Table II. Total number of incorrect responses for each syllabic nuclear group with both ACAS and BCU.

Vowel syllabic nuclear group	Monosyllables in List 67-S	Total	Errors with ACAS	Errors with BCU
a (6 monosyllables)	/a/, /ta/, /ha/, /ba/, /wa/, /ga/	72	20	23
i (5 monosyllables)	/ki/, /shi/, /ji/, /ni/, /ri	60	17	9
u (3 monosyllables)	/u/, /ku/, /su/	36	11	8
e (2 monosyllables)	/te/, /ne/	24	1	11
o (4 monosyllables)	/o/, /to/, /mo/, /yo/	48	6	10

and carrier signal simultaneously. On the other hand, our results show that the highest average score for the speech discrimination tests for BCU was about 75% at 15 dB SL and that the score of the speech discrimination test with BCU increased significantly in all pairs of sound levels. These results show that the intelligibility of the speech discrimination test for BCU is not saturated and that our highest score was better than their results. It is evident that the listeners perceived high tones induced by the carrier signal more strongly as the sound levels increased. However, our results did not show an influence in carrier frequency, although this may be a result of our use of a different list, speaker, degree of modulation, and threshold search method.

Safety considerations require that the stimulating intensity be set to less than UCL. Although Okamoto et al. [15] indicated that ultrasonic stimuli were delivered without discomfort, UCL was not measured strictly in their report. In our experiments, after measuring UCL – which was 15.1–33.1 dB SL and 18.6 dB SL on average – speech discrimination tests with BCU were performed at an intensity less than UCL. In our results, the highest average score was about 75% at 15 dB SL. For safety reasons and to support the development of BCUHA, it is very important that this high intelligibility be obtained at less than UCL.

Table III. Confusion matrix for the individual syllabic nuclear groups based on the results of monosyllable intelligibility tests with ACAS and BCU.

	Incorrect response group					
Stimulus group	a	i	u	e	o	No response
ACAS						
a	100					
i		100				
u			91		9	
e				100		
o			33		67	
BCU						
a	70	9	4	4	9	4
i		89	11			
u	25	63			13	
e	18	9		36	36	
o	50	10			40	

Our comparison of hearing confusion between ACAS and BCU according to individual syllabic nuclear groups showed a clear difference in the incorrect rates. In addition, the stimulus nuclear groups were often perceived in other nuclear groups in BCU stimuli, although most incorrect responses showed hearing confusion with the same nuclear group in ACAS stimuli. These facts indicate the possibility of a difference between BCU and ACAS in terms of speech recognition methods. Further study is needed to clarify the factors behind this difference because the mechanisms of BCU perception are still unclear.

Our results indicate that vowel articulation in BCU is inferior to that of ACAS. However, this result might have been influenced by the unpracticed subjects, as all subjects in this study heard BCU for the first time in this experiment. Therefore, it is assumed that intelligibility can be improved with training.

Conclusion

In this study, we compared BCU and ACAS in terms of speech perception tendencies in subjects with normal hearing. Our results suggest that it is possible to transmit language information with BCU stimulation to normal-hearing subjects. Although the highest average score from speech discrimination testing with BCU was about 75%, it may be possible to improve intelligibility through training or by improving signal processing. However, the possibility that BCU and ACAS differ in terms of the mechanism of speech recognition has also been suggested. Therefore, further investigation is important. This result cannot be applied directly to profoundly deaf subjects. The present findings provide important clues for the development of BCUHA. Improved sound processing and further study with hearing-impaired subjects are needed to develop the BCUHA for elderly hearing-impaired and profoundly deaf subjects.

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ORIGINAL ARTICLE

Estimation of factors influencing the results of tinnitus retraining therapy

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Abstract
Conclusion: The factors of tinnitus loudness and Tinnitus Handicap Inventory (THI) score in tinnitus patients have the potential to relate to therapeutic results of tinnitus retraining therapy (TRT). *Objectives:* To confirm what factors in tinnitus influence the results of TRT. *Patients and methods:* Twelve factors were investigated in 53 patients with tinnitus, examining the relationship between these factors and the results of TRT. A THI score was determined before and 6 months after TRT introduction (pre- and post-TRT). Moreover, the change of THI score from pre- to post-TRT (ΔTHI) was referred to as the therapeutic effect of TRT. Based on the 12 factors, subjects were respectively divided into two groups, comparing Δ THI between groups. *Results:* Two groups of greater tinnitus loudness and higher THI score showed significant increases in ΔTHI, indicating that two factors of tinnitus loudness and THI score were related to the therapeutic effect of TRT.

Keywords: *Tinnitus Handicap Inventory (THI), tinnitus loudness, sound therapy, sound generator, prognostic factor*

Introduction

In recent years, the concept of therapy for chronic tinnitus has shifted from removing to relieving the symptom. Tinnitus retraining therapy (TRT) is aimed not to resolve tinnitus completely, but to habituate to and to alleviate the symptom of tinnitus, being a clinically selected therapy for chronic tinnitus [1,2]. TRT has been performed since the 1990s, obtaining therapeutic results in approximately 80% of tinnitus patients [1–3] without remarkable side effects. Although TRT is currently one of the most effective and popular therapies for tinnitus, it still requires the accumulation of many clinical experiences and studies.

TRT is introduced to tinnitus patients who can understand its method and theory, and who can accept this therapy actively [1,2]. Based on the introduction criteria, TRT can be widely performed in patients with any characteristics of tinnitus, especially patients who are mentally restricted in daily life by tinnitus [1,2,4]. Nevertheless, we occasionally experience cases with poor therapeutic results after long-term TRT. Methodologically, TRT administration requires a long period of at least 6 months because it is a method of psychotherapy and rehabilitation. In order not to waste long periods of time in the treatment of tinnitus patients, information about the validity of TRT is valuable. Estimation of factors influencing the therapeutic results of TRT may be useful for the introduction of this therapy, since few reports are available on factors related to the results of TRT [4–7].

In this study, 12 factors concerning tinnitus patients were investigated, and we examined the relationship between these factors and the results of TRT in order to confirm which factors influence the results of TRT.

Patients and methods

The subjects were 53 patients with tinnitus (21 males, 32 females, mean 56.1 ± 15.8 years old) who consulted the specialized tinnitus clinic in our department from July 2003 to December 2004, and who selected TRT as a method for tinnitus therapy.

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The conditions of tinnitus in all subjects were characterized as follows: tinnitus was continuously perceived for at least 3 months, tinnitus pitch and tinnitus loudness did not fluctuate greatly, hearing level was not severely impaired, and a follow-up period was more than 6 months after TRT introduction. Subjects were excluded from this study if they were diagnosed as requiring other treatments for the primary disease of tinnitus.

At the first medical consultation, the subjects were asked to evaluate subjective symptoms of tinnitus using a question table for tinnitus, including a Tinnitus Handicap Inventory (THI) score [8,9], an index (ranging from 0 to 100 points) reflecting difficulties in daily life or the psychological distress caused by tinnitus (100 points means maximally distressed). In turn, otolaryngological findings (ear, nose, and throat), auditory findings (pure tone audiometry and recruitment phenomenon), and tinnitus characteristics (tinnitus pitch and tinnitus loudness) were also examined. Brain imaging and auditory evoked responses were examined, if necessary.

The program of TRT was uniformly introduced to all subjects. TRT consisted of directive counseling and sound therapy. Directive counseling was a detailed explanation to enable understanding of the cause, course, and treatment of tinnitus. Sound therapy was performed to reduce tinnitus perception by listening to noise from a sound generator (TCI Tinnitus Control Instrument, Siemens Hearing Instruments Ltd). After the introduction of TRT, the subjects consulted our clinic approximately once every 2 months. After completing the TRT program for 6 months, subjective symptoms of tinnitus, including a THI score, were re-evaluated.

The following 12 factors of interest were investigated: age, sex, laterality in the ear with tinnitus, period of tinnitus, primary disease leading to tinnitus or hearing loss, hearing level, existence of recruitment phenomenon, tinnitus pitch, tinnitus loudness, THI score, existence of concomitant drugs with TRT, and number of consulting doctors. Each factor was calculated concerning the frequency distribution, mean value, and median value. For each of the 12 factors, the subjects were respectively divided into 2 groups (group A and B), determining the borderline based on the frequency distribution (age, sex, laterality in the ear with tinnitus, period of tinnitus, primary disease leading to tinnitus or hearing loss, recruitment phenomenon, tinnitus pitch, concomitant drug use, and number of consulting doctors), or on the study data in an early tinnitus study (THI score [4], hearing level [10], and tinnitus loudness [11,12]).

