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Comparison of effects of dry versus wet swallowing on Eustachian tube function via a nine-step inflation/deflation test

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Abstract

The aim of the present study is to evaluate the effect of swallowing type (dry versus wet) on the outcome of a nine-step inflation/deflation tympanometric Eustachian tube function (ETF) test in healthy adults.

Fourteen normal healthy volunteers, between 19 and 28 years of age, were included in the study. The nine-step test was performed in two different test procedures: (1) test with dry swallows (dry test procedure) and (2) test with liquid swallows (wet test procedure). If the equilibration of middle-ear (ME) pressure was successful in all the steps of the nine-step test, ETF was considered 'Good'. Otherwise, the test was considered 'Poor', and the test was repeated at a second session.

In the dry test procedure, ETF was 'Good' in 21 ears at the first session and in 24 ears after the second session ($p > 0.05$). However, in the wet test procedure, ETF was 'Good' in 13 ears at the first session and in 21 ears after the second session ($p < 0.05$).

At the first session, ETF was 'Good' in 21 and 13 ears in the dry and wet test procedures, respectively. The difference was statistically significant ($p < 0.05$). However, after the second session, the overall number of ears with 'Good' tubal function was almost the same in both test procedures (24 ears at dry test procedures versus 21 ears at wet test procedures; $p > 0.05$).

Dry swallowing seems to be more effective for the equilibration of ME pressure. Thus, a single-session dependent evaluation of ETF may be efficient for the dry test procedure of the nine-step test. Swallowing with water may be easier for subjects, but a repetition of the test at a second session may be necessary when the test result is 'Poor'.

Key words: Eustachian Tube; Acoustic Impedance Tests; Middle Ear; Deglutition

Introduction

Eustachian tube function (ETF) is important for middle-ear (ME) physiology and the development of ME disorders.[1,2] For recognition of the association between ETF and the development of ME disease, numerous tests have been described. The predictive value of ETF tests for some ME disease has been studied. Uzun *et al.*[3] have shown that the nine-step inflation/deflation test is a reliable and easy method of predicting ME barotrauma in divers and can be useful in the evaluation of ETF in otologically healthy subjects. Miyazawa *et al.* have shown that abnormal ETF can be used to predict ME barotrauma prior to exposure to hyperbaric atmospheric pressure.[4] Fernau *et al.* have studied the effect of hyperbaric oxygen therapy on ME and ETF. They have found that patients manifesting Eustachian tube dysfunction after their first hyperbaric oxygen therapy are at significantly greater risk towards developing symptoms of fullness and serous otitis media, often requiring tympanostomy tube placement.[5] McBride *et al.* have investigated the temporal relationship between tubal function and experimentally induced rhinovirus infection in adult volunteers. They have found a causal relationship between viral upper respiratory tract infection and Eustachian tube dysfunction.[6] Uzun has evaluated the pre-dive parameters related to Eustachian tube dysfunction for symptomatic ME barotrauma in divers, and he has found that Eustachian tube dysfunction measured by the nine-step test can be a risk factor for symptomatic ME barotrauma in otherwise healthy sports scuba divers.[7] As shown in those studies, not only in patients with an otological disease, but also in normal subjects, evaluation of ETF by the nine-step test may be necessary in the otological evaluation and research.

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Sonotubometry, manometry and tympanometry are tests which can assess the ventilatory function of the Eustachian tube. It has been shown that sonotubometry is a valid physiological method of assessing ETF. A high degree of correlation with tympanometry to assess ETF has been reported.[8] However, the procedure requires training and skill for administration, as well as special equipment. Also, several authors have suggested that sonotubometry tests are not always repeatable and interpretation of the test results is difficult.[9,10] Manometric tests are technologically complicated and of little value for assessing ETF when the tympanic membrane is intact.[11] Another test which has been widely used for clinical and basic research investigations is tympanometry. Valsalva test, Toynbee test and nine-step inflation/deflation test (nine-step test)[12] are commonly used tympanometric methods for measuring Eustachian tube ventilatory function.

