Masked Patulous Eustachian Tube: An Important Diagnostic Precaution Before Middle Ear Surgery

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The Eustachian tube is normally closed, but it opens upon swallowing for only less than one second to equalize the middle ear pressure with the atmospheric pressure, and immediately closes again. Patients with patulous Eustachian tube (PET) suffer from annoying symptoms, such as aural fullness (sensation of fullness in the ear), autophonia (abnormally loud audition of own voice), audition of breathing sound, and fluctuating sensation of the tympanic membrane upon respiration. The diagnosis of PET is not difficult when patients complain of such typical symptoms. However, there is an unexpected pitfall, in which the symptoms of PET are masked by the presence of conductive hearing loss and obvious middle ear pathology. Here, we propose that this condition be termed ‘masked patulous Eustachian tube’ to promote correct diagnosis prior to planning the middle ear surgery. Four representative patients with ‘masked patulous Eustachian tube’ are presented: two exhibited symptoms after repair of chronic perforation of the tympanic membrane, one after stapes surgery for otosclerosis, and one after cholesteatoma surgery. In these patients, the symptoms of PET became evident only after surgery due to the improvement of hearing. The degree of hearing improvement varied among the patients from 15 to 40 dB in average hearing level. It is therefore important to examine the presence of ‘masked patulous Eustachian tube’, in addition to a middle ear disease for which surgery is planned. The surgeon should inform the patient of the possibility of ‘masked patulous Eustachian tube’ to avoid the postoperative disappointment. ——— otosclerosis; cholesteatoma; myringoplasty; autophonia; autophony.


The Eustachian tube is important in the regulation of the middle ear pressure. It is normally closed but opens upon swallowing for a very short period of time, i.e., less than one second, to equalize the middle ear pressure with the atmospheric pressure. If the Eustachian tube is continuously open, those with this condition suffer from annoying symptoms such as aural fullness (sensation of fullness in the ear), autophonia (abnormally loud audition of one’s own voice), audition of breathing sound by the ear, and fluctuating sensation of the tympanic membrane upon respiration, due mainly to the direct entry of sound created within the body to the ear through a patent Eustachian tube and pressure change caused by respiration (Shambaugh 1938; Perlman 1939; Miller 1961; Allen 1967; Crary and Wexler 1979; Münker 1980; O’Connor and Shea 1981; Hori et al. 2006). This condition is called patulous Eustachian tube (PET) (Miller 1961; O’Connor and Shea 1981; Virtanen and Palva 1982). The diagnosis of PET is not difficult when patients complain of such typical symptoms. In addition, relief of the symptoms in the recumbent position has great value for reaching an accurate diagnosis (Perlman 1939; Rundcrantz 1969).

However, there is an important condition in which the patulous condition of the Eustachian tube is masked by the presence of conductive hearing loss, which only becomes evident after the successful middle ear surgery resulting in hearing improvement. In such cases, patients may experience new distress even though the surgery itself has been successful and hearing improvement has been attained. Although this condition is very important, it has hardly been described in the literature.

Therefore, we propose that this condition be termed ‘masked patulous Eustachian tube’ in order to focus attention on this important condition prior to planning middle ear surgery.

Four representative patients are presented and the mechanisms for masking of the PET symptoms are discussed, as well as its diagnosis and management.

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Subjects and Methods

Four representative patients with analysis of the underlining mechanism are presented in the following section. This study was performed in accordance with the ethical standards of the committee responsible for human experimentation and with the Helsinki Declaration of 1975, as revised in 1983. The development and insertion of the original silicone plug for the patulous Eustachian plug used for treatment in case 4 had been approved by the Institutional Review Board of Tohoku University School of Medicine and consent from the patient was obtained before usage.

Four Representative Patients

Patient 1: 78-year-old female
Chief complaint: autophonia after myringoplasty

The patient had been told that she had had a perforation of the tympanic membrane since she was 17 years old. She underwent bilateral myringoplasty by her previous doctor one year before her visit to our clinic. After the surgery, she started to experience autophonia in the right ear, which was immediately reduced when she lay down. As conservative treatments failed to cure her condition, she was referred to our clinic. At the first visit to our clinic, she presented with a marked nasal voice accompanied by autophonia, which is a typical symptom of patulous Eustachian tube. The audiogram (Fig. 1) and photograph of the right tympanic membrane before and after surgery provided by the previous doctor evidenced closure of the perforation except for a small pin-hole perforation at the posterosuperior portion of the tympanic membrane and improvement of hearing after myringoplasty on the right ear. The patulous condition of the Eustachian tube was identified by tubo-tympano-aerodynamic graphy (TTAG) (Kumazawa et al. 1977) on the right side (Fig. 2). Conservative treatments including the transnasal instillation of the saline drops (Shambaugh 1938) or moisture gel mixed with Lugol’s solution into the pharyngeal orifice of the right Eustachian tube were attempted and resulted in improvement in her symptoms.

