

Short Communication

A New Therapy for Chronic Serous Otitis: Valvular Tympanostomy Tube

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Abstract

The middle ear is a closed air-filled cavity. It changes of pressure are equalized by the opening of the Eustachian tube. In the pathology of otitis media, Eustachian tube dysfunction and bidirectional gas diffusion are essential. If the Eustachian tube does not open, persistent, high negative pressure could develop in the middle ear, with well-known clinical consequences. The result of negative pressure tried to be preventing by inserting a tube/grommet/into the eardrum. Tube insertion is a successful intervention in the short term. With repeated or prolonged tube insertion has to be expected irreversible changes (eardrum atrophy, perforation, auditory ossicles damage, conductive hearing loss, tympanosclerosis, and cholesteatoma). Tube insertion makes from one pathological condition (permanently closed middle ear) to another one (permanently open middle ear). Based on the literary data and our own research, we are looking for a solution that restores the original function, i.e. the middle ear should be closed and open from time to time. Tympanostomy tube with a valve will be solution to this problem. The valve tube restores the original operation. This theoretical solution can be the basis for further research.

Keywords: Otitis media; Middle ear ventilation; Tympanostomy tube; Valvular tympanostomy tube

Introduction

The middle ear /cavum tympani+processus mastoideus/ is filled with a special gas mixture. The middle ear gas pressure is the same as atmospheric pressure, and its gas composition is very similar to that of the surrounding tissues (Tables 1-3) [1-4].

In the pathology of otitis media the Eustachian tube dysfunction and the bidirectional gas exchange is playing a part fundamental. The Eustachian tube provides a pressure equivalent to atmospheric pressure, and bidirectional gas diffusion provides a gas composition appropriate to the surrounding tissues. Eustachian tube maintains, gas diffusion eliminates partial pressure differences between middle ear and surrounding tissue. The bidirectional gas exchange is passive processes; the close of tuba is passive. The regulation of middle ear ventilation is alone determined active opening of the Eustachian tube [5].

In the case of otitis media the middle ear pressure decreases as evidenced by millions of tympanometric measurements every day throughout the world. Otorhinolaryngologists try to treat the permanently decreased middle ear pressure with a tube insertion in the eardrum. Although the tube has short-term benefits/hearing improvement, pressure equalization, etc., but it does not solve the problem in the long run [6].

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Table 1: Gases partial pressure/mmHg.

| Gas | Air pressure | Middle ear * | Surrounding tissues |
|-----------------|--------------|--------------|---------------------|
| O ₂ | 158 | 51 | 40 |
| CO ₂ | 0.3 | 46 | 46 |
| N ₂ | 596 | 616 | 573 |
| Water Vapor | 5.7 | 47 | 47 |
| Total | 760 | 760 | 706 |

*Optimal composition of middle ear gases based on our calculations.

Table 2: Gas composition of middle ear/mmHg.

| Gas | O ₂ | CO ₂ | N ₂ |
|------------|----------------|-----------------|----------------|
| Calculated | 51 | 46 | 616 |
| Measured* | 39-54 | 48-52 | 563-606 |

*According to several authors [5-7].

Table 3: Quantities of middle ear gases.

| Gas | Pressure (mmHg) | Volume (microL) | Volume |
|-----------------|-----------------|-----------------|--------|
| O ₂ | 51 | 405 | 7.1 |
| CO ₂ | 46 | 363 | 6.45 |
| N ₂ | 616 | 4861 | 86.34 |
| Total | 713 | 5269 | 99.89 |

The data refer to dry gases and a 6000 ml middle ear.

Insertion of the tympanostomy tube from one abnormal condition (permanently closed middle ear) makes another abnormal condition (permanently open middle ear). We were looking for a solution that restores the original or similar functions, that is, the middle ear should be closed and open periodically. The solution is theoretical; realization is the mission of the future, technical problem [7].

Materials and Methods

Based on the literature data and our own results, we have reached the following conclusion.

Results

Normal middle ear ventilation: The Eustachian tube is passively closed when at rest. Pressure is equal on both sides of the tympanic membrane. Bidirectional gas diffusion produces continuous negative pressure in the tympanic cavity which results mainly from the

absorption of oxygen. The tympanic membrane is slowly pushed inward (Figure 1). Presuming normal conditions partial pressure of nitrogen and carbon dioxide are stable in the tympanic cavity according to those of surrounding tissues. When swallowing the Eustachian tube is actively opened, air flows across the Eustachian tube into the cavity, pressure is equalized, and the eardrum regains its original position (Figure 1). The tube closes passively and the process repeats itself.

Otitis media chronica serosa: If closure of Eustachian tube is prolonged, there is no opening even when swallowing. In the middle ear oxygen keeps diffusing into surrounding tissues until its partial pressure becomes equalized. The partial pressures of nitrogen and carbon dioxide are practically stable in mixed venous blood and also in tissues. Owing to the absorption of oxygen negative pressure occurs in the middle ear, clinically good known pathological process starts (Figure 2). The eardrum expands and atrophies. Spontaneous restitution of normal function could happen, but if this does not happen we have to stop the pathological process. This could be achieved by the insertion tube.