A single measurement of normal resting ME pressure by tympanometry does not necessarily indicate normal ETF, but a measurement of negative ME pressure is presumptive evidence of Eustachian tube dysfunction. The Valsalva test results are not reliable indicators of ETF. When positive, they indicate only an anatomically patent and probably distensible Eustachian tube.[11] According to Bluestone and Cantekin, if negative pressure develops in the ME during or after the Toynbee test, ETF is most likely normal. If positive pressure is noted or no change in pressure occurs, tubal function may still be normal and other tests of tubal function should be performed.[13] The nine-step tympanometric inflation/deflation test developed by Bluestone is considered to be one of the best tests of ETF, especially when repeated several times in case of dysfunction signs.[12,14,15] The test is simple to perform, can provide useful information about ETF, and should be part of the clinical evaluation of patients with suspected Eustachian tube dysfunction. The nine-step test can be performed when the tympanic membrane is intact and there is no fluid in the ME.[3–7] In general, most normal adults can successfully perform all or some parts of this test.[14]

During the nine-step test, subjects are asked to swallow several times (12 times for one ear). The test may be discomforting for the test subject. In their several studies, including the present one, the authors have usually met with complaints from subjects because of dry swallowing getting harder throughout the test.[3,7,15,16] Swallows with liquid (i.e. water) may be helpful in making the procedure more comfortable and easier. The question, however, is whether swallowing with water will affect the test results or not. Although this is one of the actual questions arising during the practice of testing ETF with the nine-step test, the authors were unable to find an answer in the literature. There are several studies in which the effect of swallowing type on ETF has also been evaluated, but a different test of ETF has been used in these studies and the results are controversial.[2,17,18] Therefore, the present study has been planned to evaluate the effect of swallowing type (dry versus wet, i.e. swallows with 10 cm^3 water) on the outcome of the nine-step inflation/deflation tympanometric ETF test in healthy adults. Thus, a more comfortable and easier method could be used in performing the test in clinical applications or research.

Method

Population

A group of 14 normal healthy volunteers were studied; eight women and six men, between 19 and 28 years of age (median age: 20). The same otolaryngologist (MKA) performed the ENT examination of the subjects. Fibre-optic rhino-pharyngo-laryngoscopy was performed in all subjects. Subjects who smoked or had a history of ear disease, recent upper respiratory tract infection, use of nasal sprays, history of nasal allergy, pregnancy, abnormalities on physical examination, history of laryngopharyngeal reflux, abnormal tympanogram or audiogram, history of nasal surgery, tonsillectomy or adenoidectomy were not included in the study.

Test procedure

All subjects were tested in an upright seated position by the same author (CU). The nine-step inflation/deflation tympanometric test developed by Bluestone[12] was performed and evaluated in the manner described by Uzun *et al.*[3] In the first step, the tympanogram recorded resting ME pressure. After ear canal pressure was increased to +200 mmH_2O, subjects swallowed three times to equilibrate ME overpressure in the second step. Ear canal pressure was then returned to atmospheric pressure. If the equilibration was successful, the tympanogram documented the established ME underpressure in the third step. In the fourth step, subjects swallowed three times to equilibrate negative ME pressure. The third tympanogram of the test recorded the extent of equilibration in the fifth step. The same procedure between the second and fifth steps was performed with -200 mmH_2O ear canal pressure between the sixth and ninth steps. Failure to alter ME pressure at least 10 mmH_2O with swallowing at any of the steps (third, fifth, seventh or ninth) was considered as Eustachian tube dysfunction (tubal function was 'Poor').[14] If the equilibration was successful (observed pressure change >/= 10 mmH_2O) in all steps, ETF was considered 'Good' (Figure 1).

