderate low frequency and severe sloping high frequency hearing loss (SHFHL) [2]. Audiograms indicating EAS implant candidacy are commonly observed in individuals with sensorineural hearing loss, such as presbycusis, and noise-induced hearing loss [3,4].

The indication criteria for EAS implant in Japan with pure-tone hearing levels are demonstrating a ski-slope hearing loss as shown in Fig. 1 [5]. The average hearing level of these EAS implant candidates is usually better than that of standard CI patients. Patients meeting the indication criteria might have been overlooked due to their relatively good average hearing levels. However, these patients may have to tolerate poor speech discrimination because the benefits of acoustic amplification by hearing aids are limited [2,6,7]. Therefore,

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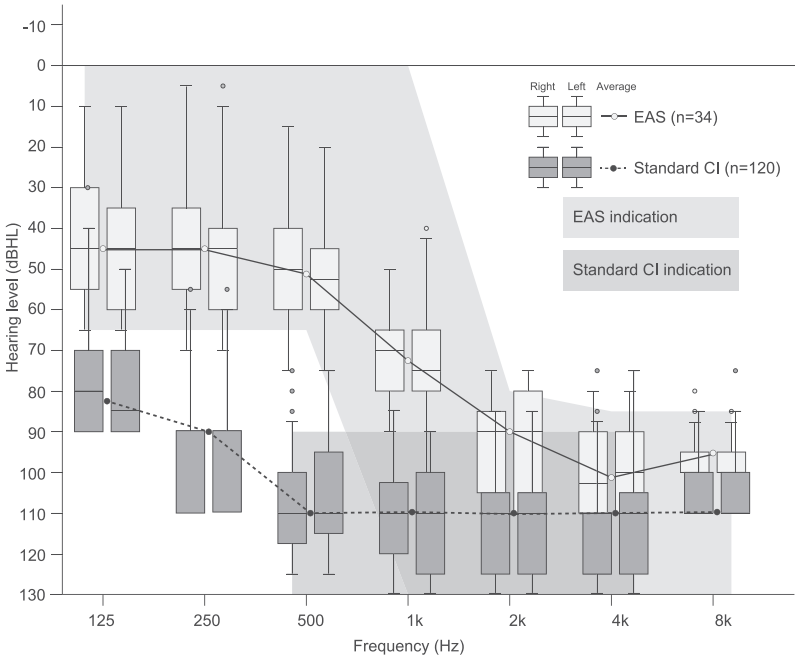

Fig. 1. Pure tone audiometric data of electric-acoustic-stimulation (EAS) implant and standard cochlear implant (CI) candidates. Box plots of the range of pure tone audiometric hearing level (dB HL) of EAS implant and standard CI candidates in each frequency. The averages of right and left ear's median hearing level in each frequency are connected with a solid line in the EAS implant candidates and with a dashed line in the standard CI candidates. The criteria of EAS implant and standard CI are illustrated in the grey area. The bottom and top of the boxes represent the 25th and 75th percentiles, respectively. The solid horizontal line within each box represents the median value. The upper whisker is equal to the minimum of (1) lower quartile minus 1.5 times the interquartile range (IQR) and (2) the minimum observation within the IQR. The lower whisker is equal to the maximum of (1) the 75th percentile plus 1.5 times the IQR and (2) the maximum observation within the IQR.

it is important not to overlook patients meeting the indication criteria and to provide them with adequate information on treatment options. Hence, the prevalence of potential EAS implant candidates in a clinical population is valuable information for healthcare professionals. However, to the best of our knowledge, there have been no detailed reports describing the prevalence of EAS implant in patients showing SHFHL.

This study aimed to estimate the prevalence of potential EAS implant candidates meeting the indication criteria by reviewing all audiometric tests performed in our department.

2. Materials and methods

2.1. Patients

In total, 17,465 auditory examinations were performed on 7356 patients who visited our department between 2011 and 2014. These examinations were conducted to diagnose otologic symptoms (e.g., vertigo, tinnitus, and hearing loss). EAS device was approved by the Japan's Ministry of Health, Labor and Welfare, and was covered by health insurance in Japan from 2014. To avoid including patients who were referred to our hospital specifically for implanting EAS device, we reviewed the data before EAS device approval in Japan. Patients with SHFHL were not intentionally referred to our department at the time. The institutional review board approved the study (29-038).

