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Video-Otoendoscopic Assessment of Tympanic Membrane Recovery Duration After Valsalva Maneuver as a Simple Screening for Eustachian Tube Dysfunction in Allergic Rhinitis

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Abstract

Eustachian tube dysfunction (ETD) is commonly associated with allergic rhinitis (AR) due to inflammatory changes affecting the nasopharyngeal and Eustachian tube mucosa. This study aimed to analyze the relationship between tympanic membrane (TM) recovery duration after Valsalva maneuver and Eustachian tube function (ETF) assessed by video otoendoscopy and ETF tympanometry in patients with allergic rhinitis. An observational analytic cross-sectional study was conducted involving AR patients and healthy controls. Tympanic membrane movement after Valsalva maneuver was recorded using video otoendoscopy, and the duration required for the TM to return to its initial position was measured. ETF was evaluated using tympanometry during resting condition and Valsalva maneuver. Patients with AR demonstrated significantly shorter TM recovery duration compared with healthy controls ($p<0.001$). Significant differences were also observed in ETF tympanometry parameters between groups. TM recovery duration showed a strong correlation with the distance between resting and Valsalva tympanometric curves in both control ($r=0.897$; $p<0.001$) and AR groups ($r=0.920$; $p<0.001$). Video otoendoscopic assessment of TM recovery duration after Valsalva maneuver may serve as a simple complementary method for evaluating ETF in allergic rhinitis patients.

Keywords: allergic rhinitis; Eustachian tube dysfunction; tympanometry; tympanic membrane; Valsalva maneuver.

Abbreviations: Eustachian tube (ET), Eustachian tube dysfunction (ETD), allergic rhinitis (AR), Eustachian tube function (ETF), tympanic membrane (TM)

INTRODUCTION

The Eustachian tube (ET) plays an essential role in maintaining middle ear homeostasis through three primary functions: ventilation, protection, and clearance of middle ear secretions. Adequate ventilation allows pressure equalization between the middle ear cavity and atmospheric environment, enabling normal tympanic membrane vibration and optimal sound transmission. Failure of these mechanisms may result in Eustachian tube dysfunction (ETD), which is associated with symptoms such as ear fullness, hearing impairment, tinnitus, and middle ear ventilation abnormalities.

ETD represents a complex clinical condition involving impaired opening or abnormal closure of the Eustachian tube. ETD may occur due to functional abnormalities, structural obstruction, or inflammatory processes affecting the tubal mucosa. Allergic rhinitis (AR) is considered one of the important inflammatory conditions contributing to ETD. Nasal mucosal inflammation, edema, increased mucus production, and inflammatory mediator release may extend toward the Eustachian tube, resulting in impaired tubal opening and inadequate middle ear pressure regulation.

Several methods have been developed to evaluate Eustachian tube function, including Valsalva maneuver, Toynbee maneuver, tympanometry ETF, tubomanometry, sonotubometry, and tubotympanoaerodynamicgraphy. However, none of these examinations has demonstrated sufficient sensitivity and specificity to become the definitive diagnostic standard for ETD. Therefore, a simple, accessible, and objective assessment method remains clinically valuable.

The Valsalva maneuver increases nasopharyngeal pressure and actively opens the Eustachian tube, resulting in positive pressure transmission to the middle

ear and outward displacement of the tympanic membrane. In individuals with normal Eustachian tube function, pressure equilibration occurs efficiently, allowing the tympanic membrane to return rapidly to its resting position. In contrast, impaired tubal function may cause delayed pressure normalization and prolonged tympanic membrane displacement.

Previous studies have evaluated Eustachian tube opening duration using specialized equipment such as pressure chambers and sonotubometry. However, the assessment of tympanic membrane recovery duration using otoendoscopic visualization has not been widely investigated, particularly in patients with allergic rhinitis. This approach may provide a simple clinical parameter that can complement existing ETF assessments. Therefore, this study aimed to evaluate the relationship between tympanic membrane recovery duration after Valsalva maneuver using video-otoendoscopy and ETF tympanometry parameters in allergic rhinitis patients compared with healthy controls.

MATERIALS AND METHODS

Study Design

This observational analytic study with a cross-sectional design was conducted at the Department of Otorhinolaryngology–Head and Neck Surgery, Dr. Saiful Anwar General Hospital, Malang, Indonesia. Participants were divided into two groups: Allergic rhinitis group and Healthy control group. The study population consisted of subjects fulfilling inclusion and exclusion criteria determined according to clinical evaluation and allergy assessment.

