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OTOLOGY

Objective assessment of autophony in patients with patulous Eustachian tube

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Abstract The objective of the present study is to evaluate the Eustachian tube (ET) acoustic patency during phonation. The sound level in the EAC during phonation of the "A" and "N" sounds was measured by microphones in the bilateral EACs of nine normal subjects and 31 patients with patulous ET. The measured sound pressure differences between the right and left ears were correlated with the differences in severity of autophony between the bilateral ears assessed by a visual analogue scale (VAS). The patulous condition was often remarkable when the "N" sound was phonated. In some patients with patulous ET, the patulous condition was indicated only by the present method, and not by conventional ET function tests such as tubo-tympano-aerodynamic-graphy or sonotubometry.

Keywords Autophony · Patulous Eustachian tube

Introduction

Patients with patulous Eustachian tube (ET) suffer from discomforts such as aural fullness, autophony, hearing their own breathing, and others [1–4]. Many of these symptoms are caused by persistent opening of the normally closed ET [5]. Therefore, evaluation of the acoustic transfer function from the nasopharyngeal cavity to the middle ear via the patulous tube is important. Conventional ET function tests, such as tubo-tympano-aerodynamic-graphy (TTAG) and sonotubometry, or the recently reported audiometry using nasally presented sound, can objectively evaluate the acoustic or pressure transfer functions via the patulous ET under the resting or swallowing conditions [5–10]. However, autophony, a common symptom of patulous ET, is an unpleasant but subjective discomfort which only occurs during phonation. Therefore, a method for the evaluation of ET function during phonation would be valuable.

In fact, patients with patulous ET often present with autophony as the only subjective symptom. The degree of patulous ET in such patients may be insufficient to cause other patulous symptoms under the non-phonating condition. The actual sound generated by phonation is transmitted via the patulous ET and can be detected directly through an otoscope introduced into the external auditory canal (EAC). This method is convenient, but objective assessment is difficult.

The present study tried to measure the sound pressure level (SPL) in the EAC during phonation using microphones introduced into the EAC as a method of objectively evaluating the subjective symptoms of autophony in patients with patulous ET.

Materials and methods

Nine normal subjects and 31 patients with patulous ET were included. The normal subjects had no past history of ear disease or any complaints of aural symptoms. The diagnosis of patulous ET was based on the typical symptoms, such as autophony, aural fullness, and hearing one's own breathing, as well as the findings of tympanic membrane

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and ET function tests, in which a pressure change in the middle ear and/or the EAC elicited by forced deep breathing and/or sniffing (pressure change in the pharyngeal space) was detected as a synchronous movement of the tympanic membrane and/or the pressure change in EAC (TTAG) measured with a commercial device (JK 04A; RION Co., Ltd., Kokubunji, Tokyo, Japan).

The SPLs in the EAC during phonation were measured with a low-noise microphone system (ER-10C; Etymotic Research, Elk Grove Village, IL, USA). The probe was sealed into the ear canal with a rubberized foam ear plug. The SPLs recorded in the EAC were amplified and analyzed using a personal computer. A mouthpiece was placed in the subject's mouth and the subject was asked to make an "A" sound (vowel sound) and an "N" sound (nasal sound). The subject wore noise canceling headphones (QC-2; Bose, Framingham, MA, USA) during recording to minimize possible interference from outside sounds, including ambient noise or leaked phonated sound from the nostril or mouth. These results were compared with the subjective severity of the autophony symptom, which was assessed using a visual analogue scale (VAS) (0 and 10 indicated "no symptoms" and "too severe to tolerate," respectively).

All parts of the present study were performed in accordance with the guidelines of the Declaration of Helsinki.