For statistical analysis, firstly, the overall result of TRT in all subjects was analyzed by paired t test, comparing the THI score before and 6 months after TRT introduction (pre- and post-TRT). For the results of TRT based on each of 12 factors, changes in the THI score from pre- to post-TRT (ΔTHI), referred to as the therapeutic effect of TRT, were compared respectively between groups A and B with Student's unpaired t test. A THI score on pre-TRT was also compared independently, to evaluate the variance of THI score in advance. As for positive or negative values for ΔTHI, the condition whereby a THI score had decreased 6 months after TRT was defined as positive, and that when a THI score had increased was defined as negative. In all cases, $p<0.05$ was considered significant.

Results

The overall results of TRT in all subjects are shown in Figure 1. The THI scores were significantly decreased between pre- and post-TRT (pre-TRT: 47.3 ± 23.1 >post-TRT: 30.4 ± 22.1).

The distributions of subjects concerning the 12 factors are shown in Table I. Since the number of subjects was hierarchically distributed, seven factors of age, period of tinnitus, hearing level, tinnitus pitch, tinnitus loudness, number of consulting doctors, and THI score were additionally calculated concerning their frequency distribution, as shown in Figure 2.

The changes of THI score from pre- to post-TRT (ΔTHI) of each factor are shown in Table II. On the analysis of THI score on pre-TRT, two factors showed a significant difference between A and B groups (A1 vs B1): the THI score and the existence of concomitant drugs with TRT. In analysis of ΔTHI, two factors showed a significant difference between groups A and B (A3 vs B3): tinnitus

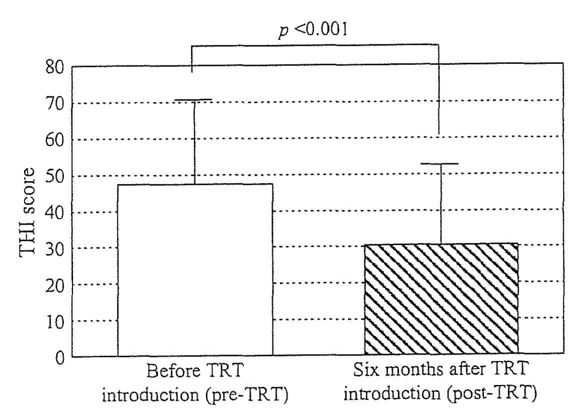

Figure 1. Overall results of TRT in all subjects. The graph shows mean$\pm$standard deviation values; $n=53$, paired t test.

Table I. Distribution of subjects based on the 12 factors investigated.

Factor	Distribution	
Age	Mean: 56.1 ± 15.8 years	Median 60 years
Sex	Male: $n = 21$	Female: $n = 32$
Laterality in ear with tinnitus	Unilateral: $n = 33$	Bilateral: $n = 20$
Period of tinnitus	Mean: 48.5 ± 79.9 months	Median: 18 months
Primary disease leading to tinnitus and hearing loss	Unknown: $n = 27$ (presbyacusis 21, idiopathic 6)	Known: $n = 26$ (Sudden hearing loss 8, Ménière's Disease 7, head trauma 3, cerebral drug-induced 2, noise-induced 2, otitis media 2)
Hearing level	Mean: 30.6 ± 22.5 dB HL	Median: 25 dB HL
Recruitment phenomenon	Absent: $n = 30$	Present: $n = 23$
Tinnitus pitch	Under 500 Hz: $n = 9$	Over 2 kHz: $n = 44$
Tinnitus loudness	Mean: 14.2 ± 10.0 dB SL	Median: 13 dB SL
THI score	Mean: 48.2 ± 24.2	Median: 44
Concomitant drug	Absent: $n = 16$	Present: $n = 37$
Number of consulting doctors	Mean: 1.62 ± 1.02	Median: 1

loudness (under 9 dB SL: 8.9 ± 9.9 < over 10 dB SL: 20.4 ± 21.5), and THI score (under 50 points: 9.8 ± 14.7 < over 50 points: 26.9 ± 21.1).

Discussion

The group with tinnitus loudness over 10 dB SL showed significantly higher ΔTHI than that under 9 dB SL. That is, TRT was more effective in patients with tinnitus over 10 dB SL, indicating a greater therapeutic effect in patients with larger tinnitus loudness. This relationship between tinnitus loudness and the results of TRT in this study was probably caused by an external sound device in TRT, a sound generator. In the methodology of TRT, listening to noise from a sound generator, mixed with the perception of tinnitus, acts to reduce the sound contrast of tinnitus [1,2]. The volume of noise is adjusted to the degree that a patient can perceive simultaneously with tinnitus, depending on tinnitus loudness [1,2]. For patients with lower tinnitus loudness, environmental sounds that patients perceive with the naked ear fulfill a role similar to noise from a sound generator. Thus, the group with tinnitus loudness <9 dB SL probably showed few therapeutic effects of TRT. For patients with greater tinnitus loudness, on the other hand, environmental sound alone is too small to replace the noise from a sound generator. Since the noise amplified by a sound generator was required, TRT with a sound generator was able to provide a more beneficial therapeutic effect in the group with >10 dB SL.

The group with THI score >50 points also showed a higher ΔTHI than that with a score <50 points on pre-TRT. This implies that TRT with a sound generator is more effective in patients with THI score >50 points, probably in patients with higher THI score. Comparing patients who were severely distressed and those who were slightly distressed by tinnitus, commonly, the patients who were severely distressed are estimated to benefit more greatly from tinnitus treatment. Therefore, the results suggest that the THI score adequately reflects the degree of distress in tinnitus patients. Moreover, the results provide supporting evidence that the criterion for TRT introduction in tinnitus patients should be the THI score >50 points [4]. Essentially, the purpose of TRT is not to recover radically from tinnitus, but to alleviate the distress caused by tinnitus, by means of directive counseling and sound therapy jointly. Since directive counseling is performed to help patients clearly understand the cause, course, and treatment of tinnitus, it seems that the therapeutic effect of TRT is influenced by how well therapists can grasp the degree of distress in tinnitus patients. However, within the short time available for routine consultation in otolaryngology, therapists are limited in their understanding of the complaints of patients by being able to ask only a few questions. Considering the results of this study, an investigation of THI score is a powerful tool for the screening of a tinnitus patient, because it facilitates the understanding of the degree of distress in tinnitus patients and can be used for the estimation of the therapeutic effect of TRT before its introduction.

Factors that estimate the therapeutic effect are probably useful to introduce new treatment, and provide further improvement to poorly responding diseases or symptoms. Few reports are available on factors that influence the therapeutic effect of TRT, while a THI score [4], a psychology test (CMI, SRQD) [6], mental and physical conditions [7], and cognitive ability [7] have been reported on. Since

