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The effects of anesthesia of the tympanic membrane on eustachian tube function

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Summary. In our previous histological studies of the tympanic membrane, we reported the presence of encapsulated nerve corpuscles that are capable of detecting middle ear pressure. Based on these findings, the relation between sensory receptors in the tympanic membrane and tubal function was examined in a clinical study. Tubal function was tested during Valsalva maneuvers and its active equilibration. Function was recorded as a change of the static compliance of the tympanic membrane on an otoadmittance meter. To paralyze the sensory receptors in the tympanic membrane, iontophoresis was used to induce anesthesia of the drum. Forty ears of 20 subjects were tested. All ears were able to equalize positive middle ear pressure without or with a single swallowing. After anesthesia, 13 ears needed more than two swallows and 4 ears failed to equalize middle ear pressure in spite of repeated swallowings. As eustachian tube function changed following anesthesia of the tympanic membranes, a neural connection between sensory receptors in the tympanic membrane and tubual muscles is suggested.

Key words: Tympanic membrane – Sensory innervation – Anesthesia – Eustachian tube function

Introduction

In a previous paper, we reported the ultrastructure of encapsulated nerve corpuscles in the human tympanic membrane and suggested that these were mechanoreceptors that could detect middle ear pressure [6]. Eden [2] used horseradish peroxidase to study central neurons of sensory and motor fibers in the middle ear and the tubal muscles. His findings indicated the presence of the feedback system from the middle ear cavity to the tubal muscles. However, in spite of extensive histological studies of the middle ear mucosa, specific sensory nerve endings have not been found [3]. In this report we have examined the possibility of the same feedback system existing between sensory receptors of the tympanic membrane and the tubal muscles.

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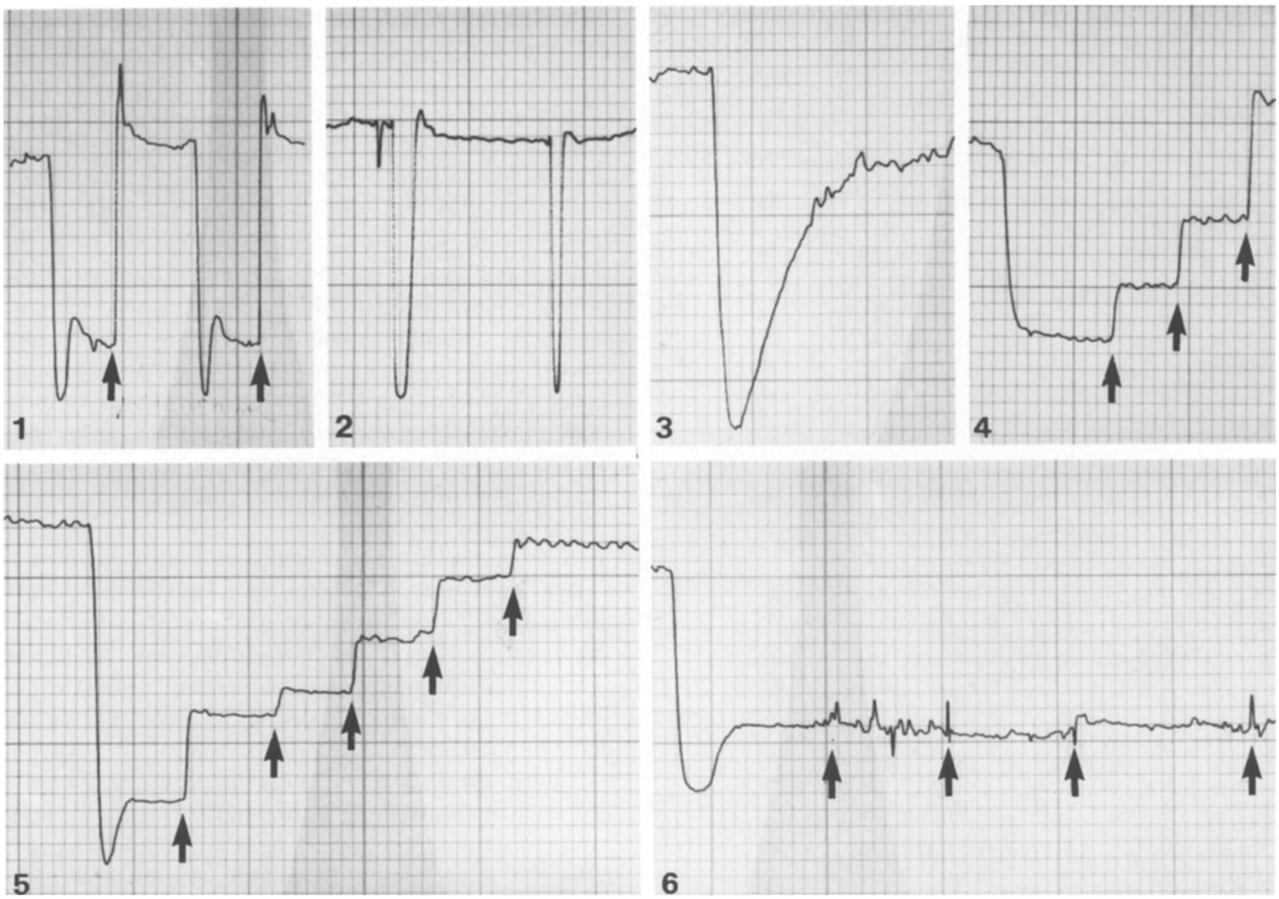
Materials and methods