Results

Normal subjects

Typical results obtained from a normal subject are presented in Fig. 1. The sound level in the EAC increased as the phonated sound level increased, but the difference in sound levels between right and left was usually less than 10 dB in most normal subjects, with the mean ± standard deviation of sound pressure difference (right–left) of −1.94 ± 4.80 for the "A" sound, 1.01 ± 5.35 for the "N" sound (Fig. 5). Although the SPL at the nasopharynx during phonation appeared to be one of the important factors affecting the absolute SPL in the EAC, adequate control of the nasopharyngeal sound level during phonation sessions was actually quite difficult. Therefore, the recorded data were analyzed based on the sound level difference between the right and left ears. Figure 1d shows a typical example of the effect of the noise canceling headphone in a normal subject. The recorded sound level was slightly increased by wearing the headphone, possibly due to the pressure effects of wearing the headphone, which compressed the ear plug medially. Similar effects were observed in two other subjects. This observation indicates that the sound levels recorded in the EAC during phonation reflect the sound transmitted via the patulous ET.

Typical cases

Case 1 is a typical patient with patulous right ET who complained of autophony in the right ear (Fig. 2). The right ET was persistently open during sonotubometry recording (about 8 s). The SPL during phonation was greater by 13.1 dB in the affected ear than in the unaffected ear.

Case 2 is a patient with severe patulous right ET who underwent trans-tympanic silicone plug insertion to control the intractable patulous symptoms [11] (Fig. 3). Trans-tympanic silicone plug insertion is intended to obstruct the isthmus of the ET, and is an effective treatment for severe cases

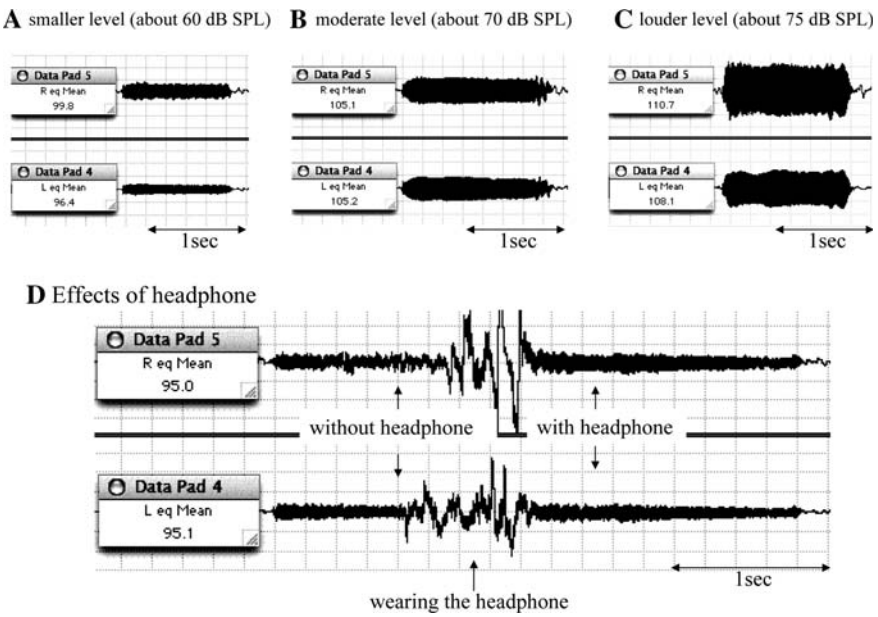
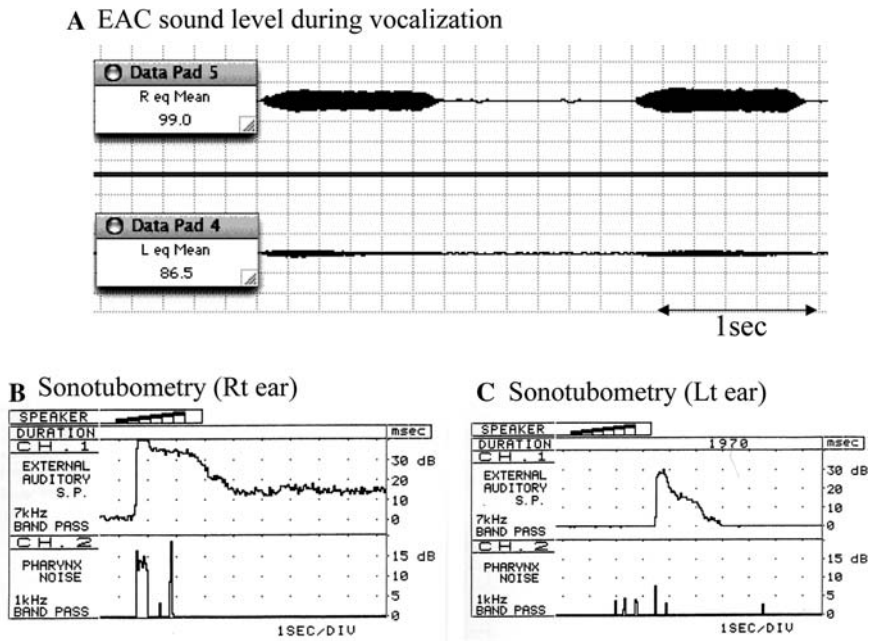