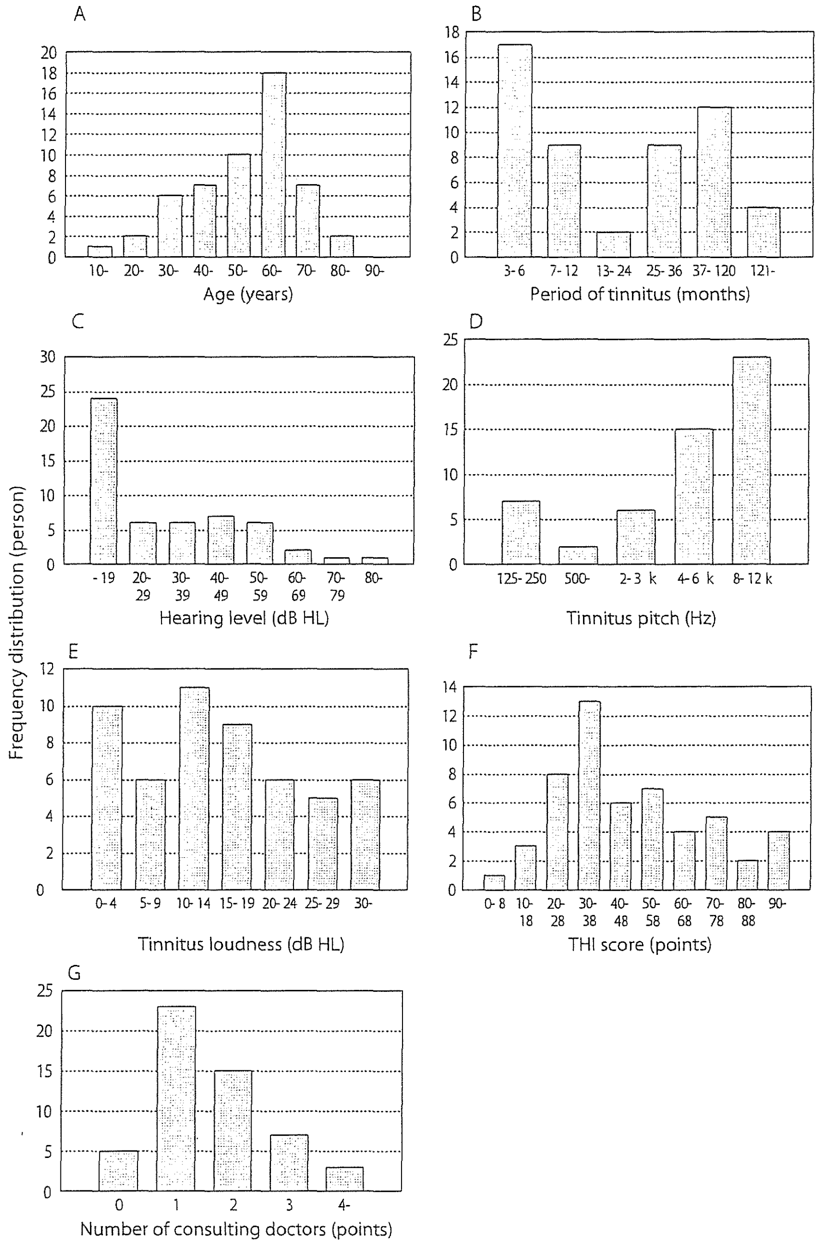

Figure 2. Frequency distribution for seven factors. (A) Age; (B) period of tinnitus; (C) hearing level; (D) tinnitus pitch; (E) tinnitus loudness; (F) THI score; (G) number of consulting doctors.

TRT is still under investigation to accumulate more clinical experiences and studies, many discussions on TRT will be required in the future.

In conclusion, the relationships between 12 factors of tinnitus patients and changes in the THI score before and 6 months after TRT (ΔTHI) were examined to estimate factors influencing the results of TRT. Consequently, two groups with greater tinnitus loudness or higher THI score before TRT showed significant increases in ΔTHI, indicating that two factors – tinnitus loudness and THI score – influenced ΔTHI. These results suggest that investigations of tinnitus loudness and THI score are useful before introducing TRT.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Table II. Changes in THI score from pre- to post-TRT (ΔTHI).

	Group A	THI score pre-TRT (A1)	THI score post-TRT(A2)	A group ΔTHI(A3)	Group B	THI score pre-TRT(B1)	THI score post-TRT(B2)	B group ΔTHI(B3)	THI score pre-TRT analysis (A1 vs B1)	ΔTHI analysis (A3 vs B3)
Age	Under 60 years (*n* =26)	47.3±22.0 (mean±SD)	33.9±24.0	13.4±17.0	Over 60 years (*n* =27)	47.3±24.6 (mean±SD)	27.1±19.8	20.3±21.2	NS	NS
Sex	Male (*n* =21)	46.8±21.8	30.9±21.9	15.9±14.1	Female (*n* =32)	47.7±24.3	30.1±22.5	17.6±22.4	NS	NS
Laterality in the ear	Unilateral (*n* =33)	43.5±23.3	26.1±19.7	17.3±21.6	Bilateral (*n* =20)	53.7±21.9	37.5±24.3	16.2±15.5	NS	NS
Period of tinnitus	Under 1 year (*n* =26)	41.3±21.3	28.0±22.7	13.3±16.0	Over 1 year (*n* =27)	53.1±23.6	32.7±21.6	20.4±22.1	NS	NS
Primary disease	Unknown (*n* =27)	41.8±22.4	25.9±18.2	15.9±20.9	Known (*n* =26)	53.1±22.8	35.1±25.0	18.0±18.0	NS	NS
Hearing level	Under 30 dB HL (*n* =30)	47.1±22.8	30.6±23.9	16.5±18.5	Over 30 dB HL (*n* =23)	47.6±24.0	30.2±19.9	17.4±20.9	NS	NS
Recruitment phenomenon	Absent (*n* =30)	50.6±21.4	32.5±24.0	18.1±17.4	Present (*n* =23)	43.0±25.0	27.7±19.4	15.3±22.0	NS	NS
Tinnitus pitch	Under 500 Hz (*n* =9)	51.8±24.1	28.0±30.6	23.8±16.9	Over 2 kHz (*n* =44)	46.4±23.1	30.9±20.3	15.5±19.7	NS	NS
Tinnitus loudness	Under 10 dB SL (*n* =16)	40.4±16.3	31.5±16.1	8.9±9.9	Over 10 dB SL (*n* =37)	50.3±25.1	29.9±24.4	20.4±21.5	NS	$p<0.05$
THI score	Under 50 (*n* =31)	31.1±10.6	21.3±13.8	9.8±14.7	Over 50 (*n* =22)	70.2±15.0	43.3±25.3	26.9±21.1	$p<0.001$	$p<0.001$
Concomitant drug	Absent (*n* =16)	37.5±19.5	22.1±12.9	15.4±15.9	Present (*n* =37)	51.6±23.5	34.0±24.2	17.6±20.9	$p<0.05$	NS
Number of consulting doctors	Under 1 (*n* =28)	45.1±23.5	32.5±22.3	12.6±14.5	Over 2 (*n* =25)	49.8±22.9	28.1±22.0	21.8±23.0	NS	NS

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The effect of visual information in speech signals by bone-conducted ultrasound

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\ prototype for a bone-conducted ultrasonic hearing aid vas developed for the profoundly deaf. Previous studies ısing bone-conducted ultrasonic hearing aid revealed ntelligibility only with the use of acoustic media in ransmitting language information. In this study, we nvestigated the effects of visual information (lip-reading nformation) on intelligibility in bone-conducted ultrasound ›erception of normal-hearing individuals. We found hat lip-reading information had clear effects on ›one-conducted ultrasound perception, showing that ;imultaneous presentation of audio and visual information mproved intelligibility to levels sufficient for speech ›erception. Our findings also suggested the efficacy ›f use of signal processing techniques in improving the intelligibility of prior consonants. *NeuroReport* 21:119–122

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Keywords: bone conduction, discrimination test, intelligibility, lip-reading, ultrasound, visual information

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ntroduction

The auditory perception of bone-conducted ultrasound s not well known in general. However, after the first esearch about ultrasonic perception in 1948 [1], sev-:ral hypotheses concerning such perception have been uggested. The possibility of audible sound generation n transmission through nonlinear processes has been uggested [2–4]; for instance, nonlinearity in transfer rom transducer to skull demodulates ultrasound into low-requency audible sounds [4]. In contrast, some research-:rs also suggested that ultrasonic perception takes place vithin the cochlea, with important contributions by :ochlear hair cells [3,5–8] or vestibular hair cells [9,10]. One study suggested that bone-conducted ultrasound-nduced vibration of the basilar membrane directly ctivated inner hair cells without outer hair cell function n the basal turn of the cochlea [8]. In other studies of nimal models, ultrasonic perception was considered to be nediated by the inner hair cell system without enhance-nent by the outer hair cell system [7,11]. Although several ıypotheses have been suggested, the mechanisms of ıltrasonic hearing have yet to be clearly determined.