Twenty-five adult volunteers (15 men and 10 women) were tested. All were in good health and had pure-tone hearing thresholds within 0–20dB and A-type tympanograms. An electroacoustic impedance bridge model (Amplaid 702; Milano, Italy) with a probe frequency of 220 Hz was used for tympanometric measurements of middle ear pressures and for indicating tubal opening and closing functions by changes in compliance. The compliance was recorded on an X-Y recorder at a chart speed of 4mm/s [5].

All recordings of the test were made as follows. The middle ear pressure was initially recorded by tympanometry. The subjects who performed the Valsalva's maneuver and showed positive pressure of the middle ear were indicated qualitatively by changes in the compliance curve. Those subjects who were able to reduce their static compliance repeated their swallowings until the compliance returned to the base line.

To paralyze the sensory receptors in the tympanic membrane, anesthesia was administered with an iontophoretic anesthetizer (FIA-02; Daiichi Medical, Japan). The external ear canal being tested was filled with 4% lidocaine solution, after which the negative pole of the iontophoretic apparatus was placed in the canal. The positive pole was placed on the subject's hand. The intensity of the electric current used was 5mA, with a duration of 12 min. In all studies the right ear was first tested. Following anesthesia, a tympanogram was recorded and subjects were asked to perfor a Valsalva maneuver. After detecting the reduction in the static compliance, the subjects repeated swallowings until any pressure differences were equalized. Following testing on the right ear, the left ear was



Figs. 1, 2. Changes in the compliance curve upon performing the Valsalva maneuver and swallowing *(arrow)* in the normal state. **Fig. 1** Type A; **Fig. 2** type B

Figs. 3–6. Typical changes in the compliance curve upon performing the Valsalva maneuver and swallowing *(arrow)* during anesthesia of the tympanic membrane. The increasing phase of the compliance curve is oblique (**Fig. 3**), occurs in tiers (**Figs. 4, 5**) or is flat (**Fig. 6**)

anesthetized and the same series of tests were carried out, as described for the right ear.

Results

Five subjects from the total group of 25 adults were unable to perform Valsalva maneuvers to create a positive pressure in one or both ears and were excluded from further study. Twenty adults (13 men and 7 women) were then available for the present investigation. All (40) ears of these 20 subjects were able to equalize middle ear pressures without or with a single swallowing: 14 of the ears resolved the pressure without swallowing (Fig. 1) and the remaining 26 ears by a single swallowing (Fig. 2). According to our classification of the middle ear pressures [5], the former is "type B" and the latter is "type A," both of which represent normal tubal function.

After anesthesia of both tympanic membranes, the number of ears with type A function decreased from 26 to 20 and the number of ears with type B function decreased from 14 to 7 (Table 1). In 2 of 7 type B ears, the increasing phase of the compliance curve changed to oblique (Fig. 3). Since this curve was perpendicular before anesthesia, the tubal patency was considered to be slightly worsened. Thirteen of the 40 ears needed more than two swallowings to equilibrate the middle ear pressures, in contrast to the findings before anesthesia. The recovery process of the reduced compliance was that of a stair-step pattern (Figs. 4, 5).

When the right ear was anesthetized, 4 of 20 ears needed more than two swallowings. After anesthesia of both ears, 6 of 20 right ears and 7 of 20 left ears needed that many swallowings. Moreover, when both ears were anesthetized, the reduced compliance in 4 ears did not increase in spite of repeated swallowing (Fig. 6) and indicating that a tubal dysfunction had occurred.