Fig. 1 Typical results obtained from a normal subject. Upper and lower traces indicate the monitoring chart of SPL in the right and left ears, respectively. The numbers on the inserted rectangles indicate the mean SPL during the phonation. **a**, **b** and **c** indicate the SPLs in the EACs during phonation of "N" at different SPLs (**a** low level, about 60 dB SPL; **b** moderate level, about 70 dB SPL; **c** high level, about 75 dB SPL); **d** shows a typical example of the effect of the noise canceling headphone



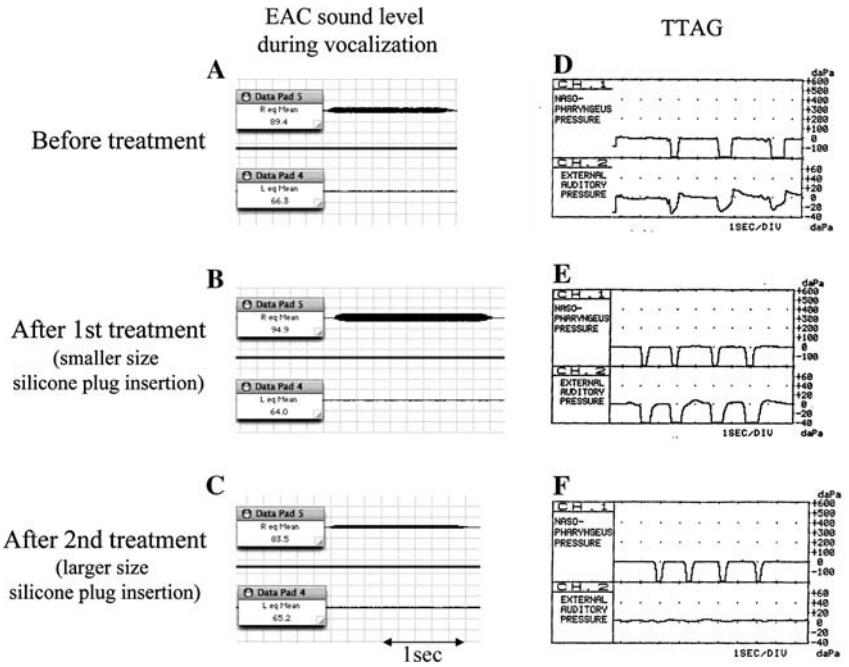


Fig. 2 Recording of EAC sound level during phonation (**a**) and the results of sonotubometry (**b**, **c**) of a typical patient with patulous right ET (case 1)

Fig. 3 Sound level recording in the EAC during phonation (**a**, **b**, **c**) and tubo-tympano-aerodynamic-graphy (TTAG) (**d**, **e**, **f**) in a patient with severe patulous right ET (case 2), in which a transtympanic silicone plug was inserted to control the intractable patulous symptoms (see text for further details)

which are resistant to conservative treatments. First, a small silicone plug was inserted, but her autophony was unchanged or slightly worsened. Then, a larger size plug was applied and her patulous symptoms almost disappeared. The findings of TTAG and the sound level recording in the EAC during phonation were basically consistent with her subjective symptoms. However, TTAG showed the synchronous movement of the pressure in the EAC had disappeared after the second obstructive treatment, whereas considerable acoustic patency during phonation was still observed.