Several differences between bone-conducted ultrasound nd air-conducted audible sound have been considered in erms of perceptual characteristics. For instance, the ›itch of bone-conducted ultrasound is independent of its requency [3,6], and is perceived as if derived from air-onducted stimuli of 8–16 kHz [5]. Bone-conducted ltrasound can mask the perception of air-conducted udible sound in the 10–14 kHz range, and this masking ; independent of ultrasonic frequency [8]. The dynamic range of bone-conducted ultrasound is narrower than that of air-conducted audible sound [8]. The most interesting characteristic of bone-conducted ultrasound is the availability of ultrasonic frequency discrimination, and speech detection is not only restricted to normal-hearing individuals, that is, they are also available in some deaf patients [10]. Regarding this interesting phenomena, several studies have been conducted from physiological perspective [12,13]. Among them, one study showed that bone-conducted ultrasound stimuli activated the auditory cortex, and showed using magnetoencephalography that ultrasound that is amplitude modulated by different speech sounds can be discriminated in the auditory cortex in some profoundly deafs [12]. Putting these findings together, practical use of an ultrasonic hearing aid system for profoundly deaf individuals would be possible. Recently, a bone-conducted ultrasonic hearing aid for profoundly deaf individuals has been developed and its utility has been evaluated [14,15]. The recognition of bone-conducted ultrasound modulated by speech signal and the intelligibility of Japanese words were 100 and 50% for normal-hearing individuals, and 40 and 17% for deaf individuals, respectively [14]. Another study investigated the intelligibility of bone-conducted ultrasonic speech in normal-hearing individuals using a Japanese monosyllable list and reported that the highest average score from monosyllable intelligibility tests with bone-conducted ultrasound was about 60%. Although these findings suggest the potential commercial viability of bone-conducted ultrasonic hearing aid, they also claimed to improve intelligibility of bone-conducted ultrasound are required in further studies.

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Regarding the practical use of bone-conducted ultrasound, however, it should be noted that the experimental conditions in these studies are unnatural. In normal conversation, not only audible information but also visual information related to speakers is used. This visual information is termed lip-reading information, and its roles have been investigated by several researchers. For example, lip-reading information has been found to be particularly useful in noisy environments [16] and for speech perception by patients with cochlear implants [17]. Normal-hearing individuals also rely on visual cues [16]. The advantages of visual information are important for practical application of bone-conducted ultrasonic hearing aid. For the purpose of development of bone-conducted ultrasonic hearing aid, hearing performance should be evaluated in actual environmental conditions, in which listeners use both audio and visual information. However, the degree of improvement of the intelligibility of bone-conducted ultrasound using lip-reading information has yet to be determined. In this study, we assessed the effects of lip-reading information on intelligibility in bone-conducted ultrasound perception.

Materials and methods

Participants

Thirteen adult volunteers (nine males and four females) participated in the study. They were all native Japanese speakers with normal hearing and normal or corrected vision. The participants' ages ranged from 22 to 30 years. None of the participants had experience with lip-reading training. They provided written consent after being informed of the nature and purpose of this study. The procedure used in this study was approved by the Ethics Committee of the Nara Medical University.

Stimuli

Speech discrimination tests were performed in three conditions: (i) audio-alone condition, (ii) audio-visual condition, and (iii) visual-alone condition. A video to evaluate auditory perception for cochlear implant patients [17] comprised of 50 Japanese monosyllables (Table 1), which was used for audio and visual presentation. In this tape, the face of a female Japanese speaker pronouncing 50 syllables was recorded. In the visual presentation, visual stimuli were presented on a color monitor placed 1 m in front of participants. A life-sized speaker appeared on the monitor. In the audio presentation, a 30 kHz sinusoidal wave was used as a carrier wave as the resonance frequency of the vibrator was approximately 30 kHz. The signal wave was amplitude modulated with speech signals. For calibration, we used a 1 kHz sinusoidal wave adjusted to the equivalent continuous A-weighted sound pressure level of the 50 monosyllables. The degree of modulation was set at 100% of this sinusoidal wave. The modulated signal is given by the following formula:

$$U(t) = [S(t) - S_{LAeq}] \times \sin(2\pi f_c t)$$

where $S(t)$ indicates the speech signal, S_{LAeq} is the minimum amplitude value of the equivalent continuous A-weighted sound pressure level of $S(t)$, and f_c indicates the frequency of the carrier wave.

Table 1 Classification of Japanese Monosyllables used in this study

a	ka	sa	ta	na	ha	ma	ja	ra	wa	ga		da	ba
i	ki	ʃi	tʃi	ɲi	çi	mi		ri			dʒi		
u	ku	su	tsu		Φu	mu	ju	ru			dzu		
e	ke	se	te	ne	he	me		re				de	
o	ko	so	to	no	ho	mo	jo	ro		go		do	

Fifty Japanese monosyllables used for intelligibility testing. Each line indicates a monosyllabic group having the same vowel nucleus.

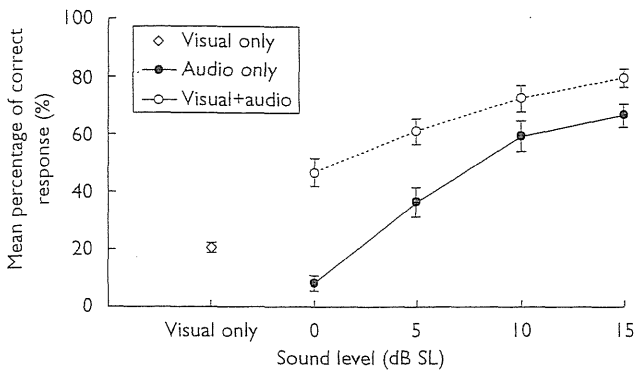
Procedure

The ultrasonic stimuli were delivered to the right mastoid through a custom-made ceramic vibrator. At the beginning of the experiment, the participants' ability to hear ultrasound was investigated with a 30 kHz sinusoidal wave amplitude modulated with a 1 kHz tone burst (stimulus duration was set at 200 ms including 20 ms rise/fall times and a stimulus rate of 2 Hz). The tone burst was prepared from the 1 kHz sinusoidal adjusted to the equivalent continuous A-weighted sound pressure level of the 50 monosyllables. The step size was 0.1 dB SL. The threshold of sensation was determined by ascending technique, which was performed at least three times. If differences were within 1 dB SL, we used the average. If the difference of responses were more than 1 dB SL, measurement was begun again.

After the measurement of sensation level, the speech discrimination tests were performed under the three conditions noted above. Audio-alone condition, audio-visual condition, and video-alone condition were presented in separate sequences. In the audio-alone and audio-visual conditions, the carrier wave was modulated with monosyllable sound output from the DVD provided with the videotape. This modulation was performed with a function generator (WF1946; NF Electronic Instruments Co., Yokohama, Japan). The ultrasound signals were increased with a high-speed power amplifier (HSA4011; NF Electronic Instruments Co.). Signal intensities were controlled logarithmically with an attenuator (PA5; Tucker-Davis Technologies, Gainesville, Florida, USA) to permit use of the dB scale. The intensity levels of bone-conducted ultrasound were set at 0, 5, 10, and 15 dB SL. The monosyllable intelligibility test was performed at every signal intensity.

The inter-stimulus interval for each monosyllable presentation was 3.0 s. The same 50 monosyllables were used at each sound level. The stimuli were presented in random order. All the experiments were carried out in a

Fig. 1



The mean percentages of correct responses on speech discrimination tests in visual-alone condition, audio-alone condition, and audio-visual condition. Vertical bars indicate SEM.

sound-proof room. Each participant was sitting and instructed to write the monosyllables presented on a prepared answer sheet during testing.

Results

In audio-alone and audio-visual conditions, mean percentages of correct responses increased markedly at 10 dB SL, and then plateaued (Fig. 1). In the audio-alone condition, the maximum percentage of correct responses of 66.5% was obtained at 15 dB SL. Addition of visual information increased the correct response rate to 79.2% at 15 dB SL. These data were examined by two-way analysis of variance, with experimental condition and sound level as within-subject factors. Analysis of variance revealed significant effects of condition [$F(1,12)=87.59$, $P<0.001$] and sound level [$F(3,36)=92.05$, $P<0.001$]. The interaction between condition and sound level was also significant [$F(3,36)=21.18$, $P<0.001$]. Post-hoc comparison revealed significant differences from 0 to 10 dB SL in each condition, but not between 10 and 15 dB SL. In visual-alone condition, mean percentage of correct responses was 20.6%. A t-test was performed between visual-alone condition and 0 dB SL in audio-visual condition, the minimum sound level, and revealed a significant difference between the two conditions [$t(24)=5.26$, $P<.001$].

