Determination of eustachius tube ventilation functioning among benign type chronic suppurative otitis media and non-otitis media subjects using sonotubometry

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Abstract. The Eustachian tube (ET) is responsible for the ventilation, protection, and cleaning of the middle ear. ET dysfunction plays an important role in the pathogenesis of otitis media cases, and thus the treatment and prognosis of these cases is extremely dependent on adequate ET function, which can ultimately affect the success rate of middle ear reconstruction practices. Data research on the ET’s ventilation function is needed to ensure the success of therapy and surgery treatments in the case of Chronic Suppurative Otitis Media (CSOM) patients. This study aims to investigate ET ventilation functioning in benign type CSOM and non-otitis media subjects and to develop another modality to measure ET ventilation functioning in patients with intact and perforated tympanic membranes. A comparative cross-sectional study of 36 benign type CSOM patients and 80 non-otitis media subjects will be conducted using sonotubometry and the rated parameter measurements of ET opening frequency, amplitude and ET opening duration. Malfunctioning ventilation of the ET is more common among benign type CSOM subjects (47%) than among non-otitis media subjects (18.75%). There is a significant difference (p = 0.002) between the ET ventilation functioning of benign type CSOM subjects and non-otitis media subjects—benign type CSOM subjects have rates of malfunctioning ET ventilation that are 3.88 times higher than those of non-otitis media subjects. Patients with benign type CSOM are more likely to experience malfunctioning ET ventilation than are non-otitis media subjects.

1. Introduction

The function of the Eustachian tube (ET) is to facilitate the ventilation, protection, and cleansing of the middle ear. To this end, the regular and active opening of the ET enables the ventilation of the middle ear and maintains pressure on that region. The ET is activated via paratubal muscle contractions such as swallowing, yawning, or the performance of other mandibular muscle movements, though the ET does not always open with every swallow. Chronic suppurative otitis media (CSOM) is the most common cause of conductive hearing loss. This condition is the topic of study in this case, as it is a decisive factor in the success of various therapies. Some tools used in the measurement of ET functioning include sonotubometry and tympanometry. Sonotubometry, in particular, can be used to measure the ventilation functioning of the ET. The advantages of sonotubometry include its ability to be used in a physiological state and the fact that it does not require the placement of non-physiological pressure on the middle ear; furthermore, sonotubometry can be performed on ears with intact or...
perforated tympanic membranes in both adult and child patients. The working principle of sonotubometry calls for a sound to be issued through the nose, into the nasopharynx ostium of the ET, and into the middle ear. During the active opening of the ET, more and more sounds are transferred; thus, high-intensity sounds can be recorded from a patient’s external acoustic canal [1-3].

Teixeira et al., used sonotubometry in their study of this issue and reported that ET activation occurred more frequently in adult patients with no history of otitis media than in adult patients with such a history. Such a result is possible because in patients with a history of otitis media, the ET does not completely heal during adulthood; additionally, such patients are vulnerable to recurrent respiratory infections that induce inflammation of the nasopharynx [4]. ET dysfunction plays an important role in the pathogenesis of otitis media cases; thus, the results of various treatments and prognoses are highly dependent on adequate ET functioning, which can ultimately affect the success rate of middle ear reconstruction practices. However, current examinations of the ET functions of preoperative patients are rare, despite the fact that such studies are essential to the successful treatment of such cases [2].