"A" sound vs. "N"sound

"A" and "N" sounds were used as phonation sounds. The difference in the recorded sound level between the right and left ears was often remarkable when the "N" sound was used (Fig. 4a, c). The level differences between the right and left ears for the "A" sound and the "N" sound are compared in Fig. 5. Basically the results were well correlated, although the level difference was sometimes only remarkable when the "N" sound was used (Fig. 6).

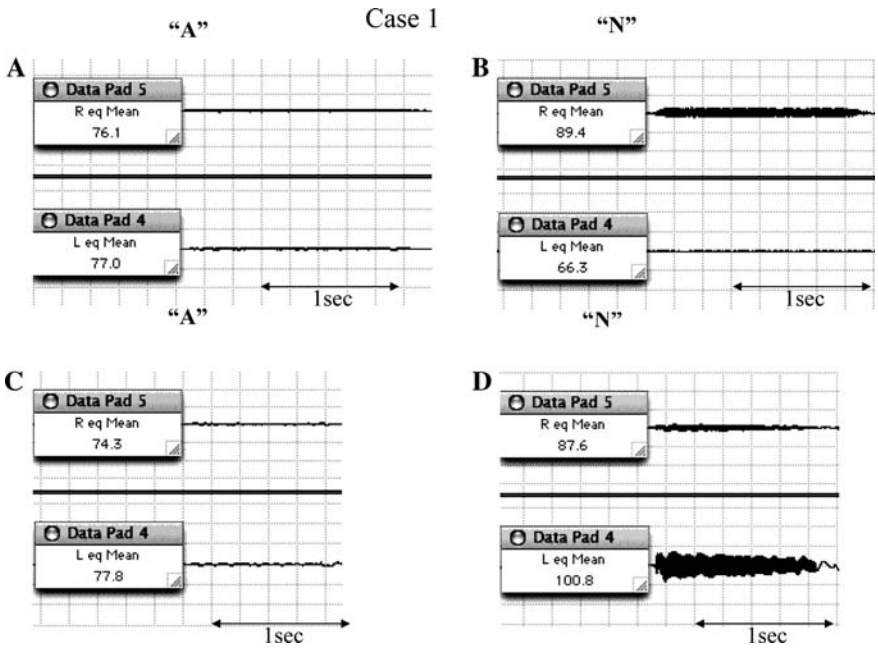


Fig. 4 Acoustic patency during the phonation of "A" and "N." The difference in recorded sound level between right and left ears was often remarkable during phonation of "N." The monitoring charts show the phonations of "A" (**a**, **c**) and "N" (**b**, **d**) from two representative patients

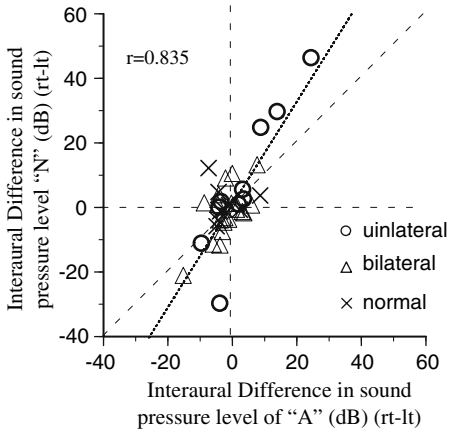


Fig. 5 Sound level differences between the right and left ears for the "A" sound and the "N" sound. The data for the patients with unilateral patulous ET and bilateral patulous ETs, and the normal subjects are shown as *circles*, *triangles*, and *crosses*, respectively. Basically both factors were well correlated although the level difference was sometimes remarkable when the "N" sound was used

Relationship with the subjective symptoms

The interaural difference of the objective symptom of autophony assessed by VAS was compared with that of the sound pressure in the EAC. These values showed a significant positive correlation ($p < 0.05$).