Discussion

The results of speech discrimination tests in this study revealed that lip-reading information strongly affected bone-conducted ultrasound speech perception. The speech intelligibility of bone-conducted ultrasound with visual information was significantly higher than that without visual information at each sound level tested. The maximum percentage of correct answers in the audio-visual condition totaled about 79% at a sound level of 15 dB SL. Moreover, at the level at 0 dB SL, the mean percentage of correct responses (46.9%) in audio-visual condition was clearly higher than the arithmetic sum of the percentages of correct responses (29.0%) in audio-alone condition (8.4%) and video-alone condition (20.6%). This result suggests that the synchronization of audio and visual information increased intelligibility in speech perception through bone-conducted ultrasound compared with the stand-alone condition. Our findings showed that the use of audio-visual information with bone-conducted ultrasound markedly enhanced the availability of information in normal-hearing individuals. Generally, hearing-impaired individuals rely on lip-reading information more strongly than do normal-hearing individuals. Lip-reading information may play important roles in the transmission of language information for the hearing-impaired who make use of bone-conducted ultrasonic hearing aid. Although intelligibility with bone-conducted ultrasonic hearing aid is as low as 17% [14], use of lip-reading information and training in lip reading will improve intelligibility in deaf individuals.

At 15 dB SL, the percentages of correct vowel perception including following vowels in the audio-alone and audio-visual conditions were 91.4 and 98.1%, respectively. This indicates that lip-reading information aids the listener in enabling near-perfect discrimination of vowels. In contrast, the percentage of correct perception of prior consonants in audio-alone and audio-visual conditions remained at 68.4 and 80.1%, respectively. The score for prior consonants was lower than that for vowels, and intelligibility was not sufficient for transmission of language information through bone-conducted ultrasound. Sound processing techniques, including emphasis on the prior consonant, will thus need to be improved.

In the audio and audio-visual conditions, mean percentage of correct responses increased markedly at 10 dB SL, and then plateaued. A similar type of saturation has been reported [15]. They conducted Japanese monosyllable intelligibility tests with bone-conducted ultrasound and found that monosyllable intelligibility scores for bone-conducted ultrasound at 25 and 30 dB did not differ significantly. The discrepancy in intensity levels at saturation between present and previous studies might be caused by differences in degree of modulation and methods of measurement of sensation. They noted that the intelligibility of bone-conducted ultrasound is not necessarily related to sound level. This might occur because participants perceive speech sounds and carrier signals simultaneously. The higher the level of sound was, the more strongly participants perceived carrier signals sounds. As the subjective pitch elicited by bone-conducted ultrasound is similar to the pitch of air-conducted sound in the 8–16 kHz range [5], our participants perceived high-tone pitch more strongly, possibly making it difficult for them to understand speech information. For reasons of safety, stimulation intensity was set to less than uncomfortable level, and it is important to transmit sound information using bone-conducted ultrasound without discomfort. No participants complained of uncomfortable sensation at 10 dB SL stimulation, the saturating intensity in our experiments. The percentage of correct responses reached 72% at 10 dB SL in the audio-visual condition. Our findings showed that the use of simultaneous presentation of audio and visual information lead to efficient transmission of speech information using bone-conducted ultrasound, while satisfying safety requirements.

Conventional hearing aids cannot improve auditory sensation in deaf individuals. Bone-conducted ultrasonic hearing aid is one possible option for them. The greatest benefit of bone-conducted ultrasonic hearing aid is that auditory perception is possible for profoundly deaf individuals without surgery. Cochlear implants are widely used by partially and severely hearing-impaired individuals to restore hearing ability. However, cochlear implants require surgery. Even if performance after surgery is inadequate, presurgical condition cannot be restored. As the bone-conducted ultrasonic hearing aid is far easier to attach than cochlear implants, it can easily be tried by deaf individuals before a cochlear implant. Our findings suggest both that bone-conducted ultrasound may be useful for sound transmission for deaf individuals and that the use of the bone-conducted ultrasonic hearing aid may be practical. In future work, we should carefully confirm the efficacy of visual information in deaf people, as we unveiled the improvement only in normal-hearing individuals in this study.

Conclusion

Our findings showed that synchronization of audio and visual (lip-reading) information contributes to intelligibility in speech perception using bone-conducted ultrasound in normal-hearing individuals. The availability of bone-conducted ultrasonic hearing aid to deaf people should be checked in future study. The score for prior consonants was lower than that for vowels, and intelligibility was not sufficient for transmission of language information through bone-conducted ultrasound. Sound processing techniques will also need to be improved.

Acknowledgements

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軟素材による外耳道再建型鼓室形成術
—20年間の経験と本法における外耳道入口部拡大法—

細　井　裕　司

要旨：真珠腫の再形成性再発の防止を目的として行っている「軟素材による外耳道再建型鼓室形成術」の20年の経験から本法を解説するとともに，本法における外耳道入口部拡大法を示した。解説事項としては，本法の手術法，中耳真珠腫手術法における本法の位置づけ，再形成性再発防止の理論，軟素材による再建の歴史と現況，適応，手術の注意点，本法におけるcavity problem，本法における真珠腫の再発，中耳真珠腫手術の考え方，本法によって使用されるようになった用語である。本法の理解のために特に耳鼻臨床の論説（97：183-192，2004）の参照を勧めた。
キーワード：中耳真珠腫，鼓室形成術，軟素材による外耳道後壁再建，再形成性再発，外耳道入口部拡大

はじめに

筆者らは1989年に「軟素材による外耳道後壁再建型鼓室形成術」を始め，1992年の日本耳科学会で「軟素材による外耳道再建を伴った鼓室形成術—Retraction Pocket防止のために—」を報告した[1]。最初の報告後多くのご意見を頂いたが否定的な見解も多かった。しかし，1994年から他施設からの報告[2]も見られるようになり，現在では多くの施設で実施されている[3]。第19回日本頭頸部外科学会で本法について報告する機会を頂いたので，20年の経験を踏まえ本法を種々な観点から解説するとともに本法における外耳道入口部拡大法を示した。本稿の20年間のまとめの部分については，過去の論文内容を含んでいる[3-7]。

手術法[7]

病巣の郭清：外耳道皮膚剥離後に骨部外耳道後壁を削除し，病巣の清掃ならびに耳小骨連鎖の再建を行う。真珠腫の進展範囲等を考慮して，粘膜を保存するなど症例に応じて清掃範囲を加減する。

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外耳道後壁の再建：通常のopen methodでは，外耳道後壁の皮膚に切開を加え，その皮膚を移動して乳突腔を覆うようにするが，本法では外耳道後壁の皮膚に切開を加えず，外耳道皮膚は筒状にしたまま用いる。大きめの筋膜を採取し，前部で鼓膜形成を行い，後部は外耳道皮膚の裏側にフィブリン糊を用いて接着する。つまり，1枚の筋膜を用いて，鼓膜形成を含め筒状の外耳道を作ることになる（図1）。

現在行われている他の手術法と本法の位置づけ

日本耳科学会では外耳道の処理に関する手術法の分類を行っている[8]。実際はいくつかの手技の組み合わせにより，9種類以上の手術工程が行われている[3]。各手術工程の優劣については，文献3）に詳述した。本法の分類は決まっていないようであるが，「外耳道後壁削除型鼓室形成術で，付帯手技として外耳道後壁再建を軟素材で行う。」という位置づけが最も自然と思っている。外耳道後壁の存在意義は，乳突蜂巣が外界に対してclosedであることと，外耳道後壁の硬度を保つということである。外界に対してclosedにする目的は，術後治癒の迅速化，術後処置の簡便化，cavity problemの防止である。外耳道後壁を堅