![Fig. 1. Audiogram of patient 1 before and after myringoplasty.](image1)

![Fig. 2. Recordings of tubo-tympano-aerodynamic graphy of patient 1.](image2)

![Fig. 2. Recordings of tubo-tympano-aerodynamic graphy of patient 1.](image3)
Patient 2: 51-year-old male  
Chief complaint: autophonia after myringoplasty  
The patient was admitted to our hospital for the treatment of alcoholic liver cirrhosis in July 2005. As hearing loss of the right ear had been noticed, he was referred to our outpatient clinic. He had a past history of surgical removal of osteoma of the right external auditory meatus in January 2005. After the surgery, perforation of the right tympanic membrane had been pointed out by a local doctor. The audiogram revealed mixed hearing loss with an air-bone gap of about 15 dB in the right ear (Fig. 3). The patch test showed improvement of hearing acuity of the right ear. The patient received myringoplasty under local anesthesia on September 9, 2005. Eight weeks after surgery, at his visit to our clinic on November 2, 2005, although the tympanic membrane was well epithelized and no perforation was visible, the patient complained of autophonia, hearing his own respiration sound and aural fullness of the right ear, which the patient had been able to ameliorate by sniffing. On his visit to our clinic three weeks later, movement of the tympanic membrane upon respiration was observed, and he was diagnosed as having patulous Eustachian tube of the right ear. This was supported by the findings of sonotubometry (Okubo et al. 1987) (Fig. 4). He was treated with saline nasal drops and insufflation of the Lugol’s solution into the pharyngeal orifice of the Eustachian tube, but continued to have symptoms, which he relieved by sniffing when they are unbearable.

Patient 3: 73-year-old female  
Chief Complaint: autophonia after stapes surgery  
The patient underwent stapes surgery (stapedotomy) for the diagnosis of otosclerosis (acquired fixation of the footplate of the stapes) on the left ear in 1995. During the surgery, the superstructure of the stapes was removed, a small hole was created in the fixed footplate, and a piston prosthesis made of Teflon was attached to the long process of the incus to convey sound to the inner ear, which resulted in marked improvement of hearing. She subsequently underwent right stapes surgery (stapedotomy) in 2004, which resulted in

Fig. 3. Audiogram of patient 2 showing the air-bone gap of about 15 dB in the right ear. ○: right air conduction before patch application, ●: right air conduction after patch application, ×: left air conduction, [•]: right bone conduction, [:] left bone conduction.  

Fig. 4. Recordings of sonotubometry of the patient 2 after myringoplasty. Closure of the Eustachian tube after swallowing was delayed on the right side, compatible with right patulous Eustachian tube. †: Eustachian tube opened, ‡: Eustachian tube closed, Sw: swallowing indicated by the pharynx noise.
improvement of hearing of the right ear (Fig. 5). After the surgery on the right ear, she started to complain of severe autophonia of the right ear, which appeared two to three times per day, mainly in the afternoon. She also noticed milder but similar symptoms of the left ear.

Her body weight was 63 kg at the age of 65 and 53 kg at the age of 73 at the second surgery. Patulous condition of the bilateral Eustachian tube was identified by TTAG with the synchronous change of the pressure in the external auditory meatus and nasopharynx (Fig. 6). The symptom of the patulous Eustachian tube in this case was considered to have been masked by the conductive deafness due to otosclerosis, and to have become evident after improvement of hearing resulting from stapes surgery. Her symptoms were partially controlled by conservative treatments, including saline instillation into the nasal cavity.

Patient 4: 43-year-old male
Chief Complaints: right autophonia, left hearing loss
Past History: right cholesteatoma surgery followed by the treatment of the patulous Eustachian tube

The patient had received canal wall down tympanoplasty (open technique) on the right ear for cholesteatoma in 1990 in a hospital affiliated with the Tohoku University Hospital. He was content with the remarkable hearing improvement after surgery. Shortly after surgery, however, he started to notice aural fullness and autophonia of the right ear, and was diagnosed as having patulous Eustachian tube on the basis of TTAG. Because of the severe symptoms of the patulous Eustachian tube, he was eventually treated by insertion of a patulous Eustachian tube plug made of silicone developed by the senior author (T. Ko) (Kobayashi 2000; Sato et al. 2005). The silicone plug was inserted into the Eustachian tube lumen through a myringotomy hole created at the anterior-superior quadrant of the tympanic membrane to narrow the lumen of the patulous Eustachian tube at its narrowest (isthmus) portion. His symptoms were remarkably reduced after this treatment with some fluctuation of symptoms thereafter.