Participants and Eligibility Criteria

Participants eligible for the allergic rhinitis group were adults aged 18–60 years who presented with allergic rhinitis symptoms and had a positive skin prick test (SPT) result. Subjects were required to discontinue oral antihistamines and oral or topical corticosteroids for at least one week prior to examination. In addition, participants were required to have at least one clinical or objective finding suggestive of Eustachian tube dysfunction (ETD), including abnormal tympanometry findings (type B or type C tympanogram) and/or ETD-related symptoms such as aural fullness, tinnitus, discomfort during pressure changes, or subjective hearing impairment.

The control group consisted of subjects aged 18–60 years without a history of allergic rhinitis symptoms and without current infection involving the nasal cavity, ear, or throat. Participants were excluded if they had a history or evidence of middle ear disorders, including acute or chronic otitis media, otitis media with effusion, tympanic membrane perforation, previous ear surgery (including ventilation tube insertion, tympanoplasty, or mastoidectomy), or temporal bone-related fractures. Subjects with adenoid hypertrophy grade II–IV involving contact with the torus tubarius, vomer, or soft palate were also excluded.

Additional exclusion criteria included structural or inflammatory nasal conditions that could independently affect Eustachian tube function, such as inferior turbinate hypertrophy (defined by bilateral nasal obstruction symptoms, endoscopic evidence of inferior turbinate enlargement, and reduction of turbinate size after decongestant testing), severe septal deviation (Mladina classification type V–VI), and acute or chronic rhinosinusitis with or without nasal polyps diagnosed based on clinical history and nasoendoscopic examination. Patients with masses, tumors, or malignancies involving the nasopharynx, nasal cavity, or ear were also excluded.

Tympanic Membrane Recovery Duration Assessment

All participants underwent otoendoscopic examination during Valsalva maneuver. Eustacure is an instrument that provides controlled and uninterrupted air pressure and flow rates, delivering a pressure range of 4.5–5.5 psi with an airflow rate of 1–2.5 L/min. This device is designed to increase middle ear pressure by collecting and compressing air within the nasopharynx and directing it toward the Eustachian tube during the swallowing process. Eustacure is manually operated and powered by a battery source. Subjects were instructed to perform Valsalva maneuver using Eustacure until tympanic membrane displacement was observed. Video recording was performed, and the duration required for the tympanic membrane to return to its initial position was measured using the Capcut software.

Eustachian Tube Function Assessment

ETF was evaluated using tympanometry during resting condition, Valsalva maneuver, and Toynbee maneuver. The distance between the highest points of tympanometric curves obtained during different conditions was analyzed as an indicator of pressure transmission and tubal function. The ETF tympanometry results were printed on legal-size paper (21.59 × 35.56 cm), and the distance between tympanometric curves was measured using the Image Measurement software.

Statistical Analysis

Data distribution was assessed using normality testing. Differences between groups were analyzed using appropriate parametric or non-parametric tests. Correlation analysis was performed to evaluate the relationship between tympanic membrane recovery duration and ETF tympanometry parameters. Statistical significance was defined as $p<0.05$.

RESULTS AND DISCUSSION

Result

A total of 48 participants were included in this study, consisting of 24 subjects with allergic rhinitis and 24 healthy controls. Baseline characteristics including demographic data and clinical evaluation were analyzed to ensure comparability between groups.

Table 1 Participant Characteristics.

	Control Group (n = 24)	Allergic Rhinitis Group (n = 24)
Tympanogram		
Type A	24	6
Type As		9
Type B		4
Type C		5
Total participant with ETD symptoms	0	17

The duration required for the tympanic membrane to return to its initial position after Valsalva maneuver was significantly shorter in the allergic rhinitis group compared with healthy controls. Patients with allergic rhinitis demonstrated shorter duration of tympanic membrane recovery, suggesting impaired pressure equalization and reduced efficiency of Eustachian tube function.

Table 2 Comparison of tympanic membrane recovery duration after Valsalva maneuver.