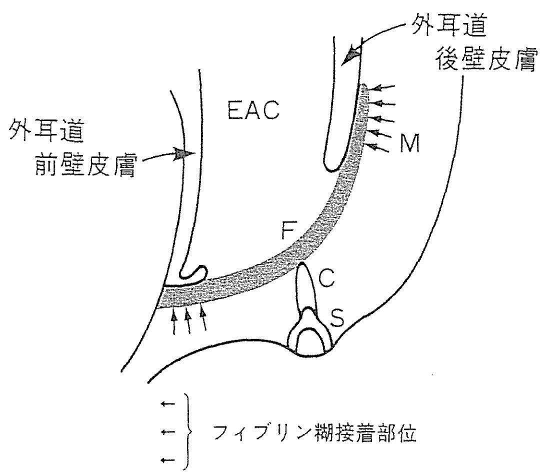


図 1　軟素材による外耳道後壁再建を示す耳の断面図
EAC：外耳道　M：乳突洞　C：コルメラ
S：アブミ骨　F：筋膜

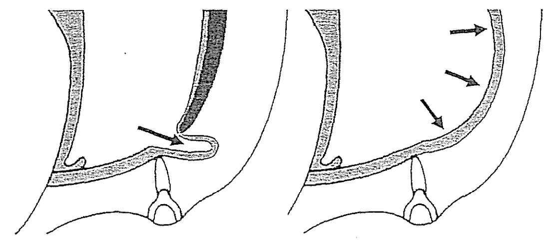


図 2　中耳腔が陰圧の場合に起こる術後変化
a：硬素材による外耳道後壁（外耳道後壁保存または硬素材による再建）
→ retraction pocket
b：軟素材による外耳道後壁再建
→ balloon like retraction

固にする目的は，retraction pocket を防止するため中耳側への陥凹する力に対抗することにあった。本法では，次に述べるように軟素材による後壁再建により closed にする利点を生かしながら，同時に軟素材による特性を生かして retraction pocket を防止しようとするものである。

本法による retraction pocket 形成防止の理論[7)]

外耳道後壁が硬素材で形成されている場合は，図 2（a）に示すように，中耳腔陰圧によって引き込まれるとポケット形成がなされ，真珠腫の再形成につながると考えられる。これに対し，後壁が軟素材で形成されていると陰圧は後壁全体に作用し，図 2（b）に示すように後壁全体として引かれるので，風船状にふくらみ（balloon like retraction と呼んでいる）retraction pocket のような狭小な陥凹は生じにくい。

本法の歴史と現況

軟素材による外耳道後壁再建の報告は多くなく，特に中耳真珠腫の術後の再形成性再発防止の目的で使用した報告は我々が最初であった[1)]。Smith et al.[9)] は Palva flap と筋膜で外耳道を再建し，Gelform で充填する方法を提案した。しかし，主な目的は再建を簡単にするためで，aggressive cholesteatomas には用いないと述べている。筆者は，retraction pocket 防止のために外耳道後壁を堅固なものにしたり，補強したり，または充填して陥凹に対抗するといった考え方を転換することにした。中耳腔陰圧などの陥凹の原因が取り除かれない以上，いくら陥凹力に対抗してもどこかに陥凹していくだろうと考えた。従って，陥凹を防ぐのではなく，陥凹が起こっても再形成性再発につながるポケット形成が起こらない方法を模索し，1989 年に軟素材による後壁再建を始めた。1992 年の耳科学会で本法を報告して以降，関連する報告を行ってきた[3)]。1994 年から他施設での報告も見られるようになり[2,10)]，以後その数は増加してきた[3)]。

2008 年 10 月に行われた第 18 回日本耳科学会パネルディスカッション「症例に則した鼓室形成術」（司会：柳原尚明，阪上雅史）において，レスポンスアナライザーを用いて会場の耳鼻咽喉科医から質問の回答を求める試みがなされた。この中で，11 歳，男児の中耳真珠腫症例が提示され，手術で後壁処理はどのように行うかという質問項目があった。回答は Canal wall up 法が 24％，Canal wall down 法（軟組織再建）が 36％，Canal wall down 法（硬組織再建）が 17％，Canal wall down 法（乳突開放型）が 16％，Canal wall down 法（乳突充填）が 7％であった。このことから，軟素材による外耳道後壁再建は国内でかなり普及していると考えられる。

表 1　tympanoplasty & soft wall で検索した英語論文

Soft-wall reconstruction of the posterior external ear canal wall. Smith PG, Stroud MH, Goebel JA. Otolaryngol Head Neck Surg. 1986 Mar; 94(3)：355-9.
Tympanoplasty with reconstruction of soft posterior meatal wall in ears with cholesteatoma. Hosoi H, Murata K. Auris Nasus Larynx. 1994; 21(2)：69-74.
Long-term observation after soft posterior meatal wall reconstruction in ears with cholesteatoma. Hosoi H, Murata K, Kimura H, Tsuta Y. J Laryngol Otol. 1998 Jan; 112(1)：31-5.
Soft-wall reconstruction for cholesteatoma surgery: reappraisal. Takahashi H, Hasebe S, Sudo M, Tanabe M, Funabiki K. Am J Otol. 2000 Jan; 21(1)：28-31.
Mastoid obliteration combined with soft-wall reconstruction of posterior ear canal. Takahashi H, Iwanaga T, Kaieda S, Fukuda T, Kumagami H, Takasaki K, Hasebe S, Funabiki K. Eur Arch Otorhinolaryngol. 2007 Aug; 264(8)：867-71. Epub 2007 Mar 6.
Habitual sniffing and postoperative configuration of the posterior meatal wall reconstructed with soft tissue. Kawase T, Yuasa Y, Oshima T, Kobayashi T. Acta Otolaryngol. 2007 Nov; 127(11)：1132-5.
Residual cholesteatoma: incidence and localization in canal wall down tympanoplasty with soft-wall reconstruction. Haginomori S, Takamaki A, Nonaka R, Takenaka H. Arch Otolaryngol Head Neck Surg. 2008 Jun; 134(6)：652-7.
Canal wall-down tympanoplasty with soft-wall reconstruction using the pedicled temporoparietal fascial flap: technique and preliminary results. Haginomori S, Nonaka R, Takenaka H, Ueda K. Ann Otol Rhinol Laryngol. 2008 Oct; 117(10)：719-26.

海外の動向はどうか。tympanoplasty と soft wall で英文の文献検索を行った結果を表 1 に示す。この中に Smith の論文が含まれていることからわかるようにすべてが私の主張に添ったものではないが，soft wall reconstruction についてそれぞれの筆者の考え方が示されている。Haginomori らの論文[11]は Arch Otolaryngol Head Neck Surg. の continuing medical education (CME) の設問に採用された。また，2008 年 6 月にトルコで行われた 8th International Conference on Cholesteatoma & Ear Surgery では，トルコの Dr. Refik Caylan が Tympanoplasty with soft wall reconstruction: Hosoi's technique というタイトルで本法を発表していた。海外でも本法を試みる施設が増加していくものと考えている。

本法の適応

積極的適応は retraction pocket から始まる後天性真珠腫で，本法の理論にそって術後の再発性再発を防止する目的で行われる場合である。先天性真珠腫や慢性中耳炎はどうか。外耳道後壁を削除して open の状態で病変の清掃を行うと操作が確実になる。Cavity problem を避けるためと術後治癒の早期化，術後処置の簡便化を目的に外耳道後壁を再建し closed にするが，中耳腔陰圧による再形成が起こりにくいタイプの中耳炎では，再建材料は硬素材でも軟素材でも結果は変わらない。その理由は軟素材で再建しても後天性真珠腫と異なり中耳腔の換気は良好なので，外耳道後壁は balloon like retraction を起こさず，後壁位置は硬素材で再建したように正常位置を保つと考えられる。先天性真珠腫や慢性中耳炎は病巣の徹底除去さえ行われれば再発の可能性は少ないので，canal wall up でも硬素材再建でもよいが，本法でも同様の結果が得られる。従ってこのような症例にも本法を用いてもよいと考えている。

本法を生かすための手術の注意点

本法の特徴を生かすための手術の注意点を以下に 4 項目挙げる。①外耳道後壁削除型鼓室形成術と同様に術野の観察は容易であることを生かして，徹底して病巣清掃を行う。②できるだけ術後

の balloon-like retraction が起こりにくくするために，真珠腫など病巣がないところの粘膜はできるだけ保存する。（本法は中耳腔陰圧の場合に balloon like retraction が起こることによって retraction pocket を防止しようという理論なので，balloon like retraction が起こることが悪いことではないが，できるだけ外耳道が正常形態を保つことを望むなら粘膜を不必要に除去しない方がよい。）③術後 balloon like retraction が起こっても，外耳道入口部から陥凹した外耳道後壁の全体が見渡せるように，facial ridge を十分低くしておく。④外耳道入口部や外耳道が狭小で術後 balloon like retraction をおこした後壁の観察が困難になると予想される場合は，次に示す本法における外耳道拡大を加える。