The test procedure was repeated at a second session only if the subject failed to change the ME pressure at any of the steps. Dry and wet test procedures were performed one after the other in the same session. The subjects were randomly assigned for the test procedures. First the dry test procedure and then the wet test procedure were performed in eight subjects, and vice versa in the remaining six subjects.

Analysis

For each procedure, the results of the first session were compared with the overall results after the

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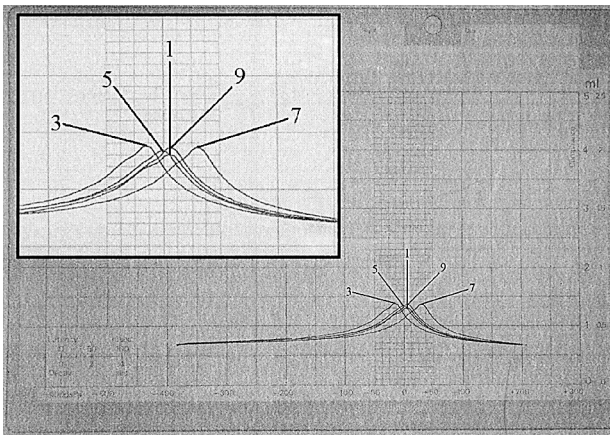

FIG. 1

An example of the nine-step test result in an ear. Eustachian tube function is 'Good' (peak pressure changes in all steps were > 10 mmH_2O); 1, 3, 5, 7 and 9 indicate tympanograms at first, third, fifth, seventh and ninth steps, respectively.

second session. The results of dry versus wet test procedures at the first session were compared. Overall results of dry versus wet test procedures were also compared.

In addition, the total number of steps with successful equilibration (pressure change >/= 10 mmH_2O) at the first session in dry versus wet test procedures were compared. A similar comparison was also done for each step (third, fifth, seventh and ninth steps).

Chi-square test was used for statistical analyses. A p value below 0.05 was considered as a statistically significant value.

Results and analysis

In the dry test procedure, 21 ears had 'Good' test results at the first session. The number of ears with 'Good' test results was 24 after the second session. The difference was not statistically significant ($p > 0.05$, Table I).

In the wet test procedure, the number of ears with 'Good' test results at the first session was 13, which was significantly smaller than the number (21 ears) after the second session ($p < 0.05$, Table I).

At the first session, the number of ears with 'Good' test results in the dry test procedure was significantly higher than in the wet test procedure (21 versus 13, $p < 0.05$, Table I). However, there was no difference in the number of ears with 'Good' test results between dry and wet test procedures after the second session (24 versus 21, Table I).

Overall, 224 equilibrations were checked during the test procedures at the first session. Half of them were measured according to the dry test procedure. The successful equilibration was observed in 91 of 112 steps (81 per cent) in the dry test procedure and in 68 of 112 steps (61 per cent) in the wet test procedure ($p = 0.001$, Table II).

Regarding the number of successful equilibrations for each step of the nine-step test at the first session, the difference between dry and wet test procedures was significant only at the fifth step (equilibration of negative pressure, Table III). Although successful equilibration was also observed more commonly at the dry test procedure than the wet test procedure in the other steps of the nine-step test, these differences were not statistically significant (Table III).

Discussion

Because of the variability of ETF, a single tubal function test may have low prognostic value on the individual level especially in patients with ME disease.[19] Eustachian tube opening and closing functions vary less in normal ears than in ears with retraction disease.[20] If a positive result is obtained, ETF is most probably good. However, if a negative result is obtained, it is advisable to repeat the test before a final conclusion on tubal function can be reached.[15,19,20] Accordingly, we repeated the nine-step test if a negative result was obtained, for a more reliable conclusion on the individual ETF (see Method section).

The nine-step test is developed on the association of swallowing and equilibration of ME pressure by the opening of the Eustachian tube. According to our experiences, the test subject may complain about the feeling of discomfort because of consecutive dry swallowing several times during the test. We thought that swallowing with water could be helpful. However, swallowing with water may change the ventilatory effect of the Eustachian tube. Thus, we performed the current study, and found that the number of ears with good tubal function was significantly smaller in the test with wet swallowing (Table I).