Discussion

The present method is intended to assess the acoustic patency of the ET during phonation, in contrast to the conventional ET function tests such as TTAG and sonotubometry. The present method can provide additional useful information concerning the patulous condition, especially in relation to the subjective symptom of autophony.

The palatal muscles related to the ET function (tensor veli palatine muscle and levator veli palatine muscle) are important in phonation, so the ET patency during phonation

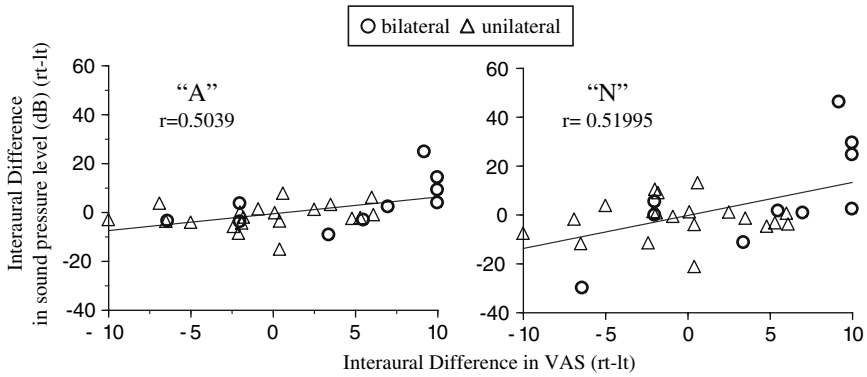


Fig. 6 Relationship between the interaural difference of the objective symptom of autophony assessed by VAS and the SPL in the EAC. Data for patients with *unilateral* and *bilateral* patulous ETs are shown as *circles* and *triangles*, respectively

may differ from that during non-phonation. The findings of TTAG and the present method are contrasted in Fig. 3, showing that the patulous condition was detected after treatment only by the present method.

The present results show that the acoustic patency during the phonation was often remarkable when the nasal sound "N" was phonated in patients with patulous ET (Fig. 5). Phonation of the nasal sound "N" or "M" is believed to cause sufficient pressure in the nasopharyngeal cavity to open the ET, especially under relatively patulous conditions [12]. In contrast, the nasopharyngeal pressure during the phonation of "A" may not be increased so much, because the soft palate tends to block the passage between the oropharyngeal and nasopharyngeal spaces. Moreover, articulation of the "N" sound contracts the palatal muscles much less than articulation of "A." These factors may contribute to the different ET patency observed between phonations "A" and "N" in patients with patulous ET. Therefore, patulous ET indicated only when "N" sound is phonated may be somewhat less severe than if the patulous condition is indicated regardless of the type of phonated sound.

In contrast to the other ET function tests, the present method uses the patient's own phonated sound as the sound source. However, this leads to difficulty in controlling the accurate sound level of the source (phonation). In this study, the recorded data were basically analyzed based on the sound level difference between the right and left ears. Therefore, we think that the present method would be useful for assessment of unilateral patulous ET, evaluation of the laterality of the patulous ET condition in bilateral cases, and monitoring the efficacy of therapy performed on the unilateral ET (untreated side used as control).

Sound level monitoring in the EAC is affected by various factors. Greater thickness of the tympanic membrane reduces the sound level in the EAC, whereas the presence of tympanic membrane perforation or ventilating tube increases the sound level. Therefore, careful interpretation of findings is required in patients with tympanic membrane perforation or with ventilating tube.

The clinical efficacy of the present method requires further evaluation, but the potential for additional information on the acoustic patency of the ET during the phonation suggests that this method may become an important clinical examination to assess the ET function of patients with patulous ET.

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