本法における外耳道拡大法

本法においても外耳道を拡大できる。以下に拡大法を２種類呈示する。

1）外耳道入口部を含む外耳道拡大法（外耳道入口部拡大術）

通常の open 法のときに行われる外耳道入口部拡大術（meatoplasty）に準じて，耳甲介腔に皮膚と軟骨を離断する切開を加え（図 3-1（a）），これを外耳道後壁に延長する（図 3-1（b））。外耳道後壁を縦切開し，外耳道入口部軟骨を切除する（図 3-1（c））ことによって，入口部を含む外耳道が拡大される（図 3-1（d））。開いた外耳道後壁が外耳道側に折りかえらないように，フラップの外耳道入口部に近い部分を皮膚部と皮下組織部の２枚に切離し，皮下組織側のフラップを近傍の組織に縫合する（図 3-1（e））。この縫合はフラップの外耳道入口部側のみでよい。直径が大きくなった分は欠損になっているので，筋膜を先ほど２枚におろした間に挟み込み，皮膚部は筋膜より外耳道側に位置するように欠損部を筋膜で覆うことによって，皮膚と筋膜で筒状の外耳道を形成する（図 3-1（f））。

2）外耳道入口部を含まない外耳道拡大法

通常の open 法と同様に外耳道後壁に T 切開を加え（図 3-2（a）），外耳道を拡大する（図 3-2（b））。左右のフラップの皮下組織の部分を二枚におろし，mastoid 側の皮下組織を近傍の皮下組織に縫合することによりフラップが外耳道側に折れ曲がって外耳道が狭くならないようにする（図 3-2（c））。二枚おろしのうち，外耳道皮膚がついたフラップは円筒状の外耳道方向に向くようにする。この二枚におろした間に筋膜を入れ，拡大された外耳道の欠損部を覆うように接着する（図 3-2（d））。このとき同時に鼓膜の欠損部も筋膜でカバーする。

外耳道入口部が狭い症例は「1）外耳道入口部を含む外耳道拡大法」の適応となり，外耳道入口部そのものはそれ程狭くないが，外耳道入口部から深部へ入ったところの残存皮膚の筒の径が小さいか，美容上外耳道入口部拡大を望まない症例は

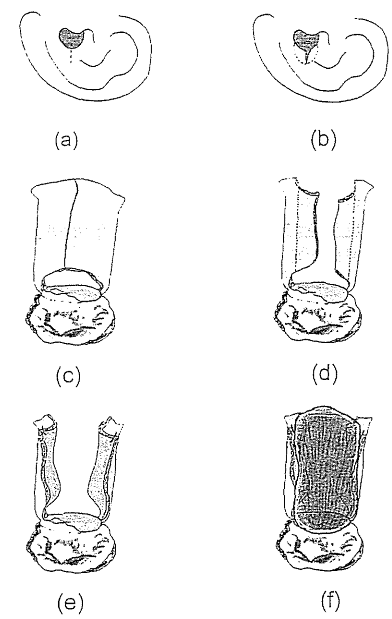


図 3-1　本法における「外耳道入口部を含む外耳道拡大法」

a：耳甲介腔に皮膚と軟骨を離断する切開をを入れる。
b：切開は外耳道後壁に延長する。
c：外耳道後壁を縦切開する。外耳道入口部軟骨を切除する。
d：入口部を含む外耳道が拡大される。
e：開いた外耳道後壁が外耳道側に折りかえらないように，フラップ上部を皮膚部と皮下組織部の２枚に切離し，皮下組織側のフラップを近傍の組織に縫合する。
f：直径が大きくなった分は欠損になっているので，筋膜を先ほど2枚におろした間に挟み込み，欠損部を筋膜で覆うことによって，皮膚と筋膜で筒状の外耳道を形成する。

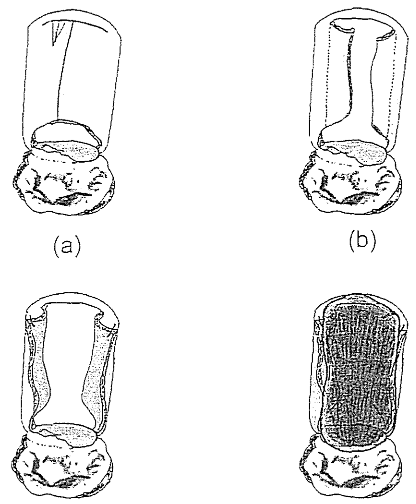


図 3-2　本法における「外耳道入口部を含まない外耳道拡大法」
a：外耳道後壁にT切開を加える。（図は外耳道側からメスの刃先が入っているところ）
b：外耳道を拡大する。
c：開いた外耳道後壁が外耳道側に折りかえらないようにフラップを縫合する。
d：直径が大きくなった分は欠損になっているので，筋膜で覆い円筒状にする。

「2）外耳道入口部を含まない外耳道拡大法」の適応と考えている。

本法に対する疑問

本法発表当初から，「柔らかい外耳道後壁はやがて大きく陥凹し，あたかもopen法を行ったようになるのではないか？」というご批判を受けた。この応答は文献3）に記載してある。本稿では以下の2つの疑問に対して，筆者の考えを述べる。

1）本法でもcavity problem（乳突腔障害）は起こるか？

応答―cavity problemはopen法において，乳突削開腔の上皮化障害から再感染，耳漏，痂皮形成がみられるものである。本法では理論上は起こらないが，例外的に起こる可能性はある。起こる場合は，いったん上皮化した軟素材による後壁が後退し，乳突削開腔の後壁に接着した後，その皮膚が栄養不良などで破れて粘膜面が露出したときにおこる。この状態が鼓膜の位置で起これば鼓膜の再穿孔にあたる。canal wall upなら外耳道後壁皮膚が破れて骨が露出した状態である。open法では図4（a）に示すように，術直後は骨面の露出した部分があり，後日上皮化していく過程で上皮化障害がおきると粘膜性肉芽が増殖し，湿潤した状態となって痂皮が付着するなどcavity problemの原因になる。本法では図4（b）のように外耳道の上皮化が終わって後に陥凹していくので理論的には上皮化障害はない。

2）本法によって真珠腫が再発することはあるか？

応答（1）：100％再発しない方法はない。再発の原因が本法を施行したことにあるのか，他の方法では起こらなかったのかが問題である。遺残性再発については，本法はcanal wall downの状態で清掃するので，遺残の率はcanal wall down法と同等であり，canal wall up法より理論的に少ない。再形成性再発は術後経過が理論どおりに進めば起きないはずである。

応答（2）：本法の理論が成り立つ手術が行われたかどうかを検討する必要がある。軟素材による再建ということばから，bridgeだけを落とし外耳道後壁は残して，その欠損部を筋膜で補修する方法などが本法に含まれている可能性がある。これらは本法で主張している再形成性再発防止のメカニズムが効かないので本法に入らない。

応答（3）：原ら[12]は本法施行の後に再形成性再発を来した後天性真珠腫の1例を報告し，その原因として再建した鼓膜の筋膜部と外耳道皮膚が一体化して内陥できなかったことをあげている。筆者も再発には至らないが，外耳道後壁が一体でballoon like retractionを起こさず，2つのballoon like retractionを起こしその間が段またはヒダのようになった症例をいくつか経験している。この場合はヒダを切除してなだらかにし一つのballoon like retractionになるよう術後処置している。

中耳真珠腫手術の考え方

真珠腫の大きさ（進展範囲）によって術式を変えるという考え方がある。例えば，真珠腫が小さいと真珠腫だけを摘出すればよいという考え方である。自然な考え方であるが，真珠腫の手術とは