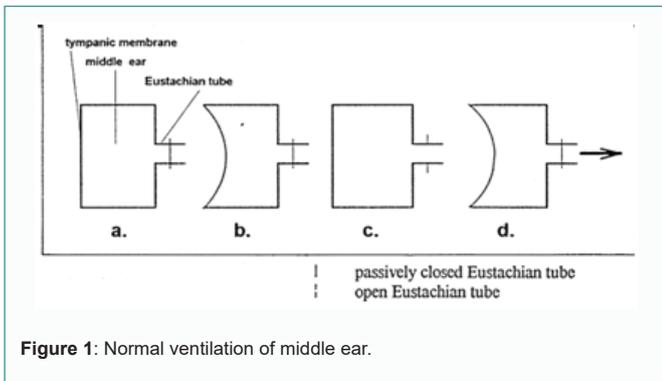


Figure 1: Normal ventilation of middle ear.

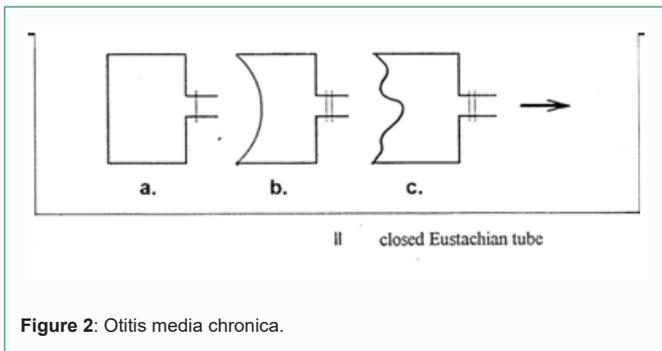


Figure 2: Otitis media chronica.

Ventilation of middle ear after tympanostomy tube insertion: After insertion of tube the tympanic cavity is continuously, spontaneously filled with atmospheric air (Figure 3). The system becomes passive and this passivity leads to structural alterations of the eardrum and the middle ear. The pressure is equal, but gas composition of the middle ear will no longer be similar to that of the surrounding tissues but to atmospheric air. Water vapor decreases and the mucous membrane dries. Pressure gradient not created in the middle ear either by positive and negative pressure.

Passivity of the system, changes in gas composition, and dehydration of the mucosa cause an inflammatory process in the long run, the clinical consequences of which are well known, the eardrum/atrophy, adhesion, cicatrix, retraction pocket, and cholesteatoma,

damage on the auditory ossicles and in mucous membrane/tympanosclerosis.

Valvular tube: A controlled valve is built into the lumen of tube. The valvular tube works as follows. The tube is closed when the pressure in the middle ear is identical with the atmospheric pressure (Figure 4). When the pressure in the cavity decreases, the eardrum is slightly depressed. If the pressure drops below a certain level, e.g. -50 daPa the tube opens and the pressure equalizes. The process is repeated.

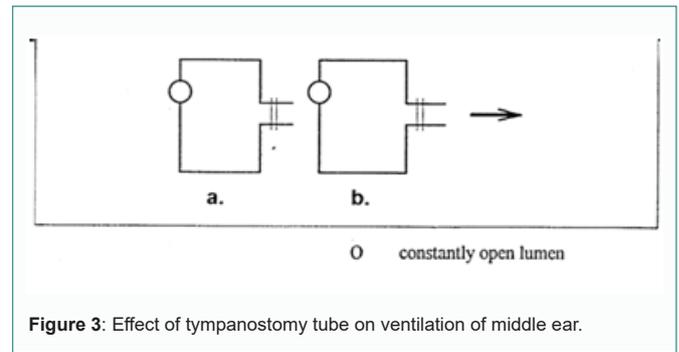


Figure 3: Effect of tympanostomy tube on ventilation of middle ear.

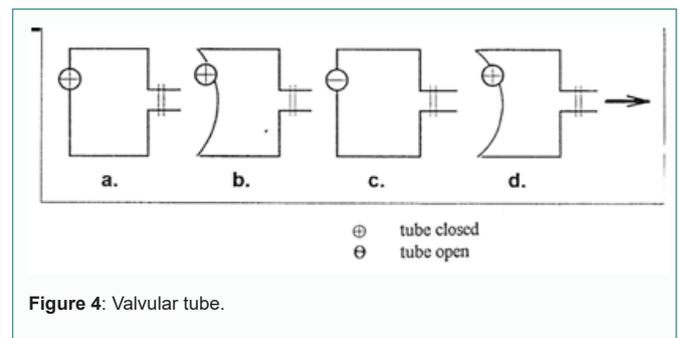


Figure 4: Valvular tube.

The closing and opening of the valvular tympanostomy tube can be controlled by changing the total pressure of the middle ear gas or by the partial pressure change of the oxygen or carbon dioxide, but it can also be controlled in time, it can even be opened and closed as desired. This is a technical question probably can be solved with nanotechnology.

The middle ear ventilation becomes again an active process and the system starts functioning. Active function has positive effect on Eustachian tubal opening. The pressure gradient towards the middle ear may help to open the Eustachian tube together with the nasopharyngeal pressure wave.

The main advantage of the valve tube: The tympanic membrane is that active move again water vapor is in the middle ear/100%/ Ear gas composition in the middle ear is similar a surrounding tissues. The valvular tube recovers original function, creates a similar state. Figure 4 shows the operation of the valvular tube.

Middle ear ventilation has been intensively researched for 30 to 40 years. They wrote everything they could. The tympanostomy tube/grommet/insertion did not solve the problem in the long term. This original article is an attempt to solve the problem theoretically.

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