The patient had left hearing loss due to a perforation of the left ear.

Fig. 5. Audiogram of patient 3 before and after right stapes surgery. ○: right air conduction before surgery, ●: right air conduction after surgery, x: left air conduction, [: right bone conduction, ]: left bone conduction.

Fig. 6. Tubo-tympano-aerodynamic graphy of patient 3 after right stapes surgery.
Patulous condition of both Eustachian tubes was identified by the Tubo-tympano-aerodynamic graphy (TTAG) with the synchronous change of the pressure in the external auditory meatus (arrows) associated with that in the nasopharynx induced by sniffing.
tympanic membrane (Fig. 7Aa) and wanted to improve his hearing, and so was referred to our clinic for a second opinion. The patch test was performed. On applying a piece of patch material made of chitin membrane to cover the perforation (Fig. 7Ac), the patient felt improvement of hearing (Fig. 7B); however, severe autophonia appeared after the procedure (Fig. 7C). When the patch membrane was slightly shifted to cover only half of the perforation (Fig. 7Ab), autophonia subsided to nearly zero level on the visual analog scale (VAS) (Fig. 7C). The Eustachian tube function test (Fig. 8) revealed the patulous condition of the Eustachian tube on the left side, although symptoms were absent when the patch material was removed.

**Discussion**

*Masked Patulous Eustachian tube*

We propose use of the concept of 'masked patulous Eustachian tube' to denote the condition in which in spite of the presence of the open Eustachian tube, the patient does not present with symptoms, but then complains of the symptoms after improvement of hearing, without morphological changes in the Eustachian tube itself. Although the masking of such symptoms could also be caused by the effective sniffing in those with PET or in those with insufficiently closed Eustachian tube (Magnuson 1978, 1981; Falk and Magnuson 1984; Kobayashi and Takasaka 1991; Yaginuma et al. 1996; Tsuji et al. 2002), this is a completely different notion from that presently described, because
sniffing causes temporary alleviation of the symptoms by narrowing the lumen of the Eustachian tube in such ears.

Masking of the PET symptoms due to the presence of conductive hearing loss

In this report we have presented four patients, in which symptoms arising from a PET became evident after middle ear surgery. They represent a few examples from larger numbers of such cases, and one may encounter in clinical practice.

The patients 1 and 2 became aware of the symptoms after myringoplasty. In the patient 3, it became evident after successfully performed stapedotomy. The patient 4 noticed the symptoms of PET in the right ear after cholesteatoma surgery with hearing improvement, and in the left ear when the patch test resulted in hearing improvement.

The incidence of the patulous condition of the Eustachian tube in patients with chronic otitis media with perforation of the tympanic membrane was previously studied by our group (unpublished data). In 106 patients (132 ears) with perforation of the tympanic membrane due to chronic otitis media, 12 patients (14 ears), 11% of the chronic otitis media, had findings of PET detected either by TTAG (Kumazawa et al. 1977) or sonotubometry (Okubo et al. 1987). All these patients lacked symptoms of PET. Of these 12 patients (132 ears), 7 patients (8 ears) underwent surgical procedures to close the tympanic membrane perforation. Of these 7 patients, 2 patients (2 ears) spontaneously complained of autophonia or aural fullness after surgery. These figures correspond to 29% (25%) of the patients (ears) with 'masked patulous Eustachian tube' who underwent surgery. As this study was a chart review, the frequency of 'masked patulous Eustachian tube' which became evident after surgery could have been underestimated. However, it may be that not all the patients with 'masked patulous Eustachian tube' suffer from such symptoms after surgery.

Using sonotubometry, Ohta et al. (2008) also showed that 20 out of 178 ears (11.2%) of chronic otitis media with perforated tympanic membrane manifested findings of patulous condition of the Eustachian tube. These results together with the patients reported in this paper indicate that identification of PET before myringoplasty and preoperative explanation to the patient of the possible occurrence of PET symptoms after surgery is important to avoid disappointment of the patient in spite of perfect surgery in terms of closure of perforation accompanied by hearing improvement.

A patient with otosclerosis may also complain the PET symptoms after successful surgery, as seen in the patient 3. Considering that the incidence of the PET in the otherwise normal population has been estimated to be 7% (Flisberg & Ingelstedt 1970) and 6.6% (Münker 1980), it is not so unusual to encounter such cases after stapes surgery. Ohta et al. (2008) have recently shown that 2 out of 30 ears (6.7%) with otosclerosis were found to have patulous condition of the Eustachian tube as evidenced preoperatively by sonotubometry. They tested for otosclerosis as a substitute for normal control in a study of the high incidence of PET in cholesteatoma. However, they did not state whether or not these cases presented with PET symptoms after surgery, as they were not yet aware of the notion of the 'masked patulous Eustachian tube'. Careful observation after stapes surgery is necessary from the standpoint of PET as well. Even though both Eustachian tubes of case 3 were in the patulous condition (Fig. 6), the patient only complained of the symptoms after the second stapes surgery. The reason why she had not complained PET symptoms after the first stapes surgery on the left ear remains as a matter of speculation, but she had lost considerable body weight during the period between the two surgeries. This may have caused the patu-
lous condition of the Eustachian tube because weight loss is one of the most important causes of PET.