2.2. Pure-tone audiometry

The patients were examined in a soundproof room, and their hearing threshold levels with air- and bone-conduction were examined by pure-tone audiometry using an audiometer (AA-78, Rion, Tokyo, Japan) and test sounds of 0.125, 0.25, 0.5, 1, 2, 4, and 8 kHz. Maximum sound pressure levels of air-conduction test sounds from the audiometer (AA-78) were set at 70, 90, 110, 110, 110, 110, and 100 dB HL at 0.125–8 kHz. If the patients were unable to hear a certain frequency test sound at the maximum pressure level, the patients were additionally examined with sound booster which maximum sound pressure levels were set at 90, 110, 125, 130, 130, 130, 125, 110 dB HL at 0.125–8 kHz.

At the beginning of the study, individuals were screened for hearing impairment through audiograms of pure-tone audiometry. If they had a hearing impairment, then the audiograms were further analyzed. The worse ear hearing levels of the patients were determined as the averages over a 0.5–4 kHz hearing range, and hearing impairment was defined as worse ear hearing levels $\geq$26 dB in this study, according to the World Health Organization Classification of Deafness and Hearing Loss [8].

2.3. Indications for EAS implant and standard CI in pure-tone audiometry

The indications for EAS implant in Japan with pure-tone hearing levels were: bilaterally better than 65 dB HL at

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0.125 kHz, 0.25 kHz, and 0.5 kHz; worse than 80 dB HL at 2 kHz; and worse than 85 dB HL at 4 kHz and 8 kHz [5], as shown in Fig. 1. The indication for standard CI in Japan, which achieved consensus in the Otorhinolaryngological Society of Japan, is bilaterally worse than 90 dB at an average hearing level over 0.5–4 kHz, also shown in Fig. 1 [9]. The number of individuals meeting the criteria for EAS (EAS implant candidates) or standard CI (standard CI candidates) were selected from the patients with hearing impairment, defined as described in the former paragraph. Both groups of candidates comprised individuals with sensorineural or mixed hearing loss, with a $\leq$10 dB average air-bone gap over 0.5–4 kHz. Individuals with acute onset hearing loss for <3 months; unstable hearing loss with hearing levels fluctuating >30 dB during 3 months; middle and external ear diseases easily improved by simple ear treatment; or psychogenic or functional hearing loss diagnosed by objective audiometry were excluded from the study.

2.4. Indications for EAS implant in speech audiometric tests

The indication criteria for EAS implant in speech perception included <60% correct using the Japanese monosyllable word test (67-S test) presented at a 65-dB sound pressure level with an appropriate hearing aid fitting (both or proffered ear) as the best-aided condition [5]. In several candidates, speech audiometry was examined without a hearing aid; in these cases, the maximum speech discrimination score with open ear was substituted for the EAS implant criteria.

2.5. Statistical analysis

A Fisher's exact test was used to compare the prevalence of drug induced hearing loss patients between EAS and standard CI patients. All analyses were performed using STATA (STATA 11.1, STATA Corp., College Station, TX). A p value <0.05 was considered to indicate statistical significance.

3. Results

In our department, 4758 (64.7%) out of 7356 individuals who visited our department between 2011 and 2014 were diagnosed with hearing impairment. Thirty-four individuals (0.71%) out of 4758 hearing-impaired individuals fulfilled the pure-tone audiometric criteria for EAS implant, whereas 120 individuals (2.52%) showed severe sensorineural hearing loss meeting the criteria for standard CI (Table 1). The demographic data of the EAS implant and CI candidates are shown in Table 1.

In the younger population, there were fewer EAS implant candidates compared with CI candidates. One individual (2.9%) out of 34 candidates met the criteria for EAS implant under 18 years of age, whereas 25 individuals (20.8%) out of 120 candidates met the criteria for standard CI in the same age group. Four individuals (11.7% out of 34) and 37 individuals (20.8% out of 120) had congenital hearing loss among EAS implant and standard CI candidates, respectively (Table 1). Drug-induced hearing loss was more commonly observed among EAS implant candidates (6 individuals, 17.6%) than among standard CI candidates (5 individuals, 4.2%) (p = 0.015) (Table 1).