A sonotubometric device is used to measure a sound that is applied to the ostium ET in the nasopharynx and delivered to the middle ear. During the active opening of the ET, sound is recorded within the external acoustic canal. The advantage of sonotubometry is that it can be performed on patients with or without intact tympanic membranes and can be conducted under physiological conditions. Additionally, sonotubometric tools are not expensive, and examinations are painless for both children and adults. Therefore, such an analysis has fairly strong diagnostic value for patients who are suspected of having ET pathology [5]. In his study, Jonathan [6] compared sonotubometric examinations to tympanometric evaluations during the assessment of patients with healthy adult ETs. To this end, he studied the ears of 50 healthy subjects aged 18–60 years with no history of upper airway infections or nasal obstruction. In sonotubometric tests, subjects were asked to swallow a mouthful of water, to swallow without such water, to yawn, and to perform some combination of those activities. If a gain of five or more opening frequencies was observed, the patient was said to have ‘normal’ ET functioning. During tympanometric examinations of the middle ear, a pressure assessment was performed before and after the implementation of a Toynbee maneuver. Judging from the data, there was no significant difference between the results of sonotubometric tests and tympanometric evaluations. Indeed, a combination of swallowing and yawning yielded the most favorable results in terms of ET opening frequency (93%) [1,7-9]. This study aims to investigate ET ventilation functioning in benign type CSOM and non-otitis media subjects and to develop another modality to measure ET ventilation functioning in patients with intact and perforated tympanic membranes.

2. Materials and Methods

This study utilized a comparative cross-sectional analysis, which aimed to determine the state of ET functioning in benign type CSOM patients and non-otitis media subjects using sonotubometry. To locate a sufficient number of benign type CSOM subjects, recruitment was conducted not only at ENT RSCM poly, but also at the Otologi polyclinic and the general ENT and Neurotology Departments of ENT-HN FKUI/RSCM. Thus, the number of subjects included in this study is expected to meet minimum requirements. This study commenced after approval was granted by the ethical review board of the Permanent Committee of Medical Research Ethics/Medical Faculty of Medicine Universitas Indonesia/RSCM. For non-otitis media subjects, recruitment was conducted at the Otologi polyclinic and the polyclinic of the Neurotology Department of ENT-HN FKUI/RSCM. The subject acceptance criteria were as follows: men and women aged ≥8 years who were willing to be the subjects of research and who (or whose parents or guardians) were amenable to signing the informed consent form. The sample size was calculated by applying a correlation formula; this resulted in samples of at least 35 patients in each group (benign type CSOM patients and non-otitis media subjects). Research preparation included the search for and collection of literature materials, the preparation of the research status and research proposal, data collection (patients’ medical records), and the evaluation of results following the examination of patients’ ET ventilation functioning using sonotubometry.
3. Results and Discussion

3.1 Results

Table 1 illustrates the subject distribution based on subject and group characteristics. Table 2 demonstrates the distribution of benign type CSOM subjects based on the subjects’ medical characteristics. Table 3 provides a comparison of ET opening frequencies, amplitude increases (in dB), and the duration of ET inclusions (in milliseconds) between benign type CSOM patients and non-otitis media subjects (for each ear). Table 4 offers a comparison of the proportion of ET functioning abnormalities between benign type CSOM subjects and non-otitis media subjects. Table 5 provides a comparison of function abnormalities between patients with active benign CSOM and those with silent benign CSOM; results were achieved using sonotubometry. Table 6 illustrates the bivariate analyses of age, sex, adenoid presence, head and neck anomaly occurrence, and education level; results are organized according to the status of patients’ ET ventilation functioning. Figure 1, 2, and 3 show the cutoff points of the opening frequency variable, the amplitude increase factor, and the measure of ET opening duration in CSOM patients; results were achieved using sonotubometry.

### Table 1. Subject distribution based on subject and group characteristics

| Article I. Subject Characteristics | Group | p-value |
|-----------------------------------|-------|---------|
| CSOM | Non-Otitis Media |
| Man | 15 | 10 | 0.056 |
| Woman | 15 | 30 |
| Age group: | | |
| 8–18 y.o. | 2 | 0 | 0.013* |
| 18–55 y.o. | 24 | 40 |
| >55 y.o. | 4 | 0 |
| Education: | | |
| Low (Elementary/Junior High) | 16 | 0 |
| Moderate (Senior High) | 9 | 0 |
| High (College) | 5 | 40 | 0.001* |