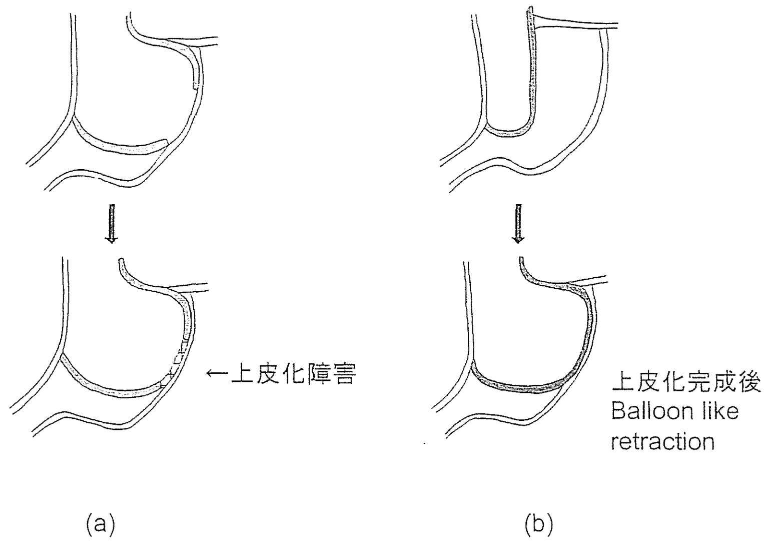


図 4　cavity problem に関する open 法と本法の相違
a：open 法では術後経過の中で上皮化していくので上皮化が障害される可能性がある。
b：本法では上皮化が完成してから陥凹していく。

何かを再度考えてみる。中耳真珠腫は中耳腔陰圧などの原因が作用した結果として中耳腔に形成されたものであるとすると，行うべきは結果としてできた真珠腫の除去と原因の除去の２つになる。小さいか大きいかのサイズの問題は，発見されたときが小さいうちであるか，大きくなってからかの発見時期の問題であろう。小さい真珠腫も発見されるのが遅れると，大きくなるはずである。このように考えると，中耳腔の換気不全などの原因がすでに手術の前に取り除かれている症例では，サイズが大きくても真珠腫の除去のみで再発しないだろうし，小さい真珠腫でも手術時にまだ原因が取り除かれていないと再発することになる。つまり，サイズが小さいから再発しないとは言えない。真珠腫再形成の原因が手術時に存在するかしないかを術前，術中に判断することは困難である。従って，真珠腫が再発する原因は取り除かれていないという仮定のもとに手術を行うべきではないだろうか。

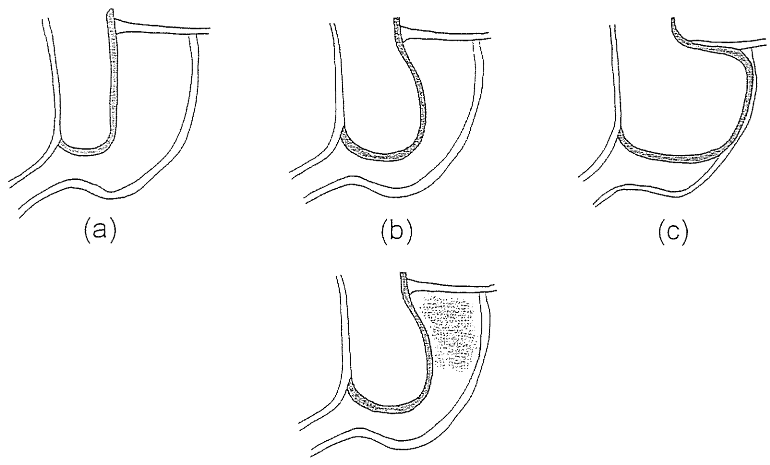
用　　語

本法に関して使用している用語を以下に３つあげる。これらの用語は他施設の論文でも使用されるようになり，定着してきている。

1) 軟素材：従来外耳道後壁再建材料は骨など硬素材であった。軟素材としたのは硬素材に対するもので，筋膜など材料を指定しているのではなく，柔らかい素材の性質を表現しようとした。実際は筋膜，骨膜，結合織なので軟組織と表現されることもある。

2) Balloon-like retraction（風船状陥凹）：retraction pocket に対して用いている。中耳腔陰圧で外耳道後壁が内陥する場合でも，再形成性再発に結びつく狭小な陥凹ではなく，風船状に大きく内陥することを表す（図４（b））。

3) それぞれの症例に見合った最適の外耳道後壁位置：術後に時間経過とともに外耳道後壁は後退していくが，約１年で最終的な外耳道後壁の位置に落ち着く[6]。この位置がそれぞれの症例の中耳腔の換気能に見合った外耳道の位置であると考えている。図５（a）は換気能良好で後壁は正常位置を保っている。図５（c）は換気能が悪く外耳道後壁は mastoidectomy cavity の後壁まで後退している。図５（b，b'）はその中間で外耳道後壁は中等度に後退している。b は乳突腔の含気化良好例，b'は含気化不良例で，乳突腔は肥厚粘膜で覆われた場合を示す。CT の軟部組織様陰影は肥厚粘膜による場合が多い。



(a)　(b)　(c)　(b')

図 5　術後 1 年が経過した時点での外耳道後壁位置
a ：外耳道後壁は後退せず（balloon like retraction は起こらず）後壁は正常位置を保つ。
b ：外耳道後壁は中等度に後退している。乳突腔は空洞治癒している。
b'：外耳道後壁は中等度に後退している。乳突腔は肥厚粘膜で覆われている。
c ：外耳道後壁は最大限に後退し，乳突削開腔後壁に接着している。

おわりに

本稿は第 19 回日本頭頸部外科学会（稲福繁会長）のビデオセミナー「軟素材による外耳道再建を行う鼓室形成術—考え方から実際まで，20 年間の経験から—」の内容のうち，文献 3，7）の内容と重複する部分をできるだけ除いて執筆した。本法の理解のために文献 3）と 7）も合わせて読んでいただけたら幸いです。

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総　説

語音聴力検査
—最近の動向—

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要旨：語音聴力検査に関する研究の最近の動向を知る目的で，最近10年間の内外の原著論文を分析検討した。検討対象は，掲載誌，研究目的，研究対象，研究方法，タイトルに含まれる用語などである。その結果，研究の目的は補聴器や人工内耳の評価が最も多かった。次いで，症例報告の中で語音聴力検査結果を示す場合のような単純記載が多く，語音聴力検査結果を深く分析する研究は少なかった。大部分の研究が語音聴力検査をことばの聞き取り，聞き分け能力を測定することによって社会生活における不自由度を推定するために行われており，難聴の鑑別診断のために使用された研究は少なかった。この10年間の研究動向を30年前の語音聴力検査研究動向と比較すると，難聴の鑑別に資する目的が大幅に薄れたことがわかる。社会の高齢化に伴い難聴者の増加が予想され，語音聴取能力の評価法としての重要性はますます増していくと考えられる。

ーキーワードー
語音聴力検査，文献検索，補聴器，人工内耳，障害部位診断

はじめに

日本聴覚医学会の語音聴覚検査法（2003）（平成20年６月に名称変更され，現在の表記は「日本聴覚医学会聴覚検査法　２．語音聴力検査法（2003）」[1]）には，「検査の目的は２つに大別できる。(1)難聴者のことばの聞き取り，聞き分けの能力を測定することよって，社会生活における不自由度や社会適応度などを推定する。(2)語音聴取能と純音聴取能を比較検討することにより難聴の鑑別診断に重要な情報をもたらす。更に積極的に，検査語音に種々のひずみを加えた加工音声，または聴取方法を工夫した両耳聴取などにより，難聴の鑑別，きこえの仕組みの解明に関する資料を提供する。」という趣旨が記載されている。

このような重要な目的を持った語音聴力検査に関連した研究は活発に行われているのだろうか。それらは上記２つの目的のうちどの目的で行われ，どのような研究テーマの中で行われているのだろうか。この疑問に答えるために，最近10年間の内外の原著論文を分析し，最近の傾向を調べた結果を報告するとともに，筆者が30年以上語音聴力検査に関わり，いくつかの研究成果を報告してきたことを振り返りながら現状を考察する。

最近の論文からみた語音聴力検査に関連した又は語音聴力検査を用いた研究動向

１．検討方法

(1)　基本事項

1999年７月〜2009年６月（10年間）の間に発行された原著論文について，国内は医学中央雑誌から「語音聴力検査」をキーワードに，海外はPubMedから「speech audiometry」をキーワードにして検索した。海外論文は非常に多数にのぼるので，検索するにあたってcore clinical journalsに絞った。検索された論文の中から，内容が発語明瞭度に関する