Group	Recovery Duration	p-Value
Control group	2,04 sec	<0,001
Allergic Rhinitis group	0,82 sec	

ETF tympanometry demonstrated significant differences between allergic rhinitis patients and controls. The distance between the highest points of tympanometric curves during resting condition and Valsalva maneuver showed significant differences between groups, indicating altered pressure transmission through the Eustachian tube in allergic rhinitis patients.

Table 3 Comparison of ETF tympanometry parameters.

Parameter	Control Group	Allergic Rhinitis Group	p-Value
Rest-Valsalva Curve Distance	1,72 cm	0,66 cm	<0,001
Rest-Toynbee Curve Distance	1,73 cm	0,62 cm	<0,001
Valsalva-Toynbee Curve Distance	1,95 cm	0,90 cm	0,003

Correlation analysis demonstrated a strong positive relationship between tympanic membrane recovery duration after Valsalva maneuver and the distance between resting and Valsalva tympanometric curves. These findings indicate that prolonged tympanic membrane displacement after Valsalva maneuver is associated with better Eustachian tube function.

Table 4 Correlation analysis.

Group	Correlation coefficient (r)	p-Value
Control group	0,897	<0,001
Allergic Rhinitis group	0,920	<0,001

Discussion

In this study, 24 subjects were included in both the control and allergic rhinitis (AR) groups. Tympanometry findings in the AR group showed various patterns, including type A (n=6), type As (n=9), type B (n=4), and type C (n=5) tympanograms. Furthermore, 17 subjects in the AR group reported symptoms suggestive of Eustachian tube dysfunction (ETD), including aural fullness, tinnitus, and ear discomfort. These findings indicate that not all patients with allergic rhinitis demonstrate abnormal tympanometric results despite the presence of ETD-related symptoms. Previous studies have reported similar findings, suggesting that Eustachian tube impairment in allergic rhinitis may occur without detectable middle ear pressure abnormalities. Jayadevan et al. reported that only 38.6% of allergic rhinitis patients exhibited abnormal tympanograms (type C), while the majority maintained type A tympanograms. Similarly, Parsel et al. found that among patients with ETD symptoms based on the ETDQ-7 questionnaire, only 16.1% and 22.8% demonstrated type B and type C tympanograms, respectively, while the remaining subjects showed type A tympanograms. These findings suggest that Eustachian tube dysfunction associated with allergic rhinitis may represent an early or mild functional impairment that is not always accompanied by measurable tympanometric abnormalities.

Interestingly, several AR subjects in this study demonstrated type As tympanograms. To date, the presence of type As tympanograms in allergic rhinitis or ETD populations has not been specifically reported. Although both type A and type As tympanograms indicate normal middle ear pressure, type As is characterized by reduced compliance, reflecting increased stiffness of the tympanic membrane or ossicular chain. Reduced compliance may influence tympanic membrane mobility during pressure changes and potentially affect tympanic membrane recovery duration and ETF tympanometry measurements. In this study, ETD was evaluated primarily from the perspective of middle ear pressure regulation; therefore, subjects with type As tympanograms were considered within the same spectrum as type A tympanograms. However, because the effect of tympanic membrane stiffness on tympanic membrane recovery duration and ETF tympanometry was not specifically investigated, further studies are required to determine whether abnormal findings in patients with type As tympanograms are

primarily related to impaired Eustachian tube ventilation or mechanical restriction of tympanic membrane mobility.

The present study demonstrated a significant difference in tympanic membrane recovery duration after Valsalva maneuver between healthy controls and allergic rhinitis (AR) patients. The mean recovery duration was 2.04 seconds in the control group and 0.97 seconds in the AR group. This parameter reflects the Eustachian tube opening duration (ETOD), which represents the time required for pressure transmission and subsequent restoration of the tympanic membrane position after Eustachian tube opening. Physiologically, the Eustachian tube plays an essential role in middle ear ventilation by maintaining pressure equilibrium between the middle ear and atmospheric environment. Eustachian tube opening is primarily facilitated by contraction of the tensor veli palatini and levator veli palatini muscles, allowing air passage into the middle ear. Under normal physiological conditions, the Eustachian tube opens intermittently for approximately 0.4 seconds during swallowing to maintain middle ear homeostasis. In this study, the control group demonstrated a longer ETOD compared with the AR group. The ETOD value in healthy subjects was lower than previously reported values, with Mikolajczak et al. and Wolber et al. reporting ETOD values of approximately 2.7 and 2.2 seconds, respectively. Meanwhile, the AR group showed a shorter ETOD of 0.97 seconds, which differs from previous findings by Meyer et al., who reported an ETOD of 2.9 seconds in patients with unclassified ETD.