Chi square: Dan Fischer* (significant proportion)

### Table 2. Distribution of benign type CSOM subjects based on subjects’ medical characteristics (n=30)

| Article II. Subject Characteristics | Amount | Percentage (%) |
|-----------------------------------|--------|----------------|
| Tympanic membrane perforation | | |
| Right | 19 | 52.7 |
| Left | 17 | 47.3 |
| Ear secretion | | |
| Yes | 20 | 55.5 |
| No | 16 | 44.5 |
| Anomalous head and neck abnormalities | | |
| Yes | 0 | 0 |
| No | 30 | 100 |
| Adenoid hypertrophy | | |
| Yes | 2 | 6.7 |
| No | 28 | 93.3 |
| Head and neck tumors | | |
| Yes | 1 | 3.3 |
| No | 29 | 96.7 |
Table 3. Comparison of ET opening frequencies, amplitude increases (in dB), and the duration of ET inclusions (in milliseconds) between benign type CSOM patients and non-otitis media subjects (for each ear)

| Sonotubometry   | CSOM          | Non-Otis Media | p-value |
|-----------------|---------------|----------------|---------|
|                 | Med | Range    | Med | Range    |         |
| Right opening   | 5.0 | 0–8      | 6.0 | 1–12     | 0.024*  |
| Right amplitude | 7.0 | 0–30.9   | 9.3 | 5.1–26.2 | 0.543   |
| Right duration  | 13.0| 0–44.2   | 28.9| 10.6–112 | 0.001*  |
| Left opening    | 5.0 | 0–8      | 6.0 | 1–15     | 0.008*  |
| Left amplitude  | 9.6 | 0–29.4   | 9.3 | 5.3–30.0 | 0.862   |
| Left duration   | 11.6| 0–33     | 30.0| 8–96     | 0.001*  |

Mann Whitney* (significant proportion)

Table 4. Comparison of the proportion of ET functioning abnormalities between benign type CSOM patients and non-otitis media subjects

| Group                   | Sonotubometry | Total |
|-------------------------|---------------|-------|
|                         | Abnormal      | Normal |
| Benign type CSOM        | 17            | 19    | 36    |
| Non-otitis media        | 15            | 65    | 80    |
| Total                   | 32            | 84    | 116   |

Chi Square p = 0.002* OR = 3.88 (1.64–9.18)

Table 5. Comparison of function abnormalities between patients with active benign CSOM and those with silent benign CSOM using sonotubometry

| CSOM type      | Sonotubometry | Total |
|----------------|---------------|-------|
|                | Abnormal      | Normal |       |
| Active benign CSOM | 10            | 10     | 20    |
| Silent benign CSOM   | 7             | 9      | 16    |
| Total              | 17            | 19     | 36    |

Chi Square p = 0.709 OR = 1.14 (0.56–2.32)

Table 6. Bivariate analyses of age, sex, adenoid presence, head and neck anomaly occurrence, and education level according to patients’ ET ventilation function status (n = 116)