Table 1. Number of swallowings needed to establish normal middle ear pressures. ∞ indicates that compliance stayed in a reduced position in spite of the repeated swallowings

Subject	Right ear			Left ear	
	Control	Anesthesia		Control	Anesthesia
		Right ear	Both ears		Both ears
1	1	1	0	1	1
2	1	1	1	1	1
3	1	4	∞	0	5
4	1	5	5	1	2
5	0	0	0	0	1
6	1	1	2	0	1
7	0	0	0	1	1
8	1	1	∞	0	∞
9	0	0	1	0	1
10	0	0	0	0	0
11	0	0	0	1	1
12	1	3	4	1	5
13	1	1	1	0	1
14	1	1	1	1	1
15	1	1	1	1	1
16	0	5	1	0	1
17	1	0	0	1	∞
18	1	1	1	1	1
19	1	1	2	1	2
20	1	1	1	1	3

Discussion

After topical anesthesia of the tympanic membrane, many of our subjects felt some dull sensation on external ear pressures or stated that they could not detect the air coming into the tympanic cavity during the Valsalva maneuver. This indicates the presence of pressure-sensitive receptors in the tympanic membrane, as suggested previously [6].

The anesthetized ear shows a tendency to need more swallowings before equalization of middle ear pressure occurs. The stair-step pattern of the compliance curve recorded on the anesthetized ear resembles the pressure curve obtained at the inflation-deflation test of traumatically perforated ears [4]. As in normal ears, the pressure difference of the middle ear is practically equalized by a single swallowing: that is to say, the eustachian tube stays open until the middle ear pressure is equalized in its normal state.

The static compliance in the right ears of two subjects (nos. 3 and 8) returned to the base line by the fourth and first swallowings, respectively, when the right ear was anesthetized. After anesthesia of the left ear in these subjects, this compliance stayed in a reduced position in spite of repeated swallowings. This suggests a neurological connection between the tubal muscle and the tympanic membrane of the opposite side.

Encapsulated nerve endings are located in the peripheral area of the tympanic membrane [7]. This area is innervated by the mandibular nerve, which also innervates the tensor veli palatini muscle. Root fibers of the mandibular nerve enter the principal sensory nucleus or the mesencephalic nucleus in the pons. Collaterals form monosynaptic or polysynaptic pathways and those mainly uncrossed and crossed neurons end in the motor nucleus of the trigeminal nerve [1]. We suggest that neuroanatomical connections of sensory and motor neurons in the pons may be the reason why equalization of the middle ear pressure was more difficult in our subjects when both ears were anesthetized.

The preservation of normal equalization of middle ear pressures in 26 ears after anesthesia of both ears may be partly attributed to the ineffectiveness of the anesthesia used. Since iontophoresis can fail to produce sufficient anesthesia in certain cases, further studies must consider more effective methods for achieving anesthesia.

Our present study indicates the presence of a relation between sensory receptors in the tympanic membrane and tubal function. In general, tubal opening is not a simple movement associated with swallowing or yawning and may be controlled by a feedback system originating in the tympanic membrane. The presence of these receptors must be taken into consideration when tubal function tests are performed. It is possible that the presence of these receptors may affect the course of middle ear diseases and the results of tympanoplastic surgery.

References

1. Carpenter MB (1976) Human neuroanatomy, 7th edn. Williams and Wilkins, Baltimore
2. Eden AR (1981) Neural connections between the middle ear, eustachian tube and brain. Ann Otol Rhinol Laryngol 90:566–569
3. Lim D, Jackson D, Bennett J (1975) Human middle ear corpusles – a light and electron microscopic study. Laryngoscope 85:1725–1737
4. Miller GF (1965) Eustachian tubal function in normal and diseased ears. Arch Otolaryngol 81:41–48
5. Morimitsu T, Enatsu K, Matsumoto I, Ushisako Y (1981) A new test of eustachian tube function with otoadmittance meter: tubotympanometry. Acta Otolaryngol (Stockh) 91:207–214
6. Nagai T, Tono T (1989) Encapsulated nerve corpuscles in the human tympanic membrane. Arch Otorhinolaryngol 246:169–172
7. Wilson JG (1911) The nerves and nerve endings in the membrana tympani of man. Am J Anat 11:101–112

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