The difference in ETOD values between this study and previous reports may be attributed to variations in measurement techniques. Previous studies assessed ETOD using pressure chamber systems, allowing controlled and standardized application of pressure during Valsalva maneuver. In contrast, this study used Eustacure-assisted Valsalva maneuver, which facilitates pressure generation but does not provide continuous measurement or regulation of the exact pressure applied. Therefore, variations in the pressure generated among participants may have influenced ETOD measurements. Furthermore, previous studies quantified ETOD using impedance tympanometry, which directly evaluates changes in middle ear pressure, whereas the present study measured ETOD based on visual observation of tympanic membrane displacement using video otoendoscopy. Thus, the parameter obtained in this study represents the duration of visible tympanic membrane positional recovery rather than the exact duration of middle ear pressure equilibration. The shorter ETOD observed in AR patients should therefore be interpreted cautiously, as these findings may not be directly comparable with previous studies using different measurement modalities. Further validation studies comparing video otoendoscopic assessment with established objective Eustachian tube function tests are required to determine the clinical significance of this parameter.

The present study demonstrated that all ETF tympanometry curve displacement distance parameters were greater in the control group compared with the allergic rhinitis (AR) group. Greater displacement distance of tympanometric curves indicates more effective transmission of pressure changes through the Eustachian tube (ET). In this study, the distance between curves was measured geometrically in centimeters using Image Measurement software from printed ETF tympanometry graphs rather than being expressed directly as pressure units (daPa). Therefore, these parameters should be interpreted as visual representations of tympanometric curve displacement following pressure changes during ETF assessment. The smaller distance values observed in the AR group suggest impaired pressure transmission and reduced Eustachian tube ventilatory function. This finding is consistent with the proposed mechanism of allergic rhinitis-associated ET dysfunction, in which mucosal inflammation, edema, and increased luminal resistance may impair Eustachian tube opening and pressure regulation.

The present study demonstrated a very strong correlation between tympanic membrane recovery duration after Valsalva maneuver and the distance between the highest points of resting and Valsalva tympanometric curves in ETF tympanometry. Physiologically, Valsalva maneuver increases nasopharyngeal pressure, facilitating Eustachian tube (ET) opening and allowing air transmission into the middle ear. This process increases intratympanic pressure, resulting in lateral displacement of the tympanic membrane. The greater the pressure transmitted through the ET, the greater the tympanometric curve displacement distance observed after Valsalva maneuver. To date, no previous studies have specifically quantified the distance between ETF tympanometric curves as an objective parameter of Eustachian tube function. The findings of this study may serve as a potential surrogate marker for estimating Eustachian tube opening duration (ETOD). A greater displacement distance between resting and Valsalva tympanometric curves may reflect more prolonged pressure transmission through the ET, which corresponds to a longer duration of tympanic membrane recovery after Valsalva maneuver.

CONCLUSIONS

This study demonstrated significant differences in tympanic membrane recovery duration after Valsalva maneuver between healthy controls and patients with allergic rhinitis (AR). Patients with AR showed a shorter recovery duration compared with healthy controls, suggesting altered Eustachian tube (ET) pressure regulation and ventilation dynamics in allergic rhinitis.

Furthermore, ETF tympanometry parameters showed significant differences between groups, with smaller displacement distances between the highest points of tympanometric curves in the AR group compared with controls group, indicating impaired Eustachian tube function in patients with allergic rhinitis.

A very strong positive correlation was observed between tympanic membrane recovery duration after Valsalva maneuver and the distance between resting and Valsalva tympanometric curves in both control and AR groups. These findings suggest that greater displacement of ETF tympanometric curves is associated with longer tympanic membrane recovery duration and indicate that video otoendoscopic assessment of tympanic membrane recovery may serve as a simple complementary parameter for evaluating Eustachian tube ventilatory function. Further studies with larger sample sizes, standardized pressure-controlled Valsalva maneuvers, and comparison with established objective Eustachian tube function tests are required to validate its diagnostic applicability.

Competing Interests: The authors declare that there are no competing interests.

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