| Variables            | ET Ventilation Function | Abnormal n (%) | Normal n (%) | p-value | Crude OR | CI 95% |
|----------------------|-------------------------|----------------|--------------|---------|----------|--------|
|                      |                         |                |              |         |          |        |
|                      |                         | Abnormal       | Normal       |         |          |        |
| Age                  | 8–18 y.o.               | 0 (0%)         | 2 (1.7%)     | 0.140   |          |        |
|                      | 18–55 y.o.              | 28 (24.1%)     | 79 (68.1%)   |         |          |        |
|                      | >55 y.o.                | 4 (3.5%)       | 3 (2.6%)     |         |          |        |
| Gender               | Man                     | 11 (9.5%)      | 27 (23.3%)   | 0.819   | 0.904    | 0.38   |
|                      | Woman                   | 21 (18.1%)     | 57 (49.1%)   |         |          | 2.14   |
| Adenoid              | Hipertrofi              | 2 (1.7%)       | 1 (0.9%)     | 0.184   | 0.181    | 0.02   |
|                      | Absent                  | 30 (25.9%)     | 83 (71.6%)   |         |          | 2.07   |
| Head and neck tumor  | Yes                     | 0 (0%)         | 1 (0.9%)     | 1.00    |          |        |
|                      | None                    | 32 (27.6%)     | 83 (71.5%)   |         |          |        |
|                      | Elementary              | 4 (3.4%)       | 4 (3.4%)     |         |          |        |
|                      | Junior High             | 7 (6.1%)       | 7 (6.1%)     | 0.006*  |          |        |
| Education level      | Senior High             | 5 (4.3%)       | 4 (3.4%)     |         |          |        |
|                      | College                 | 16 (13.8%)     | 69 (59.5%)   |         |          |        |
3.2 Discussion
Benign type CSOM subjects were classified into three age groups: 8–18 years, 18–55 years, and older than 55 years. This classification was made based on the anatomical and physiological changes that occur between adolescence and adulthood. Kaneko et al. [10] and Handzick-Cuk [11] determined that...
the ETs of children over seven years of age begin to resemble the anatomy of those found in adults. ET functioning improves with age, and middle ear pressure levels begin to take on normal levels in all healthy children at roughly five to six years of age. This repair process is disrupted when abnormalities or anomalies of the head and neck are present; these abnormalities include such conditions as the presence a palatal gap, microcephaly, down syndrome, and others. Kaneko [10] and Handzick-Cuk [11] found that most secretory otitis media cases occur in patients under the age of three. Between three and five years of age, changes in otoscopy and tympanometry occur, ultimately reaching normal levels at approximately age six. Additionally, the ET undergoes other changes with age, such as decreases in paratubal muscle strength, a diminishment of support tissues, and a reduced diameter of the TVP and LVP muscles; these changes can affect the ventilation function of the ET.

This study included five (16.67% of total subjects) benign type CSOM patients with high education levels (advanced or Bachelor’s degrees), nine (30%) patients with middling levels of education (high school degrees), and 16 (53.33%) patients with low levels of education (junior high school or elementary school experience); importantly, these groups had statistically significant differences in terms of association (p = 0.001). It was concluded that those with low levels of education tended to have high rates of recurrence in terms of CSOM. This result is in line with the findings of Verhoeoff [12] and Acuin [13], who found that low levels of education caused patients to be less aware of and less able to identify the symptoms of the disease in themselves and less likely to seek medical attention. Additionally, low levels of knowledge among the elderly population regarding health, especially concerning CSOM, led to high rates of incidence, recurrence, and complications relating to CSOM.

Regarding the gender of this study’s subjects [14], participants of each gender were included in the benign type CSOM group. With respect to non-otitis media subjects, there were 30 (70%) female subjects and 10 (30%) male subjects. In his study of this issue, Crippsa [15] found that male subjects with a history of otitis media have a tendency to pass the condition onto their offspring. This is in contrast to the findings of Verhoeoff [12], who argued that the incidence of otitis media is unrelated to gender. A study of ET ventilation functioning found that 17 benign type CSOM subjects had impaired functioning, while 19 benign type CSOM subjects had normal functioning. Furthermore, analysis of the right ears of 80 non-otitis patients revealed that abnormal ET functioning was found in 15 subjects, while 65 participants demonstrated normal ET functioning; thus, a significant association was found between the two groups (p = 0.002), with an OR of 3.88 (1.64–9.18). These results indicate that patients with benign type CSOM can be affected by an aggravation of ET ventilation functioning that is 3.88 times greater than that of non-otitis media subjects (IK 95%) (1.64–9.18) [12,15-16].