During swallowing, passive mechanical factors and active muscular variables can contribute to ETF.[18] Leider *et al.* evaluated ETF by sonotubometry in otologically normal young adults. They found no significant difference in ETF with changes in liquid bolus and type of swallowing (dry versus wet swallowing). They have pointed out that active muscular effect is not changed during swallowing with or without water; but passive mechanical factors may change.[17] However, in our study, findings showed that swallowing with water could be less

TABLE I

NINE-STEP TEST RESULTS OF DRY AND WET SWALLOWING TEST PROCEDURE (n = 28 EARS)

	Dry test procedure		Wet test procedure	
ETF	At the 1st session	After the 2nd session	At the 1st session	After the 2nd session
Good	21	24	13	21
Poor	7	4	15	7
	$p > 0.05$		$p < 0.05$	

ETF = Eustachian tube function

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TABLE II

THE NUMBER OF EARS WITH SUCCESSFUL EQUILIBRATION IN ALL STEPS OF THE DRY VERSUS WET TEST PROCEDURE

ETF	Dry	Wet	Total
Good/Success	91	68	159
Poor/Fail	21	44	65
Total	112	112	224
	$p = 0.001$		

ETF = Eustachian tube function

effective in the equilibration of the ME pressure (Tables I and II). In addition, in their study on the opening action of the Eustachian tube and mode of swallowing movement in comparison with soft palate movement, Okubo and Watanabe have found that the sound pressure created by the Eustachian tube action in dry or residual barium swallowing (residual/saliva) is higher than that in barium (liquid) swallowing.[2] From their results, they have concluded that during dry or residual swallowing, the soft palate descends along the posterior pharyngeal wall earlier than in the case of liquid swallowing. The descending soft palate probably facilitates the action of the levator palati and tensor palati muscles which helps the Eustachian tube to open.[2] Dry swallowing seems to be more effective for the equilibration of ME pressure when the nine-step test is evaluated on the basis of a single session measurement, especially at the inflation phase (between the third and fifth steps), which was the phase of the equilibration of negative ME pressure (Table III). However, there was no statistically significant difference between the final test results of the dry and wet swallowing test procedures after the second session (Table I).

- **The nine-step tympanometric inflation/deflation test is considered to be one of the best tests of Eustachian tube function when the tympanic membrane is intact**
- **This study evaluates the effect of test procedure (dry versus wet swallowing) on the outcome of the nine-step test in normal subjects**
- **Wet swallowing seems to be less effective for the equilibration of middle-ear pressure in normal subjects than dry swallowing**

TABLE III

THE NUMBER OF EARS WITH SUCCESSFUL EQUILIBRATION AT EACH STEP OF THE DRY VERSUS WET TEST PROCEDURE

	Number of ears with successful equilibration ($n = 28$)			
Test procedure	3rd step	5th step	7th step	9th step
Dry	22	22	24	23
Wet	18	15	18	17
p value	0.236	0.048	0.064	0.075

No difference was found for the outcome of ETF between a single and a two-session dependent test in the dry swallowing test procedure (Table I). Therefore, a single session test procedure may be sufficient for the evaluation of the ETF with the dry swallowing test procedure in normal subjects. However, if the wet swallowing test procedure is preferred for patient comfort, the unsuccessful results should be checked with repeated test procedure either with dry or wet swallowing in a second session for a final outcome of ETF.

Conclusions

Dry swallowing seems to be more effective than swallowing with water for the equilibration of ME pressure in the nine-step inflation/deflation test performed in normal subjects. And, a single-session dependent evaluation of ETF may be efficient for the dry test procedure. Swallowing with water may be easier for subjects, but a repetition of the test in a second session may be necessary if the test result is 'Poor'.

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