The median hearing levels of EAS candidates, the average of left and right ear, at each frequency were 45 dB, 45 dB, 51.3 dB, 72.5 dB, 90 dB, 101.3 dB, and 100 dB at 0.125 kHz, 0.25 kHz, 0.5 kHz, 1 kHz, 2 kHz, 4 kHz, and 8 kHz, respectively (Fig. 1). The median hearing levels of CI candidates, the average of left and right ear, at each frequency were 82.5 dB, 90 dB, 110 dB, 110 dB, 110 dB, 110 dB, and 110 dB at 0.125 kHz, 0.25 kHz, 0.5 kHz, 1 kHz, 2 kHz, 4 kHz and 8 kHz, respectively (Fig. 1).

Speech audiometry was examined in 14 out of 34 EAS implant candidates meeting the pure-tone audiometric criteria. The speech discrimination scores of 10 candidates ranged from 22% to 75%. The median score was 50%, while the 25th and 75th percentiles were 45% and 62%, respectively (Fig. 2). Ten

Table 1
Demographic data and comorbid conditions of the EAS and CI candidates. SD indicates standard deviation.

		Electric-acoustic stimulation (EAS)	Standard cochlear implant (CI)
Number of candidates, meeting pure-tone audiometry criteria (n)		34	120
Sex	Male	18	51
	Female	16	69
Age	range (years) [mean age ± SD]	17–86 [66.1 ± 14.8]	3–94 [49.5 ± 27.8]
	subgroup ≤18 (years)	1 (2.9%)	25 (20.8%)
	19–60	7 (20.6%)	39 (32.5%)
	61–74	13 (38.2%)	30 (25.0%)
	75≥	13 (38.2%)	26 (21.7%)
Primary disease of hearing loss			
	Idiopathic	25 (73.5%) (Congenital 4 (11.7%))	95 (79.2%) (Congenital 37 (30.8%))
	Middle ear disease	2 (5.9%)	8 (6.7%)
	Inner ear disease	1 (2.9%)	4 (3.3%)
	Middle + inner ear disease	0	4 (3.3%)
	Acoustic neuroma	0	4 (3.3%)
	Drug-induced	6 (17.6%)	5 (4.2%)

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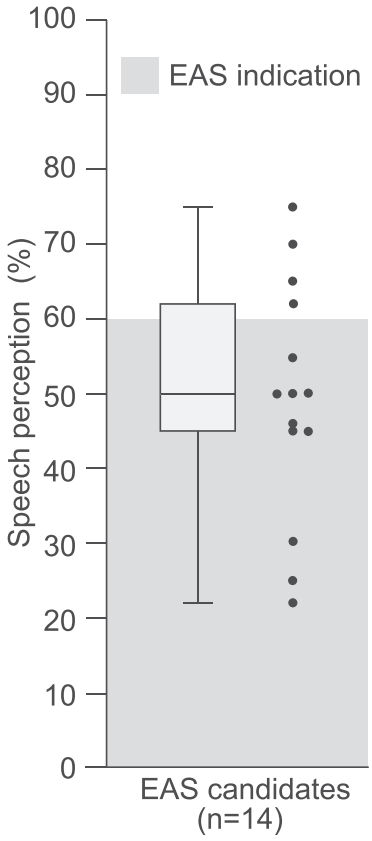

Fig. 2. Speech perception test of electric-acoustic-stimulation (EAS) implant candidates.
Box plots of the range of speech perception test (67-S, Japanese monosyllable test) of EAS implant candidates. The criterion for EAS implant, <60%, is illustrated by the grey area. The bottom and top of the boxes represent the 25th and 75th percentiles, respectively. The solid horizontal line within each box represents the median value. The lower whisker is equal to the minimum observation. The upper whisker is equal to the maximum observation.

candidates out of 14 candidates (71.4%) fulfilled the EAS implant indication criteria of speech audiometry.

After the approval of EAS device in Japan in 2014, two individuals out of 34 EAS implant candidates (5.83%) received implanted EAS device by the end of 2018. The candidate reasons for not choosing EAS implantation are presented in Table 2.

Table 2
EAS candidate outcomes after 2014.