In patients with acquired cholesteatoma it is well known that the Eustachian tube is often patulous (Magnuson 1978, 1981; Falk & Magnuson 1984). A sniffing habit induced by the aural discomfort is found in about 25-30% of the cases (Kobayashi et al. 1996; Ohta et al. 2008), such habit being created to alleviate autophonia by collapsing and locking the lumen of the Eustachian tube. After sniffing, the patient’s hearing is partially decreased due to the retraction of the tympanic membrane, but the patient is usually accustomed to the decrease of hearing, and interestingly rather complains of hyperacusis (so called acquired hyperacusis) if the patient’s Eustachian tube becomes open upon swallowing or yawning at the recovery of the normal tympanic membrane position. This mechanism constituting a vicious cycle has been well elaborated by Magnuson and his group, who also cautioned about the risk of the recurrence of the middle ear diseases after surgery (Magnuson 1978, 1981; Falk & Magnuson 1984).

In these patients, as proposed by the present report, when the hearing further deteriorates due such reason as the erosion of the ossicles according to the growth of cholesteatoma, this in turn alleviates the annoying PET symptoms including autophonia. If surgery is performed on such ear and remarkable hearing improvement is obtained, the PET symptoms recur and induce the patient to resort to the sniffing habit and potentially induce the retraction of the reconstructed tympanic membrane (Hasegawa et al. 2006; Kawase et al. 2007).

**Mechanism of the masking and unmasking of the PET symptoms related to middle ear surgery**

In our previous communication, we reported results of model experiment simulating the PET and analysis of the sound conduction from the nasopharynx to the middle ear (Kawase et al. 2006). The facilitation of sound conduction to the middle ear was more marked for the lower frequency tones, especially below 1000 Hz, and this seemed to explain the mechanism of autophonia, which is the most annoying symptom of PET. The severity of the autophonia is apparently dependent on the hearing acuity of the ears with PET as seen in the left ear of the case 4 (Fig. 7). However, the existence of conductive hearing loss suppresses the severity of PET symptoms such as autophonia or audition of one’s own breathing sound, and the patient complains of severe symptoms of PET when improvement of hearing is attained by successful surgery. It is still unknown quantitatively how much postoperative hearing improvement would unveil the PET symptoms.

**Diagnosis and management of masked PET**

Based on these observations, the authors believe that before middle ear surgery, it is important to perform the Eustachian tube function test, not only to detect stenosis of the Eustachian tube, but also to detect the patulous condition of the Eustachian tube, to reveal the existence of the ‘masked patulous Eustachian tube’ even in the absence of the clinical symptoms of PET.

Lacking typical clinical symptoms of PET and with diversity of middle ear pathology in these ears, diagnosis may be difficult without administration of the Eustachian tube function test or newly developed imaging methods using sitting CT (Yoshida et al. 2003; Yoshida et al. 2004; Kikuchi et al. 2007). However, conventional methods such as auscultation of patient’s voice through a rubber tube between the patient’s ear and that of the examiner, movement of the tympanic membrane upon forced respiration or sniffing in cases when the tympanic membrane is intact, as well as attention to the emergence of the typical clinical symptoms of PET when a patch membrane is applied on the perforation, are helpful to detect PET in these cases.

As shown in the present report, treatment for these cases after manifestation of PET symptoms varies from patient to patient according to the severity of the symptoms, from conservative treatment, such as instillation of saline or moisture gel mixed with Lugol’s solution into the pharyngeal orifice, to surgical methods.

**Conclusions**

In ears with hearing loss subjected to the middle ear surgery, it is important to examine whether or not there is ‘masked patulous Eustachian tube’ in addition to the middle ear disease for which surgery is planned. Because of the presence of conductive hearing loss, typical symptoms of patulous Eustachian tube are absent, and the presence of obvious middle ear pathology makes preoperative diagnosis difficult. Most important is the awareness of the possibility of such condition. The patch test and the Eustachian tube function test apparatus are useful to detect such condition preoperatively. Once such preoperative tests have indicated the presence of the patulous condition of the Eustachian tube in ears subjected to surgery, the surgeon should inform the patient of the possibility of ‘masked patulous Eustachian tube’ to avoid the postoperative disappointment, which may lead to patient-surgeon conflict.

**References**