Khayat [17] found that adenoid presence is at its highest level when patients are seven years of age. Young patients are more likely to express complaints that result from adenoid presence; as such subjects have a small nasopharyngeal space and an increased frequency of upper respiratory tract infections. Two patients with benign type CSOM, one person with bilateral type CSOM and one subject with unilateral benign type CSOM displayed adenoid hypertrophy; in the non-otitis media group, no patients exhibited adenoid hypertrophy. Moreover, two research subjects had both adenoid hypertrophy and impaired ET ventilation functioning, and one patient had adenoid hypertrophy but no ET function disturbance. A comparison of these two proportions was found to be insignificant (p = 0.184) using the Fischer test. There was no significant effect of adenoid enlargement on ET ventilation functioning in this study, as the number of patients with adenoid hypertrophy was small and not evenly distributed. Additionally, according to Acharya [18], only grade IV adenoids tend to significantly affect ET ventilation functioning; importantly, only grade I and II adenoid enlargements were found in this study’s participants. In this study, only two subjects with adenoid hypertrophy were examined; this scarcity is due to the fact that subjects were ≥8 years of age and thus any existing adenoids had likely already disappeared. However, it is possible for adenoids to persist into adulthood if patients experience infection or a high recurrence of reflux into the nasopharynx. Seibert [19] argued that adenoid hypertrophy can cause a blockage of the opening of the ET, which may affect the cilia on the ET mucosa; this can affect the ventilation and cleansing functions of the ET. Additionally, adenoid
hypertrophy can facilitate fibrosis in the support tissues of the ET. Adenoid hypertrophy can also result in obstructions of the ET tract, thus causing an accumulation of fluid in the ear, which, if left untreated, can cause cerebral spinal fluid (CSF). Moreover, adenoidectomy surgery can also lead to complications such as the onset of sikastriks, which can cause obstructions of the ET mouth [18-20].

This study only included one patient with a head and neck tumor; thus, this proportion was not significant (p = 1.000); certainly, this value cannot be used to represent the variable of head and neck tumors to ET ventilation functioning, as the sample size was only one ear. This particular patient had suffered from a postoperative nasopharyngeal carcinoma two years prior and had a history of fluid discharge from the ear, which began one year after commencing a course of chemoradiation. Tumors of the head and neck following chemoradiation can cause impaired ET functioning due to inflammation, blockage, a loss of elasticity, poor ventilation, and the onset of mucociliary disorders of the ET, which can affect the three important functions of the ET—ventilation, drainage, and protection. Seibert [19] argued that the effects of radiation on the growth of head and neck tumors can cause damage and trauma to the periphery of the middle ear structure, especially the ET. In such patients, normal ET ventilation functioning is possible if the patient had begun treatment for CSOM eight months prior to the radiation course. Tumors in the nasopharynx can also cause fluid to build up in the middle ear, which may result in CSOM [19].

4. Conclusion
Benign type CSOM subjects had smaller proportions of ET opening frequency, increased amplitude and shorter opening durations than did non-otitis media subjects. There was a significant difference (p = 0.002) between the ET functioning of benign type CSOM patients and non-otitis media subjects; benign type CSOM subjects were at a 3.88 times greater risk of impaired ET ventilation functioning than non-otitis media subjects. There was a significant difference between the frequency of ET opening and the duration of ET clearance among benign type CSOM subjects with non-healthy otitis media; no significant difference was found with regard to amplitude increases. Based on the ROC curve, it was concluded that the cutoff point of the opening frequency parameters is 5x at a sensitivity of 96% and a specificity of 100%. Furthermore, the amplitude parameter was deemed to have a cutoff value of 8.275 dB at 68.4% sensitivity and 70.6% specificity. Regarding the parameter of duration, the cutoff point was 12.05 ms at 52.9% sensitivity and 52.6% specificity. The parameters of ET opening frequency, amplitude increase, and opening duration act as a reference for the presence of impaired ventilatory ET functioning in patients with either intact or perforated tympanic membranes. In patients with benign type CSOM, ET ventilation functioning can serve as an indicator of the success of medical treatments or of preoperative preparation of the middle ear.

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