Number of candidates for EAS (n)		34
Informed about EAS	EAS surgery received	2 (5.9%)
	Not received EAS surgery	16 (47.1%)
Reasons for avoiding EAS surgery[a]		
Did not feel hearing impairment		2 (5.9%)
Comfortable with hearing aids		4 (11.8%)
Elderly		4 (11.8%)
Did not want surgery		2 (5.9%)
Eosinophilic otitis media		2 (5.9%)
Lost to follow up		2 (5.9%)
Uninformed about EAS and were lost to follow-up		16 (47.1%)

[a] A main reason of avoiding EAS was chosen from each patient.

4. Discussion

In this study, we examined the prevalence of EAS implant candidates meeting the criteria of pure-tone audiometry among hearing-impaired individuals. The prevalence of EAS implant candidates was 0.71% (n = 34 out of 4758 individuals), which was less than that of standard CI candidates (2.52%, n = 120). To the best of our knowledge, this is a first report to present the estimated prevalence of EAS implant candidates with detailed information.

There have been few reports published describing the prevalence of candidates for EAS or standard CI. The estimation of the global prevalence of hearing impairment, by the analysis of 42 studies from 29 countries, was 1.4% for children aged 5–14 years, 9.8% for females >15 years of age, and 12.2% for males >15 years of age [10]. Pediatric CI candidates between the ages of 12 months and 6 years in the United States were considered to be 12,816 children among the total population of 231 million [11]. Şahin et al. estimated 11.7 million people worldwide as CI candidates (9.2 million adults, 2.5 million children) [12]. From their estimation, the prevalence of CI candidates is 1.67% when the world population is estimated at 7 billion. Gstoettner et al. cited a paper by von Ilberg et al. [1] reporting that individuals with good hearing in the low frequencies are estimated to comprise approximately 1.64% of the clinical population in a tertiary care academic referral center [13]. However, the basis of this estimation was not described in detail in the Gstoettner et al. and von Ilberg et al studies.

The number of EAS implant candidates in the younger population, <18 years old, was lower than that of the standard CI candidates. The reason for this is that many children with severe hearing impairment were referred to our hospital for standard CI implantation during the observation period. Moreover, at this period of time, EAS device had not been approved by Japan's Ministry of Health, Labor and Welfare, and was not covered by health insurance in Japan. Therefore, children with SHFHL only were not referred for surgery.

The percentage of drug-induced hearing loss was significantly higher in the EAS implant candidates (17.6%) than in the standard CI candidates (4.1%). A number of compounds are currently in clinical use with known ototoxic properties such as aminoglycoside antibiotics, salicylates, anti-malarial drugs, heavy metals, and loop diuretics. The symptomatic hearing loss due to drugs is typically at a high frequency, progressing from higher to lower frequencies with prolonged treatment despite the differences in chemical composition and function between the relevant drug groups, except aspirin, which can result in a flat audiogram [14]. For this reason, patients with drug-induced hearing loss need to be carefully observed as potential candidates for EAS implant.

Only two of 34 EAS implant candidates (5.83%) were implanted with EAS device after the approval of EAS device in Japan in 2014. As shown in Fig. 2, more than 70% of the EAS implant candidates showed lower speech perception (<60%). This discrepancy means that many of the EAS implant

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candidates can withstand hearing loss with hearing aids, even if they meet the indication criteria for EAS implant. The EAS implant candidates with ski-slope hearing loss in general have 1–1.5 dB/year more progression of pure-tone audiometry compared with that in an age and sex-matched reference group [15]. Therefore, patients with ski-slope hearing should be followed carefully even though they do not have EAS implantation.

To the best of our knowledge, this study is the first to report the prevalence of both EAS implant and standard CI candidates at an academic tertiary referral center. The present study was conducted in a tertiary referral center; therefore, the risks of selection bias and spectrum bias are limitations. Although the prevalence of EAS implant in this study population should be higher than that in the general population, it is valuable information for health care professionals examining audiograms. Accordingly, patients can obtain adequate information on further examinations and treatment options.

5. Conclusion

The percentage of EAS implant candidates meeting the pure-tone audiometric criteria was 0.71% (n = 34) among the hearing-impaired individuals (n = 4758) in our department. Two individuals among 34 EAS implant candidates received EAS implantation. Healthcare professionals should carefully examine the audiograms of patients with high frequency hearing loss with regard to meeting the indication criteria for EAS implant. This will enable patients to gain access to adequate information relating to further examinations and treatment options.

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Disclosure statement

The authors declare that they have no conflict of interest.

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